University of Southampton

Faculty of Humanities

An experimental approach to understanding Aurignacian projectile technology in NW Europe

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Abstract

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Archaeology

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Understanding the challenges and trials faced by early Upper Palaeolithic people in north-west Europe has been an avenue of investigation since the earliest archaeological research of this time period. In the decades since, huge amounts of time and effort have been invested in studying the lithic and osseous tools found in caves, rock shelters and rare open-air sites. However, this time and effort has almost exclusively been focussed on understanding the objects that have stood the test of time, with little consideration of the components that may have once been attached to these surviving objects. The components that no longer survive are at least as important as the surviving parts. They can offer different insights into the challenges faced by the first modern humans in Europe which can give indications of the likely hunting or movement strategies of these early groups. Limited experimental study has shown that the osseous points of the Aurignacian (c. 44-31 ka cal BP) are almost certainly spear points and that they were effective at causing wounds to Pleistocene herbivores. However, like much past literature, the focus has been on the spear tips rather than the whole of the spear.

This thesis changes tack from previous research in that it gives the limelight to the other components and materials that would have made an Aurignacian spear. It also investigates the possible reasoning for the manufacture and form of the spear tips, but with a view on the relationship with the other parts. Key questions will look at the role other Aurignacian tools played in the production of spears and if glues or mastics were required. Whether the spear tips were over-engineered or whether they were carefully designed to improve the longevity of more valuable components (such as the spear shaft). If resource management can be identified based on simulated plant biomes of Europe during Marine Oxygen Isotope Stage 3 and organic samples from around Europe, and what it tells us about sources of viable spear shafts. How these spears may have performed is tested using semi-controlled throwing experiments at a sports field, and in a drop tower, with a focus on all the components of the spear. Finally, what the experimental, biome, organic sample and archaeological evidence are used to evaluate the hunting strategies of Aurignacian groups in NW Europe.

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Research Thesis: Declaration of Authorship

Print name: James Dilley

Title of thesis: An experimental approach to understanding Aurignacian projectile technology in NW Europe

I declare that this thesis and the work presented in it is my own and has been generated by me as the result of my own original research.

I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;

2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;

3. Where I have consulted the published work of others, this is always clearly attributed;

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6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;

7. None of this work has been published before submission;

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This feels like the end of one long, hard journey; dreamt of for many years with a new one about to begin.

Definitions and abbreviations

Date abbreviations

(circa) **c. 44-31 ka cal BP** (kilo annum (calibrated years) before present).

MIS 3

Marine (Oxygen) Isotope Stage 3, ranged from ~59-25 thousand years ago (Barron & Pollard 2002).

Aurignacian

Sub-period of the Upper Palaeolithic in Europe, proceeded by the Gravettian sub period. Dating to c. 44-31 ka cal BP. Considered to be the first dispersal of modern humans into Europe.

Gravettian

Sub-period of the Upper Palaeolithic in Europe dating to c. 32-23 ka cal BP, follows the Aurignacian and followed by the Solutrean or Epigravettian in some parts of Europe (Bennett *et al.* 2019)

Magdalenian

Sub-period at the end of the Upper Palaeolithic in Europe dating to c. 17-12 ka cal BP. Follows the Solutrean in western Europe (specifically the Franco-Cantabrian regions). Followed by final Upper Palaeolithic sub-periods and Mesolithic transition.

Split-based point

A type of spear point made of antler (typically from reindeer or red deer) from the early Aurignacian. The point has a basal split thought to be created to accommodate a spear shaft. Shortened to “SBP in text.

Semi-controlled

In reference to experiments or procedures; semi-controlled means some of the variables are controlled. Some variables such as weather/climatic conditions or variations with natural materials cannot be fully controlled. Efforts are made to control as many variables within reasonable possibility.

Lithic

A tool that is made of stone, typically by percussion in a process called flintknapping.

Osseous

A material that is bone, antler or ivory.

Flexion

A term for bending.

Ballistics gelatine

Gelatine that has been calibrated to a similar consistency of swine muscle tissue.

Mastic

Plant or tree derived gum, sap or tar used as an adhesive.

ANPP

Annual net primary productivity

Projectile

An object that is thrown into a space by the exertion of a force. In archaeologically terms this might be a slingshot, arrow, javelin or cannonball.

Point

Often used in archaeological or ethnographic literature to describe the tip of a spear when it is made of a different material to the spear shaft, such as a lithic or osseous point.

Haft

The handle of a tool such as a knife, axe or sometimes spear.

Shaft

The long, narrow component of an arrow or spear which is typically made of wood.

Joint

In reference to arrows or spears, this is the place at which the spear or arrow head is connected to the shaft. The shaft may have a notch or accommodate the point or have a bevelled tip which is accommodated by a split or notch in the spear/arrow point.

Proximal end

Closer to the point of attachment. In reference to a spear head, the proximal end would be the end which is joined to the spear shaft.

Distal end

The end at the further distance to the point of attachment. In reference to a spear head, the distal end would be the sharp tip.

Chapter 1: Introduction & research strategy

Introduction

The Aurignacian, 38,000-27,000 14C BP (44 – 31 ka when calibrated using the CalPal2007HULU curve; Jöris *et al.* 2011; Davies *et al*. 2015), is of social and cultural interest due to the appearance of new tool types and objects of a strongly symbolic or ritual significance made in a variety of media, including osseous materials such as bone, antler and ivory (Mellars 2004). This wave of objects that identify Aurignacian assemblages causes it to clearly stand out from prior hominin deposits. Within these new tool types, osseous projectile points emerge consistently and are used as phase markers for the Aurignacian (Peyrony 1933). Most commonly known are the antler split-based points (SBPs), which were identified as useful markers during early excavations by Lartet, Peyrony and Henri-Martin during the 19th and 20th centuries (Lartet 1861; Knecht 1993). These artefacts were quickly labelled as probable projectile points (likely to be from hand-thrown spears) and manufacturing theories soon followed. A later theory by Arthur Jelinek proposed that the osseous points were hafted awls for use in clothing manufacture (Jelinek 1994). However, this suggestion seems unlikely, as awls tend to have very narrow points with only mild expansion towards the proximal end (Tejero 2016). The Aurignacian points would seem too wide (flattened in cross0section) for use as an awl in clothing production. Out of these early excavators, two main theories were developed by Henri-Martin and Peyrony. These theories have acted as the basis for later experiments and subsequent theories regarding different aspects of hafting the SBPs. Research into the usage and maintenance of these projectiles has been somewhat limited, possibly because of the on-going debate over hafting and armatures (Knecht 1993; Tartar *et al.* 2013). As well as split-based points, other styles of osseous points appear in the Aurignacian. Simple, bevelled and spindle based points (see Fig. 1) demonstrate a development or diversification, possibly as hunting strategies or raw material selection changed, though clear diachronic change has been questioned by Davies *et al.* (2015). The advantages of these changes in style have been investigated, but no clear reasoning established (Rees 2003). Potential hafting systems have been debated and investigated, Knecht (1991) proposed hafting could involve a small piece of osseous material labelled as a “shim”, which acted as an armature (see Fig. 1). Tartar and White (2013) suggested instead that the “shim” was instead waste material from SBP manufacture and suggested hafting was based around fitting a bevelled wooden shaft tip into the point split. Beyond hafting, some attention has been given to the maintenance and alteration of SBPs. Doyon and Knecht (2014) explored the damage and re-tooling of the experimental sample set produced by Knecht in 1995. They were able to demonstrate consistent changes to SBPs, based on changes (via re-sharpening) to the proximal length, but pointed out the impossibility of identifying specific episodes of use and change based on morphometry. It was also noted that, due to the durability of split-based points, force of projection and/or impact needed to be increased before clear damage occurred (Doyon & Knecht 2014).

Some Aurignacian lithics have been investigated in an attempt to determine whether they were used as barbs or armatures, potentially in combination with an osseous tip (Hays *et al.* 2001). It is clear that there is a large gap in the understanding of Aurignacian hunting equipment. This is partly due to limited research, but also because existing literature has not looked into, or tested, the construction of a whole spear, its use, maintenance and eventual loss.

Like hunting strategies, there are different types of spears. Those strategies can determine the type of spears used and *vice versa*. The earliest type of spear identified in European prehistory is the wooden thrusting spear, or "lance" from Lower Palaeolithic sites such as Clacton, Lehringen and Schöningen which are discussed in more depth later (Gaudzinski 2004; Thieme 2005). These spears had no lithic or osseous tip, but instead were sharpened by scraping with stone tools and often hardened by exposure to fire (Thime 2005). There have been suggestions by some researchers such as Thieme (2005) that these spears could have been thrown much like sharpened wooden spears used by modern Aboriginal groups (as discussed in chapter 2: A view to a kill). However the form of these Palaeolithic spears and those thrown by hunters in the modern era are quite different. The Palaeolithic examples were made from long, thick branches from evergreen timber such as Pine, Larch or Yew that are robust and unlikely to bend without huge strain. Complete examples from Schöningen indicated they could be up to 2m in length (Thieme 2005). By comparison, thrown wooden examples from Australasia were made using light, flexible shafts (see chapter 2 for full accounts). These earliest Palaeolithic spears were used by hominins that existed prior to the arrival of anatomically modern human and some researchers have shed doubt on these hominin's ability to throw spears over arm like modern humans (Churchill 2002). Ethnographic examples of wooden thrusting spears appear far more similar to the European Palaeolithic examples (Churchill 2002). However, it has been argued the use ethnographic evidence in determining differences in spear technology and hunting strategies between hominin groups is unreliable (MacDonald 2019). The first composite spears with a lithic tip are likely to have existed alongside the use of Levallois technology in the Middle Palaeolithic (Schmitt 2003; La Porta 2019). Complete examples of spears from the Middle Palaeolithic have not yet been found, though wooden fragments at least indicate they were using wood for tools or tool hafts (Gaudzinski-Windheuser & Roebroeks 2011; Aranguren *et al.* 2018). Adhesive remains on the base of Levallois points from a variety of sites also indicate these spear tip-like tools were almost certainly hafted (Lazuén 2012). Debate continues as to whether these spears were purely thrusting spears/lances or whether they were ever thrown (Lazuén 2012; Milks *et al.* 2019). The variation in size of Levallois point may suggest a variety of spear types such as heavier lances with larger flakes and lighter lances or even throwing spears with smaller points (Shea *et al.* 2001). With the arrival of anatomically modern humans in Europe we see a more consistent lithic spear tip size that would suggest these modern humans are tending to favour lighter spears (Mellars 2006; Szmidt *et al.* 2010). As discussed in this thesis, hafting systems in the Upper Palaeolithic are still debated, though if modern humans are favouring throwing spears they would need to source lighter, flexible timber to make a suitable shaft. As explored by Milks et al. (2019), lances rely on linear thrusting action that is greatly improved with practiced technique and driving force from the user. Throwing spears such as javelins or darts from a spear thrower require shafts that are light and flexible both for aerodynamic qualities in terms of reduced air resistance and ballistic curve through the air (Ellis 1997). Upon impact with the target (or hard surface), the thrown spear benefits from a shaft that is flexible and able to absorb sudden shock as this reduces stress on the spear tip as smaller, thinner spear tips are generally more fragile (Pétillon 2003).

Past experimental research into spears and projectiles has almost exclusively been restricted to effectiveness of the spear/projectile tip (particularly lithic examples). Some research combines investigations into the production of tips, or occasionally focuses on production, with incidental testing of testing the tips produced during the research. The typical methods for testing the effectiveness of spear or projectile tips are usually with a calibrated crossbow that shoots at either a ballistics gel or cadaver target. The ammunition with replica tip is shot, the action recorded and the state of the tip analysed and discussed. This provides a set of results that are typically viewed one-dimensionally, as the research interest is focussed on how the tips performed under highly-manipulated circumstances on a target that is often very close to the starting position of the spear/projectile tip. This approach generates data that tests such spear tips under conditions close to those of a lance rather than a javelin, and highlights the importance of understanding the whole of the spear and its use. Although such an approach does provide evidence of effectiveness in quite a narrow perspective, it does not allow for a broader view of a spear/projectile tip's use and engagement that could be seen as closer to 'real-world' scenarios. This means the experiments are only giving a narrow glimpse on artefacts that will have gone through a long list of different utilisation scenarios. In the Upper Palaeolithic, these tips were not (generally) shot from a crossbow, nor at a set distance or angle. It is also unlikely they were used indoors within a laboratory environment. When the other components that make up a spear or projectile, such as the binding, glues and shaft are considered, that initial narrow view becomes narrower still. In theory, the most important part of a spear or projectile such as an arrow or javelin is the (normally) wooden shaft. Without one, it is just a piercer or knife tool, as it cannot fulfil its primary purpose as a tool with long reach (in hand or flight). Despite this, the spear shaft very rarely gains much consideration in the literature, beyond assuming it was probably made of wood (see chapter 2: Missing the mark in past experimental literature). Clearly, different species of tree offer timber with very different properties; the same can be said for different parts of the same tree. Producing a tool that its user would rely upon in a critical moment, such as in a hunt or fight, places emphasis on the raw materials being of good enough quality to withstand the strains of their primary function (Bleed 1986). In climatically-challenging regions, supplies of suitable timber for spear shafts can be very low to non-existent. In North-West Europe during Marine (Oxygen) Isotope Stage (MIS) 3 (~59-25 thousand years ago ('ka')), the growing season was very short, and inadequate for many types of vegetation other than the hardy lichens, grasses and shrubs (Alfano *et al.* 2003; Willis & Van Andel 2004). This would have placed an even greater strain on obtaining suitable timber for spear shafts in regions where Upper Palaeolithic humans are known to have operated and hunted with variants of spears (lances or javelins).

Therefore, to provide a wider picture on the role of spears and projectiles from the past (specifically NW Europe during MIS 3 in this thesis), it will be necessary to broaden the research focus when investigating them. Rather than concentrating almost exclusively on the research of spear tips, it is vitally important to hold the other components of a spear or projectile in equal consideration. A spear, after all, cannot be a spear without a spear shaft. A broader research approach will offer new insights on the strategies of the people who used spears during MIS 3 and, through experimentation, demonstrate why the importance of spear elements such as the shaft cannot be left unquantified. Previous researchers such as Davies *et al.* (2015) have clearly identified a gap in our understanding of Aurignacian hunting strategies that could be resolved through experimental testing of replica artefacts to measure efficiency in relation to strategy.

The Aurignacian is generally considered the time in which *H. sapiens* began to fully disperse and colonise Europe (Davies *et al*. 2015). The movement strategies of these early pioneers has received much interest for their presence in Europe during MIS 3 (Davies 2001; van Andel & Davies 2003; Mellars 2006; Dinnis 2012). This is due to the likely climatic difficulties that they would have faced (Huntley *et al.* 2013). Regionally specialised hunting of reindeer (*Rangifer tarandus*) in the Dordogne, red deer (*Cervus elaphus*) in Cantabria and equids in northern Germany, meant the lives of Aurignacian people to some extent revolved around their movements (Grayson et al. 2002; Straus 1992; Niven 2007). However, this specialisation was not exclusive, as some diversification to exploit other prey such as bovids and smaller, fast-moving fauna is apparent at many Aurignacian sites to varying levels (Discamps *et al.* 2011; Fa *et al.* 2013). Aurignacian archaeology in Western Europe is concentrated in central and southern France, continuing farther south and west into Cantabrian and Catalan Spain

(Mellars 2004). However, scarcer Aurignacian archaeology to the north in Brittany, Belgium and Britain demonstrates that at least some of these people ventured into higher-latitude regions (NW Europe) with a colder annual climate, as demonstrated by the Stage Three Project (Fig. 6) (Mellars et al. 2000; Huntley et al. 2013). It is quite possible that these northern sites represent stations used by hunters following reindeer during their seasonal migrations, though unlike central Europe and SW Europe, this has not been intensely explored using stable isotopic data (Conard & Bolus 2008; Richards & Trinkaus 2009). Reindeer can travel thousands of kilometres for the colder seasons to find areas suitable for foraging (Hoare 2009). This northern migration during autumn avoiding areas with a snow depth of over 50cm would have meant that hunting groups following herds had to operate in a higher latitude region during the coldest months (Burch 1972). The scant few remains left by occupants at northern sites suggests occupation was as temporary as possible (Dinnis 2012; Mellars 2006; Binford 1980). However, it is difficult to determine whether northern Aurignacian sites can be categorised into Binford's (1980) fine or coarse trace sites, as several suffered from antiquarian-style excavations, resulting in loss of potentially diagnostic material. It is unclear what their exact hunting strategies might have been (intercept or herd following etc), but possible strategies are discussed with reference to Upper Palaeolithic sites and past experimental research in Chapter 2.

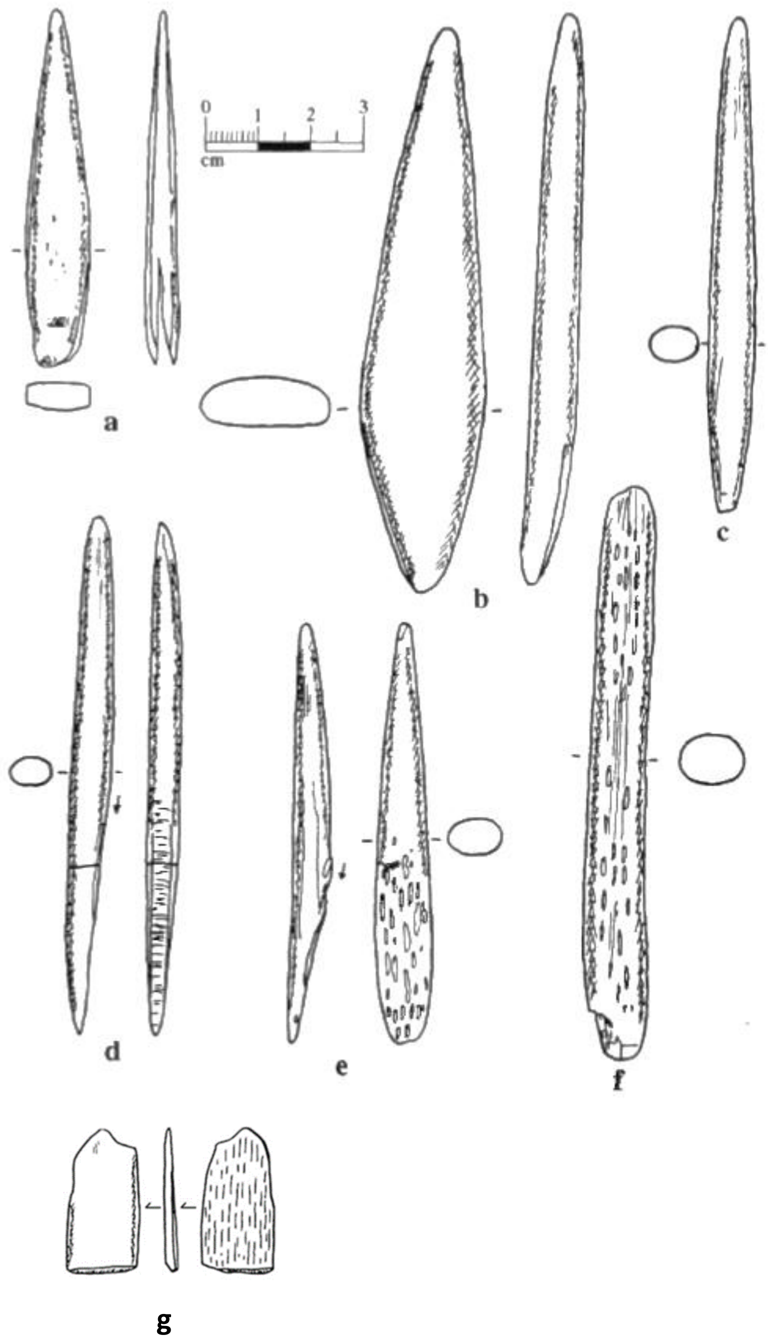

Fig. 1: Aurignacian osseous points, all from the Dordogne except f (SW Germany):

(a) split-based point (Abri Castanet)

(b) lozenge-shaped point (La Ferrassie)

(c) spindle-shaped point (La Ferrassie)

(d) laterally-bevelled point (Laugerie-Haute)

(e) single-bevelled point (Laugerie-Haute)

(f) mammoth-rib point (Brillenhohle)

(g) "shim"
(Abri-Castanet)
(From Knecht 1993: page 36)

Research aims

This PhD aims to set early Upper Palaeolithic (c. 44-31 ka BP) projectile technology into a broader economic and ecological context. It will go beyond the hafting method and take a step back into raw material management, before proceeding to evaluate hafting strategies, and usage and maintenance in their broader ecological context. The raw materials used for making the osseous points have been concisely and extensively covered, especially by Knecht (1991). Knecht and later researchers have also addressed the issue of binding agents and possible mastics for affixing the SBPs, although only briefly. There has been very little consideration of the haft itself. Experiments conducted have used straight wood available either as dowelling or a native hard wood (ash, hazel etc), but have not considered the wood used from an archaeological or palaeoecological perspective. Therefore, it is one of the aims of this PhD to highlight the problems and possible solutions to sourcing usable wood for projectile hafts in an environment similar to that of Europe during MIS 3. As highlighted by Huntley (*et al.* 2013), growth of temperate woodland in northern Europe would have been limited to zero annual net primary productivity (ANPP), while further south it would have been very minimal and restricted to boreal species (Huntley *et al.* 2013). However, it should be noted that this was based on a fairly coarse modelling scale and does not account for small refuge pockets such as sheltered valleys with south facing slopes. Such refuges could be resource draws for Aurignacian groups incorporated into a journey route or even the destination of a specialised resource gathering journey. A similar conclusion was reached by Pryor and others (2016) regarding firewood usage at Pavlov Hills (Czech Republic) during the Gravettian around 30,000 years BP. It is unlikely that boreal woodland in this landscape would have offered sources of wood suitable for spear shaft production. Low ANPP would result in very dense, twisted branches and shoots that would be unsuitable for much other than firewood (Huntley *et al.* 2013; Pryor *et al*. 2016). Trees growing under high stress due to a short growing season, limited soil or harsh weather conditions cannot be expected to yield long, straight sections of wood that can be utilised for throwing spears (Koch *et al.* 2004). This low productivity also prevented tree replenishment for firewood, further restricting exploitation (Pryor *et al.* 2016). It is likely that timber of a suitable length and straightness, but high density (from slow growth), would still be unsuitable for use as throwing spears, due to the stresses and strains of launching and impact, as it would have limited flexion to absorb shock (this will be tested during throwing and drop tower experiments: research question 3). An inability to absorb shock could result in a broken spear shaft or point. Therefore it seems likely that hunters would have to source spear shafts from an area where there was a higher ANPP, and probably more temperate species present. Such extra measures would place a huge value on spear shafts that had suitable throwing spear characteristics, and demanded a heightened level of curation. Extra care may be in the form of devising a method to reduce the chance of spear shaft damage at the expense of another component or time input into overall production so it becomes over-engineered (see Bleeds (1986) maintainable and reliable systems in Chapter 2: A view to a kill). This will be explored during this research by collecting wood samples from a variety of different woodlands in temperate and boreal environments. The alternative option for the Aurignacian hunters would have been to use the best of a poor selection in their local environment. This would presumably have had a detrimental effect on spear performance (although this will be tested), but may not have had a strong enough effect to require sourcing more suitable timber from a distant source.

Following that, replica spears made using wood and antler tips will be tested experimentally through a variety of approaches. Semi-controlled environment tests, as well as open conditions, will be employed to observe the spears in in a stepped sequence. Even if hunting live game was possible, it would be very difficult to analyse the spear effectiveness carefully. Therefore, semi-controlled experiments can be used to build the stepped sequence of use (launch > flight > impact > maintenance or discard). These tests will evaluate whether the existing hafting theories fall short of what the spears require to function to their full potential, thus prolonging their use-life. This thesis will highlight the issues surrounding available hafting wood in Europe during MIS 3, and the potential ecological and mobility implications this could have for the Aurignacian people who were present in (northern) Europe.

Small experiments in using osseous-tipped spears have previously been restricted to throwing replicas at a variety of targets from a short distance, or shot from a calibrated crossbow or from a bow (Knecht 1997; Nuzhnyi 1998; Shea et al. 2001). Although this may show that the spears could work under those conditions, it does not demonstrate how they would work under real world conditions. Therefore, this thesis will test replicas in open-air flight conditions on a sports field to determine whether they work adequately as projectiles when thrown from the hand. It has not been considered by previous researchers that such spears may require extra flight stabilisation or propulsion, nor the effect of different spear shaft weight/density. Without testing the spears under these conditions, it cannot be assumed that they were used as javelins at all. Another consideration is that the spear shafts may have been composite in a similar fashion to later spears and harpoons from the Magdalenian (Pétillon *et al.* 2016). Foreshafts made of a certain type of material (not necessarily wood) may play a role in balancing the spear, as well as assisting in easier re-hafting during hunt activities. These issues will be discussed later, in Chapter 2.

Research questions

The main aim of this research study is to explore and assess the steps that follow the production of an osseous-tipped spear, and to set those into broader palaeoecological contexts. The production and hafting methods have received the most attention, with limited consideration for anything in the process besides the spear points themselves. The following research questions have been created to understand and consider other aspects of the spears and materials beyond the morphologies of the osseous tips. The implications of the results of these tests will be discussed, to evaluate these questions in the second half of this thesis.

Manufacture

Question 1: When producing osseous points and spears, what roles do other Aurignacian tools play?

Sub questions: 1a: Are mastics required to secure the points?

1b: How efficient and effective are replica lithic tool-types in the manufacture of projectiles?

Question 2: Are any Aurignacian spear point forms over-engineered? Or were they carefully manufactured to improve the whole spear's longevity and/or protect the spear shaft from damage?

Question 3: To what extent can resource management be identified when comparing palaeo-environments to the spread, presence and behaviours of Aurignacian people?

Sub-questions: 3a: Were there any sources of useful wood in northern regions, or did people have to manage resources carefully?

3b: What does this tell us about Aurignacian hunters? Did people have to prepare spear shafts to transport before moving north into areas with little to no useable wood? Could an exchange of spear shafts over a long-distance have been another solution?

Use and effectiveness

Question 4: How do Aurignacian osseous-tipped spears perform when used in semi-controlled conditions (sports field, thrown by experienced javelin thrower, drop tower)? Were they throwing or thrusting spears?

Sub-question: 4a: Do they require drag or fletching to ensure stable flight?

Question 5: Does the osseous spear point suit small group/solitary hunting strategies, as proposed by Tartar & White (2013)?

For these questions to be addressed, an experimental approach will be used, in combination with ethnographic accounts of projectile technology used by groups in the more recent past. Within these ethnographic accounts, there is evidence that cannot be seen in the archaeological record of the Aurignacian. To answer questions regarding sourcing raw materials in the Aurignacian, samples of wood from a variety of environments (some environments similar to those of MIS 3 in NW Europe) will be collected and their properties defined and tested to determine if there could have been any usable types of wood in a MIS 3 environment in North West Europe.

Hypotheses for testing

Experimental testing is designed to evaluate a main and alternative hypothesis, while wood sampling results have a null and alternative hypothesis. The research questions will be discussed through the thesis and hypotheses summarised in the concluding chapter.

Experimental hypothesis:

Main hypothesis 1 – Osseous-tipped spears work successfully in semi-controlled flight conditions when thrown by experienced javelin throwers, without the need for extra stabilisation (see Research Question 4).

Alternative hypothesis 1 – Osseous-tipped spears do not work well as javelins in semi-controlled flight conditions when thrown by experienced javelin throwers. There is need for flight stabilisation in the form of fletching or extra weight near the spear tips (see Research Question 4).

Main hypothesis 2 – Aurignacian spear points are engineered to improve the longevity of the spear shaft, while offering adequate penetrative power and resistance to sudden impact damage (see Research Question 2).

Alternative hypothesis 2 – Aurignacian spear points are over-engineered and do not improve the longevity of spear shafts. Insufficient penetrative power and resistance to impact damage is clear (see Research Question 2).

Main hypothesis 3 – Mastics improve the composite strength of Aurignacian spears (see Research Question 1a).

Alternative hypothesis 3 – Mastics do not improve the composite strength of Aurignacian spears (see Research Question 1a).

Wood sample hypothesis:

Null hypothesis – Any species of wood in cold or high latitude regions could be used for spear shaft production (see Research Question 3).

Alternative hypothesis – Species of wood in cold or high-latitude regions are not suitable for spear production. Sources of viable timber would have to be sourced in warmer, temperate regions (see Research Question 3).

Research constraints

For this PhD, less emphasis will be spent on analysing the Aurignacian osseous tool assemblages. This avenue has been thoroughly explored by Knecht in her doctoral thesis (1991) which refers back to previous in-depth analyses in the "Fiches Typologiques de l'industrie osseuse préhistorique" (Delporte *et al.* 1988). Much of Knecht's analysis and images were useful when creating replica points; this research will be supported by accessing collections containing Aurignacian points and tools to gain a first-hand view in order to produce accurate replicas based on dimensions, weight (especially for the osseous points) and observations of production traces/marks. This research will test some of Knecht's interpretations of osseous points, as described in her diagrams and figures. This is not to suggest her images are poorly presented, but rather that there may be missing details or alternative manufacturing methods that could assist in producing accurate replicas.

Ethnographic and anthropological accounts offer information and hypotheses about hunting practices and people from more recent groups that could not be extrapolated from archaeological evidence. However, there is some scope for misinterpretation of accounts, depending on the descriptions used for objects. An example of this is the difference between arrows and javelins or darts (Nuzhnyi 1998). In some accounts, it is not made clear what type of projectile is being discussed. This can render such accounts partially or completely invalid for this research, as the relevance of an arrow used in a very different hunting scenario to one used in NW Europe during the Aurignacian is probably limited. As some of the accounts come from different regions, certain accounts or certain projectile types within accounts will be more important than others. Accounts from cold regions, where hunting groups used osseous-tipped javelins to dispatch deer, will be more important than accounts from warm regions where hunting groups used wooden (or metal) tipped arrows to dispatch small game. It is also noteworthy that even if accounts suggest very similar scenarios (Frison 1991; Nelson 1899; Binford 1980) to those that may have played out during the Aurignacian, they might not be perfect analogues, as there are many environmental and climatic differences between the present and MIS 3 (Huntley *et al.* 2013).

In the collection of wood samples to determine their viability as spear shaft timber, it was not possible to collect a large dataset from many different cold or high latitude regions. This was simply an issue of available time. The aim was to obtain around 30 samples from several locations. Potential future research on this aspect will be discussed in the final chapter, in the light of the testing results (Chapter 5). Another issue is that even if some present-day regions have similar climatic characteristics to those in Europe during MIS 3, they will not be exactly the same. Atmospheric carbon dioxide levels were lower during the Aurignacian at 200 parts per million by volume instead of today's 345 ppm (Huntley *et al.* 2003). This means there could have been unexpected sources of timber in isolated tree stands or sheltered areas that were available during MIS 3 but not in the present day. The samples of wood collected will not represent consistent traits within a species across an area. All trees will have grown slightly differently due to a number of different factors such as altitude, exposure, availability of soil, soil moisture, local growing season, etc (Koch *et al.* 2004). These will all have an effect on the tree's physiology. Therefore, it will be necessary to collect appropriate samples of tree species (informed by the palaeo-environmental record) within an area to try and form a range of comparable variations.

During the reproduction of Aurignacian spear points, it was necessary to practise producing osseous points, as it was not a process the researcher was familiar with. Methods devised and compared in past experimental literature were used as guidelines and tested. However, it is important to note the final replicas produced for use in experiments may not be as good in quality as Aurignacian examples. In regards to replica stone tools, based on over 14 years' experience of flintknapping, accurate replicas were not an issue. The species and type of wood to use as the spear shaft for experiments were a problem, as a main question of this research is to try and determine what usable timber might have been available during MIS 3, despite the current absence of any known preserved wooden shafts. Dowelled wood offers a relatively consistent variable with some degree of control; however it has been highlighted that modern materials (or materials that have been prepared using modern methods) can result in unreliable results (Wood & Fitzhugh 2018). Instead, best efforts were made to find long, straight lengths of wood from the same species of trees identified in organic samples from MOIS 3.

During flight tests, the main aim was to determine whether osseous-tipped spears could be used as hand-thrown spears. The overall investigation aimed to put these spears through simulated hunting scenarios, although these tests were not complete representations of how they were used. This would require a test that involved a simulated hunt within a semi-controlled area that held live animals. Such a test would be unrealistic and unethical, so spear testing must be broken down into individual variables, i.e. a separate flight in a sports ground, testing in a wind tunnel and penetration tests on ballistics gel. Pétillon *et al.* (2011) summarised a similar point made by Knecht (1997), that the torsion and bending stresses on a spear point in a live animal will be much higher than in a dead one. In other words, a spear as a whole could easily be damaged by the prey animal as it is attempting to escape or is falling. However, there are also problems when using animal cadaver targets, as, while they may be slightly more ethical than shooting at live prey, they will only present the characteristics of a body that is starting to stiffen from *rigor mortis.*

Thesis outline

Chapter 2

Contextualisation of the Aurignacian in NW Europe and Early Upper Palaeolithic archaeological sites recovered from the 19th century onward. An overview is presented of past experimental literature of Upper Palaeolithic projectiles in comparison to anthropological accounts of more recent hunting groups who used similar equipment and practices. The attention given in past literature to raw materials and movement patterns (specifically timber) is highlighted and includes other literature from different time periods that include preserved wood from spears. Comparisons are made to movement patterns, based on surviving raw materials such as lithics and shells, to infer possible patterns associated with wood procurement.

Chapter 3

An overview of palaeoclimatic, environmental and ecological conditions in NW Europe during MIS 3 is presented in this chapter. Pollen and charcoal records from sites across NW Europe will be discussed to highlight the dominance of certain tree species and the complete lack of other tree species in specific regions (in reference to sourcing spear shafts). Palaeoclimatic and plant productivity models are included to demonstrate the difficult growing conditions for different plant types.

Chapter 4

This chapter will provide the methodology for this thesis in:

- Data collection of wood samples and replication of reindeer antler projectile points by a combination of production theories (Peyrony and Henri-Martin) using replica Aurignacian tools.
- Production of replica spears using reproduced antler points, discussion on hafting techniques, and evaluation of the use of mastics to secure spear point.
- Testing of spears under semi-controlled conditions by experienced javelin throwers.
- Testing of short spears in a drop shaft against different impact materials.
- The production of replica Aurignacian tools to make antler spear points will be evaluated with discussion on the roles played by different tools to address research question 1. Observations of hafting methods for Aurignacian spears will be assessed and evaluated.

Chapter 5

Results from testing flight and semi-controlled use of replica spears are presented and discussed. The condition of spears after testing will also be analysed and discussed. Research Question 4 is addressed using the flight results, to assess whether osseous-tipped spears were suitable as javelins and/or required extra flight stabilisation. Research question 2 (improved spear shaft longevity or over-engineered spear points) will also be addressed. The research sub-question 1a, assessing the potential necessity of mastics, is addressed following flight testing through observing replicas that did and did not have mastic applied during production. Results from drop tests will be discussed in relation to thesis question 2.

Chapter 6

Characteristics of wood samples are presented and discussed to determine if any high latitude or cold climate species would be suitable for spear shaft production to answer sub question 3.

Chapter 7

The conclusions to this thesis will evaluate the rationales behind using osseous materials for spear points during MIS 3. They will discuss of potential future research into resource management in other time periods and regions and future research priorities.

Summary

This thesis takes a new approach to investigating spear and projectile technology in Palaeolithic archaeology. Understandably, spear points have been the main focus of research, as they have a far greater chance of surviving in the ground than wooden spear shafts and hafting components. However, this is not to suggest that the other components were less important or did not present their own problems in procurement and preparation before application. Using wood samples from environments similar to those of MIS 3 in NW Europe, and experimental data, it will be possible to highlight some of those problems and challenges faced by Aurignacian people. The extent to which performance of Aurignacian spears was a combination of effectiveness balanced against maintainability/longevity, and efficiency against reliability, will be evaluated. There are components that are near-redundant when isolated (i.e. the osseous point alone cannot be a spear), but they should be highly effective when all parts are combined (osseous point, wooden shaft, possibly mastic and/or binding agents) (Bleed 1986). Certain components were probably harder to obtain or produce than others, so an emphasis on preserving their longevity may have had to come at the price of some effectiveness. The efficiency of osseous-tipped spears has previously been debated in existing literature to answer questions regarding their preference to flint-tipped spears (Knecht 1993; Tartar *et al.* 2013). The reliability of osseous points has received some attention by Rees (2003) and Knecht (1993), but with only limited consideration of the implications of resource management.

This thesis will shed a new light on resource management, and indicate and explore the value of raw materials that are often overlooked. Comparing archaeological, experimental and anthropological evidence will provide a well-rounded view of Aurignacian hunting strategies. However, instead of suggesting hunting scenarios, this thesis will instead focus on equipment preparation and resource management before hunting trips. The absence of spear shaft evidence must not stop us from evaluating early Upper Palaeolithic projectile technology holistically (not just focusing on projectile tips).

Chapter 2: Setting the (hunting) scene

Contextualising the Aurignacian in NW Europe

Classically, the Aurignacian has been seen as the arrival of the first anatomically modern humans into Europe who brought major technological changes and different hunting strategies (Tartar & White 2013). They entered a climatically challenging landscape that had been previously occupied by Neanderthal groups for many tens of thousands of years (van Andel & Davies 2003, Mellars 2004). The arrival of these new people brought a distinct change to artefacts found by antiquarians and archaeologists, resulting in the creation of separate time periods. The earlier Mousterian was of course eventually succeeded by the Aurignacian, though a transitional period in between, known as the "Châtelperronian", is considered either to be a Neanderthal response to new Aurignacian ideas and technology (Mellars 2004), or to have arisen without Aurignacian input or inspiration (d'Errico *et al.* 1998). Bar-Yosef and Bordes (2010) felt strongly that evidence of a relationship between Neanderthal and Châtelperronian assemblages is too weak, though they did point out that identifying the "makers of the Châtelperronian" remains difficult and open to further investigation (Bar-Yosef & Bordes 2010, pp. 592). The use of osseous materials for tools and ornamentation in some Châtelperrionian sites, alongside the use of ochre within an assemblage of distinct Mousterian characteristics, suggests what has been labelled as "acculturation" (Harrold 1989; Mellars 2004), if not independent invention (d'Errico *et al.* 1998). To effectively evaluate such claims of acculturation or independent innovation, both clear evidence of intentional working on osseous material and accurate dating results are key.

Nevertheless, production of osseous tools from the Middle Palaeolithic (and older) do exist across Europe (though scanty and lacking in standardisation outside individual sites), providing further evidence to suggest bone and ivory were a utilised tool media before the appearance of anatomically modern humans (Gaudzinski 1999, Villa & d'Errico 2001; Davies *et al.* 2015). Piercing tools or spear points made of bone have been identified from a number of sites across Europe (Fig. 2) (Villa & d'Errico 2001: 78).

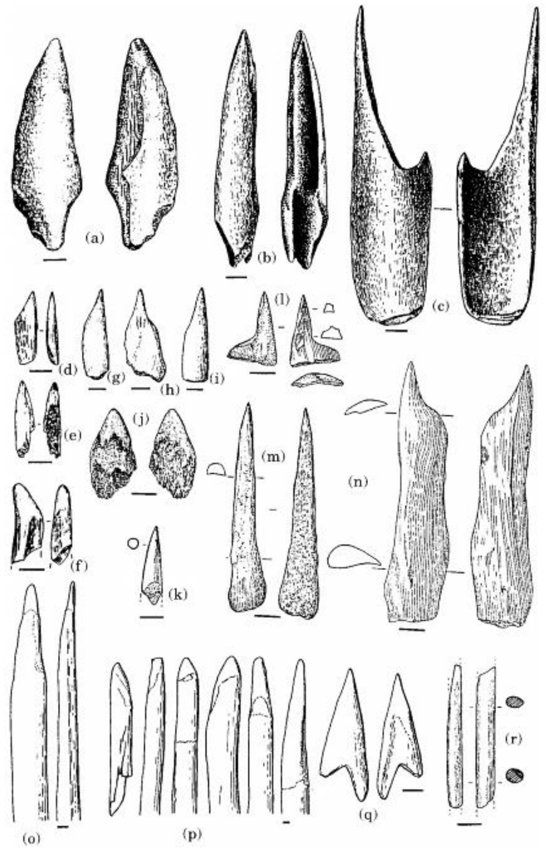

Fig. 2: Sites represented are Butesti (Spain) and Budzujeni (Moldovia) (a-c), Promlom II (Crimea) (d-f), Grotte de l'Hermitage (France) (g-i), Grotta del Broion (Italy) (j), Combe Grenal (France) (k), Combe Grenal (France), layer 16, (l)–(n) Camiac (France), (o)–(q)

Fig. 3: Ivory points from Torralba and Ambrona (Spain) showing a consistent style that appears to be created by a cut through most of the ivory before the blank is split off creating a tail. The tail may be one of the first examples of a "tang" (a continuation of the tool blade material into the haft) (Villa & d'Errico 2001).

Scarce Lower Palaeolithic ivory points have also been found at Torralba and Ambrona (Spain) dating to 300 ka (Fig. 3) (Falguères *et al* 2006). These demonstrate further usage of different media for tools other than stone or wood (Villa & d'Errico 2001). However the original excavators of the ivory points (Clark Howell and Lesley Freeman in 1961-63 and 1980-83) have received firm argument from Haynes (1988) that the "points" are instead natural tip breakage seen in modern African game reserves. Despite surface appearances, the ivory points from Torralba and Ambrona may show signs of developing hafting technology. By making a partial truncating cut through the ivory before detachment, a tail is left. This tail has almost certainly been created to facilitate easier hafting, rather than being an accidental by-product of manufacture. To attach a fully truncated section of ivory to a wooden haft would be extremely difficult, and probably result in a very weak join. An extension of the tool or weapon blade (or tip) from the proximal end is known as a "tang". There are grounds to argue the ivory points show the first example of a tang in any tools from the European Palaeolithic dating to at least 300 ka year ago (Falguères *et al* 2006). In comparison to Aurignacian osseous points, the earlier Neanderthal examples appear crude, though examples of osseous tools appear elsewhere, e.g. Castel di Guido (Radmilli & Boschian 1996), and Salzgitter-Lebenstedt (Gaudzinski 1999). It is possible that in the case of the ivory points from Torralba and Ambrona, the form of the points is dictated by the material and its working characterics as discussed above. Later Aurignacian point manufacture and form was almost certainly affected by the raw materials (as discussed by Tartar & White 2013), though there may have also been some input from a focus towards strategy and specialisation which will be explored to answer thesis question 5. At Salzgitter-Lebenstedt, 30 worked bones were recovered pre-dating the appearance of anatomically modern humans with a range of 58,000 and 48,000 14C BP (Gaudzinski 1999). One of the osseous artefacts from the assemblage appears to have been worked into a point with a notched base (Gaudzinski 1999; Davies *et al.* 2015). However the lack the standardised form in comparison to their later counterparts sheds doubt on claims of acculturation.

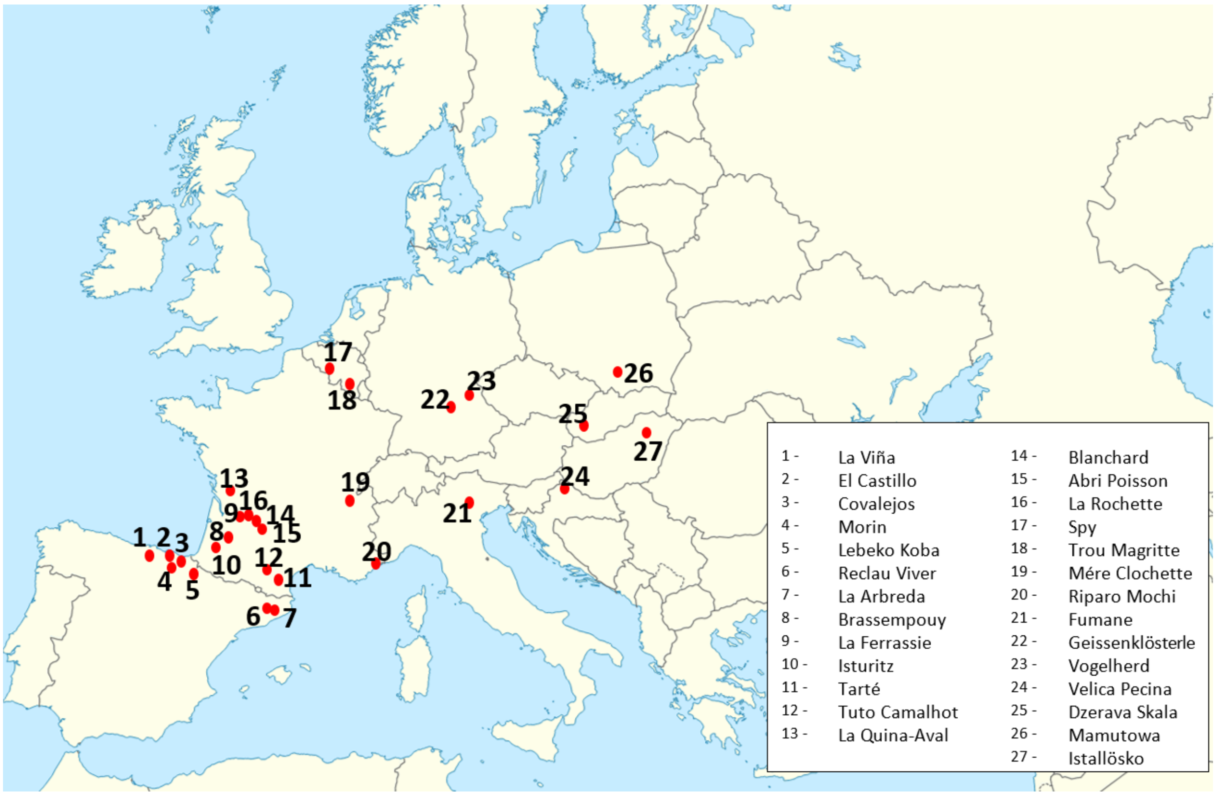

Fig. 4: Map of Europe showing some of the main Aurignacian sites that yielded split base points (derived from Tejero 2016). Map template from: https://en.wikipedia.org/wiki/Template:Location_map_Europe

Fig. 5: Location of split-based points and tongued pieces in Europe (from Tartar & White 2013: page 2742)

The settlement of Aurignacian groups in Western Europe is well-known to be concentrated in south-western France and northern-eastern Spain (see Figs. 4 and 5). This region during MIS 3 has been identified as an area that could offer rich tundra and steppe, with warmer oceanic winters that allowed longer growing seasons (Mellars 2004; Alfano *et al.* 2003; Davies et al. 2003). These regions (especially the Dordogne) also offered natural shelters in the limestone cliffs that had been occupied prior to the arrival of Aurignacian groups, such as at La Ferrassie and other caves in the same valley which are now buried under fallen scree (Peyrony 1934; Knecht 1993). The narrow river valleys in which these people lived almost certainly acted as natural highways for migrating herds of reindeer. Mellars (2004) defended his earlier work (1973) in which he concluded Aurignacian hunters specialised in reindeer in south-western France, based on the dominance of this species in assemblages (at around 90%). It has been contested by Grayson et al. (2002), who indicated that the quantitative aspects of specialisation showed that reindeer were only around 70% dominant. Their research showed some sites had a greater frequency of bovids and other cervids such as red deer. Mellars countered by firstly referring to a number of sites with a reindeer faunal dominance of over 90%, and secondly questioning why Grayson et al. felt the need to suggest he was initially incorrect, as a 70% dominance of reindeer (even taken as the lowest estimate) still suggested specialisation. Neither particularly address the form of specialisation, as the latter can take many forms. In this case the argument focusses on the broader specialisation of species-focussed hunting. However, many Palaeolithic sites show individual-focussed hunting, such as at Stellmoor where prime-age adult males were the focus (Weinstock 2000), or a focus on body elements such as at Amvrosievka (Ukraine) where Epigravettian hunters only removed fillets and fat from bison (Julien 2011). At Amvrosievka, hunters appear to have driven bison herds uphill into a ravine with hunters waiting at the top. They did not select certain ages or a sex when making these mass-kills (Julien 2011). This type of specialisation on certain body elements appears to have been created from an available feast of bison meat; therefore, hunters only bothered to remove their favourite cuts. Interestingly, Julien (2011) notes the bison were also not migratory. This is interesting because Fontana (2017) argues reindeer in the Dordogne area were not migratory (see below). Evidence of tactic reuse by hunters at sites such as Amvrosievka indicates Aurignacian hunters in NW Europe may have still used the landscape to their advantage when creating hunting strategies on an annual basis (rather than opportunistic use of certain points in the landscape on the day of the hunt).

Some researchers have suggested the seasonal migration of reindeer into foraging grounds would have likely meant the primary prey of Aurignacian hunters were temporarily absent in the Dordogne (Hoare 2009, Price *et al.* 2017). However, Fontana (2017) has argued that reindeer may not have migrated out of the Dordogne area (though her study focussed on a timescale after the Aurignacian of 30,000 and 15,000 cal BP), according to evidence derived from teeth, antlers and foetal bones. La Madeleine would have therefore seen reindeer hunting all year round, joining other sites such as Fourneau du Diable, Combe-Saunière, Badegoule, Laugerie-Haute and Abri-Pataud (Fontana 2017). This would have given the Aurignacian people several options: hunt other animals, follow the reindeer, or store meat. It is clear from many Aurignacian assemblages that hunters turned to other prey animals such as horse, bovids or other cervids further south (Dinnis 2012, Straus 1992, Niven 2007). Smaller (fast-moving) game was also exploited to supplement the supply of meat from large mammals at some sites, such as at Arbreda (Spain), where European rabbit (*Oryctolagus cuniculus*) remains were found in large quantities (Lloveras *et al.* 2016). Other small game from Arbreda in the form of fish and birds (though a species list was not included) indicates a somewhat opportunistic approach to meat procurement (Lloveras *et al.* 2016). Hunters operating in more northern regions, such as Belgium or Britain, may have had to use herd-following or encounter hunting tactics to create opportunities (Szmidt *et al.* 2010; Jacobi & Pettitt 2000; Dinnis 2012). Yet due to the colder mean annual temperatures and harsher environments, such trips were probably short-term actions due to the high energy costs involved (Binford 1980). While raw material procurement (particularly for wood and lithics) for hunting tool maintenance proved restrictive, because resources were covered in snow or frozen which would make them harder to lift from the ground and more fragile (Willis & Van Andel 2004). It is therefore likely that raw material procurement had a similar seasonal cycle to that of food in the form of seasonally ripe fruits and nuts or migrating prey animals.

The British Aurignacian is best described as a series of single events or activities at sites across Britain. The limited number of identified artefacts can only offer a frustratingly narrow view on the movements of people in a challenging environment. Perhaps the most well-known mark left by Aurignacian people (albeit very late Aurignacian or even early Gravettian at 33,000 ka Jacobi & Higham 2008) was at Goat's Hole cave, where a young male (known as "The Red Lady of Paviland") was buried, accompanied with ivory grave goods and remains covered in red ochre. Perhaps an example of a hunting party struggling to maintain itself? Here, unlike other Aurignacian sites in Britain is evidence of re-use or a longer episode of activity. Around 4000 lithics have been recovered in total as well as osseous objects, though sadly no osseous spear points (Dinnis 2012). Dinnis (2015) was able to identify a regional lithic phenomenon in the form of Paviland burins which have been found elsewhere in Britain and Belgium. This could suggest the same group(s) operated in this region, or that living in this region demanded a strategy response seen in different lithic products (Dinnis 2015). A location such as Paviland would have surely felt like a frontier, far from more forgiving conditions to the south. Even further north at Ffynnon Beuno (North Wales), excavations in the late 19th century yielded fauna expected in an assemblage from MIS 3. Only six lithic artefacts remain in museum collections from what must have been a much larger quantity recovered (Dinnis 2012). Burins from Ffynnon Beuno have been used by Dinnis (2011) to identify other isolated Aurignacian objects such as at Hoyle's Mouth (Pembrokeshire).

With few opportunities to recover secure radiocarbon dates for the British Aurignacian (other than Paviland), comparisons to assemblages from Belgium have been made to aid in determining a relative age (Dinnis 2012). Not far to the east along the Gower from Paviland cave is Longhole cave which yielded a large assemblage of mammalian fauna from MIS 3 and a collection of lithic material (Dinnis 2015). Of particular interest was a carinated burin made from a piece of "drift flint", which appeared to show similar technical characteristics to burins and bladelet production assemblages from Maisières Canal (Belgium) and Paviland Cave. These distinctive characteristics encouraged Dinnis (2015) to identify the tools as Aurignacian. Other Aurignacian sites in Britain have also only yielded a small assemblage of distinctive Aurignacian material, giving an impression of Binford's (1980) fine-grained deposits (although arguably the condition of the assemblages was affected detrimentally by early excavation methods). Isolated or small Aurignacian assemblages from Kent's Cavern (Devon), Pin Hole (Creswell Crags), Hyaena Den (Wookey Hole) and Aston Mills (Worcestershire) suggest Aurignacian groups were certainly present across Britain (up to N. Wales/Nottinghamshire: see Fig. 7), and not restricted to the south of what is now Britain (Dinnis 2015; Shaw *et al.* 2016). The only osseous points from Britain are from Uphill Quarry and Hyena Den. The example from Uphill is far more diagnostic of an Aurignacian point (almost certainly a split-based point or lozenge point), despite missing much of the proximal end and tip (Jacobi *et al.* 2000). It is unclear whether the damage to the Uphill Quarry point was caused during use or later, as it eventually ended up in a fissure (now destroyed by quarrying). This damage patterning will be tested by the throwing and drop shaft experiments. The example from Hyaena Den is also osseous and could be considered a point, but unlike the Uphill Quarry point it may be a simple or bevelled point, if not another type of tool altogether, see Fig.6 (Dinnis 2012).

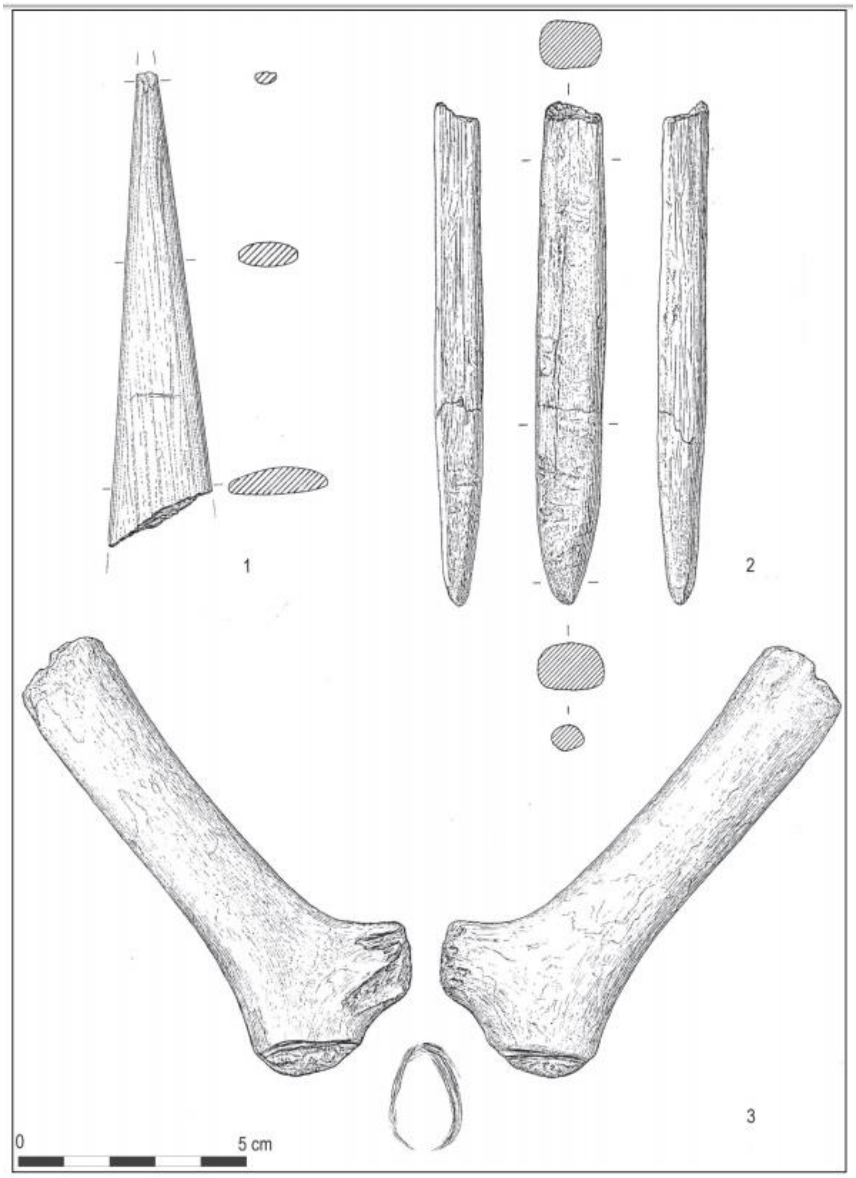

Fig. 6 Aurignacian point from Uphill Quarry (1), Probable bevelled tool from Hyaena Den (2) and modified antler from Pin Hole, Creswell Crags (3). The modified antler from Pin Hole is one of only a few reliable indicators of Aurignacian presence at Creswell Crags (From Dinnis 2012: page 71)

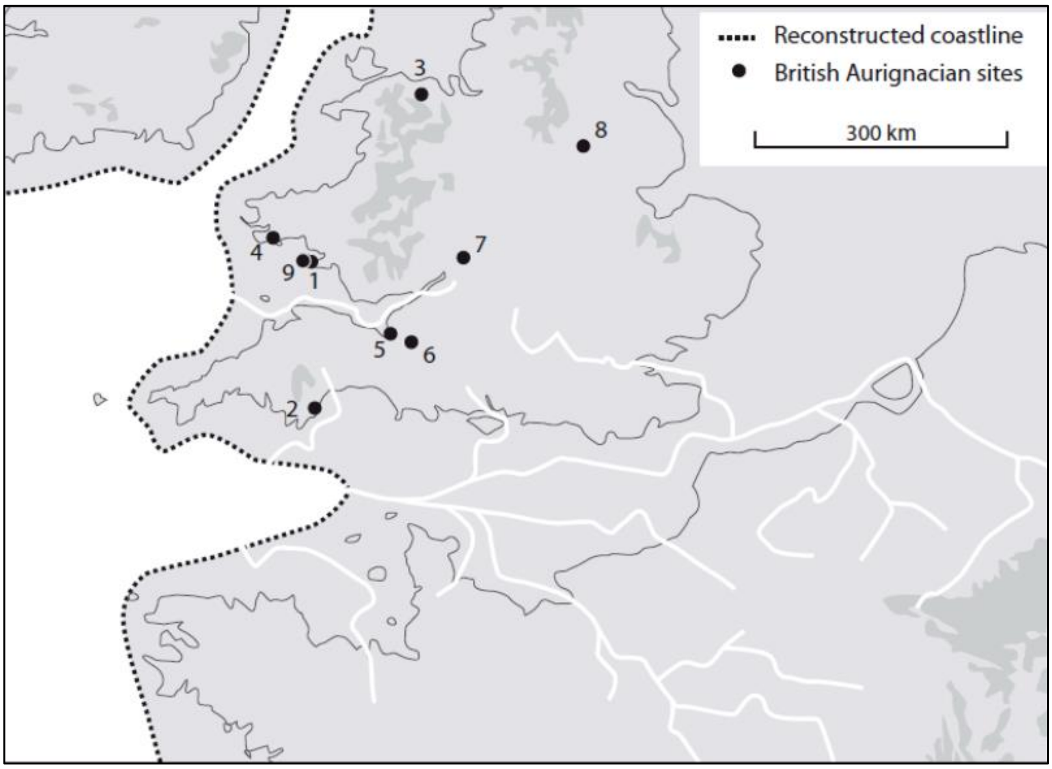

Fig. 7: British Aurignacian site: 1. Longhole; 2. Kent's Cavern; 3. Ffynnon Beuno; 4. Hoyle's Mouth; 5. Uphill Quarry; 6. Hyena Den; 7. Aston Mills; 8. Pin Hole; 9. Paviland Cave (from Dinnis 2015: page 69).

Generally, Aurignacian evidence in northern Europe tends to be limited, although sites such as Maisières Canal (Belgium) prove that when people did travel north, they spent time creating lithic tools from good quality local flint (Dinnis 2012, Moreau *et al.* 2016). Usefully, the Aurignacian from Maisières Canal can be attributed to the warm Huneborg II interstadial, dating it to c. 32,000 – 33,000 ^{14}C BP, thanks to the loess deposits (Dinnis 2012). Mellars (2006), points out that the initial dispersal of Aurignacian people into northern Europe can be tied into warm stages between c. 36 – 38 ka cal BP after an initial dispersal into southern Europe between c. 43 – 45 ka cal BP. This warmer phase would have made it possible to exploit raw materials no longer absent (organic) or locked in permafrost (lithics), although in the case of trees it can still take many decades for species to spread into new areas (Koch *et al.* 2004) A possible temperature rise of between 5°- 8°C, based on simulated biomes, would have meant rare pockets of woodland must have been more common and widespread (Mellars 2006, Van Andel & Davies 2003, Barron & Pollard 2002). This would have made a westward movement across Europe easier for people who originated in the south east if forest biomes carrying raw materials and food resources were a strong draw (Mellars 2006). The starting region of this Aurignacian migration seen through a technological movement model has been attributed to two areas, the Balkans and previously the Near East (Mellars 2006). The Near Eastern evidence for Aurignacian technology comes from Ksar Akil, Hayonim Cave, Manot Cave and Kebara in the Levant

(Newcomer 1974; Belfer-Cohen & Bar-Yosef 1981, 1999; Mellars 2006). Here a blade and bladelet-based technology (Fig. 8), supported by osseous tools and points (Fig. 9), has been argued to be the beginnings of what is later seen in Western Europe (Ronen 1976; Bergman 1981; Newcomer 1974; Goring-Morris & Belfer-Cohen 2006). However there is some debate as to whether the blade and bladelet technology seen in the Levant (also known as Ahmarian) is linked to the Protoaurignacian (Goring-Morris & Belfer-Cohen 2006). Recently the Ahmarian has been incorporated in a "Leptolithic lineage" which precedes the Levantine Aurignacian (Fig. 8) (Goring-Morris & Belfer-Cohen 2006: 301). Frequent changes to the timeline of technological development in the Levant region have made it difficult to define a clear development through time (Goring-Morris & Belfer-Cohen 2006).

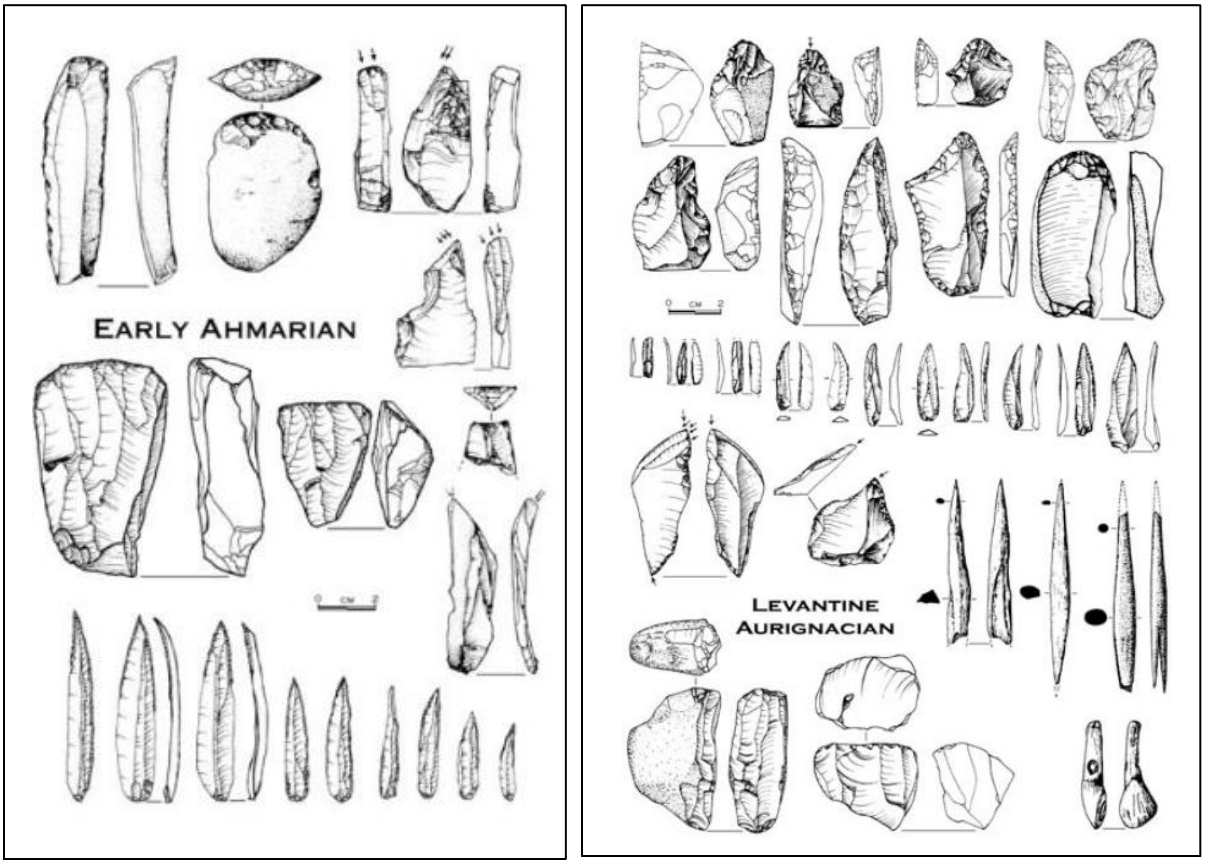

Fig. 8 A "typical Ahmarian assemblage" alongside a "typical Levantine Aurignacian assemblage" (From Goring-Morris & Belfer-Cohen 2006: 300 and 303)

Osseous points from Ksar Akil (Fig. 9) show clear standardisation, though are far from identical to split-base points (Newcomer 1974). A split base point from Kebara cave (Fig. 8) does, however, appear to be far closer in resemblance to European split-based points, and is made from antler instead of bone (Goring-Morris & Belfer-Cohen 2006).

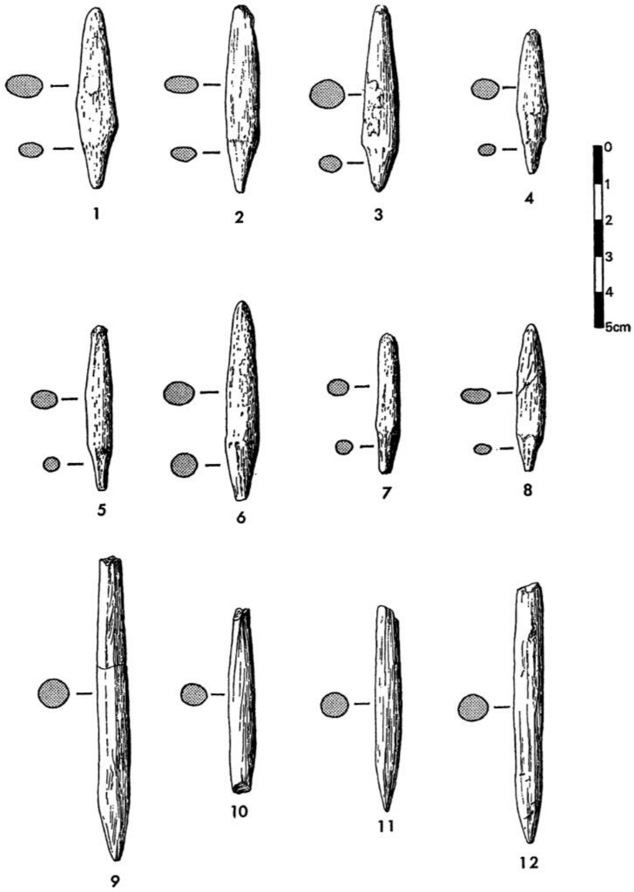

Fig. 9 Bone points from Ksar Akil, Lebanon (from Newcomer 1974: 144)

The alternative to that model is that a true Aurignacian technology begins to take shape at sites such as Bacho Kiro and Temnata (Bulgaria) at around 43,000 BP before back-migrating eastwards (Garrod 1953; Bar-Yosef & Belfer-Cohen 1996, Belfer-Cohen & Bar-Yosef 1999, Bar-Yosef 2000; Mellars 2006). However, more recent evidence from Manot Cave, Kebara Cave and Hayonim Cave, in Western Galilee, suggests Levantine bone points are later than European osseous points, which may indicate a back-migration of osseous hunting technology-wielding people (Goring-Morris & Belfer-Cohen 2006; Sarig *et al.* 2019).

The Balkan origin and migration model for osseous hunting tools is supported both by earlier dates (48 ka cal BP) than those from the Levant, and is much closer geographically to central and western European sites (Mellars 2006). This is not to suggest that people in the early Upper Palaeolithic could not have travelled such a distance, though there is a significant evidence gap between the Levant and the Balkans. Mellars (2006 pp. 175) notes in particular a "virtual lack of well-documented and fully published early Upper Palaeolithic sites from the intervening region of Turkey". This could suggest either the back-migration theory is missing a huge amount of material from sites that should exist between the Balkans and the Levant (Mellars 2006; Sarig *et al.* 2019), or that the osseous points from Ksar Akil and Kebara represent an isolated innovation, with no contact from the north-west (though this is highly unlikely). If the Levantine Aurignacian is removed as the progenitor of the European Aurignacian at this point (based on the Manot Cave evidence), lithic and osseous evidence from Bulgaria appears to be the current starting line (Kozłowski 2004). Bacho Kiro and Temnata in northern Bulgaria, are key sites in the argument for the origins of a classic form of Aurignacian (Mellars 2006). The lithic assemblage is comprised of blades that show strong similarities to diagnostic Aurignacian stone tools such steep-fluted end scrapers and backed blades (Kozłowski 2004; Mellars 2006). The sites are tantalisingly close to the Danube valley, so it would not be unreasonable to suggest that this river valley was used as a convenient migration route, as it has been (both up- and down-stream) in the following millennia (Muttoni *et al.* 2014; Price *et al.* 2001; Davies 2001). Following the river west would have taken early Aurignacian people into Eastern Europe and onto the Central European plain, leaving sites such as Willendorf II (Austria), Geißenklösterle, Hohle Fels and Keilberg-Kirche (Germany) at c. 37,000 – 39,000 ^{14}C BP, (42,000 – 44,000 cal BP) and eventually creating Aurignacian site-rich regions in western France at 35,000 –37,000 ^{14}C BP (40,000 – 41,000 cal BP) (Mellars 2006; Hublin 2015). Once we see the arrival of Aurignacian people in Eastern and Central Europe, it seems clearer that people could be pulled westward by migratory prey herds (based on tooth enamel isotope data from later sites in the Hamburgian and Ahrensburgian) across the North European Plain (Price *et al.* 2017). Though the results of Price *et al.* 2017 showed the east-west migratory range of these reindeer was limited in its extent and comes from later sites, Aurignacian groups may have also been pulled westward by other raw materials (Price *et al.* 2017).

Heidi Knecht's research on Aurignacian projectiles, starting with her thesis (1991), continued the intermittent earlier studies of Hahn (1988), Albrecht *et al.* (1977), Delporte *et al.* (1983), Peyrony (1933) and Henri-Martin (1931). In general, Knecht's thesis, with accounts of Aurignacian deposits from Western European sites, is a fairly complete summary of excavations from the 19th century onwards. A detailed background of the identification and use of Aurignacian points by Peyrony created the technocomplex and its five-phase sequence (though not universally agreed) (Tejero 2016). The first phase was represented at La Ferrassie, and the fifth (Aurignacian V) at Laugèrie-Haute (Peyrony 1933). The split-based point was the first recognised type ("*pointe d'aurignac*") by its morphology for the Aurignacian in Europe, due to its presence in early Aurignacian levels at several sites (Tejero 2016).

Peyrony (1933) defined the phases based on the type of osseous point (see Fig. 1) from his sequence at La Ferrassie:

Aurignacian I – Split-based point

Aurignacian II – Lozenge-shaped point

Aurignacian III – Lozenge-shaped point with oval section

Aurignacian IV – biconical point

Aurignacian V – cylindro-conical point with single-bevelled base.

Peyrony's sequence has since been questioned, as some of the types do not fit cleanly to some of the Aurignacian assemblages from key type-sites such as La Ferrassie; phase V is now considered outside the Aurignacian (Knecht 1993). Knecht's own morphological study of osseous points from France, Belgium and Germany explored the wider presence of osseous point types from the Early Aurignacian through to the Gravettian. She suggested that variation in morphology over such a wide geographic area may be down to groups encountering manufacturing or performance problems rather than a gradual technological shift in design (1993). Her later papers focused on possible hafting techniques for each spear point type, testing Henri-Martin's original theories (1931) using experimental and ethnographic data (Knecht 1993). Her research forms a foundation for later research (including this thesis) to begin applying stronger experimental approaches in combination with ethnographic information, whilst considering climatic conditions and resource management. The experimental research conducted by Knecht and other authors is discussed later.

Missing the mark in past literature

The production method for split-based points has been the main focus for experimental research, as outlined earlier. Beyond the main debate between Henri-Martin (1931) and Peyrony (1933), as well as hafting systems such as armatures or mastics, little has been extensively examined beyond this stage. Usage and maintenance have been considered by latter researchers; however, this is supported by only light experimental study. A broader view of hunting equipment in literature from similar environments or similar hunting styles reveals that there is an important aspect that is often missing. It is perhaps best summed up by Friesen's (2013) list of factors that affect decisions on hunting methods, including: biology and behaviour of prey species (body mass, speed, group size, predictability), environment and landscape of hunting ground (barriers or bottlenecks), nature of the social group (specifically hunting group size), and finally the culture and knowledge of the society carrying out the hunting (here Friesen mentions "weaponry available", but does not expand on the point). The missing part to Friesen's list is raw materials availability for hunting equipment, though he does admit the list is not exhaustive. Friesen's research into the prehistory of the Canadian Arctic is a reasonable proxy environment for Aurignacian hunters in NW Europe. The dominant prey species, environment and climate in the prehistoric Canadian Arctic (based on pollen, charcoal and faunal samples) indicate a tangible connection to NW Europe during MIS 3 (covered in Chapter 3). Essentially, without the right raw materials or even serviceable materials, certain hunting strategies and methods are not possible without a wide resource catchment or seasonal movements to include resource gathering (Friesen 2013; Smith 2013). It is surprising that resource management has not had a greater bearing on research into hunter-gatherer societies, especially as early pioneering research such as Binford's (1980) foraging subsistence-settlement systems clearly identified its importance. Could it be perhaps that the part played by resources is simply assumed and not considered to be dynamic or at least multifaceted? This seems unlikely, as it has clearly been identified by some researchers that locations with predictable resource yield are economically important, even defendable (Dyson-Hudson & Smith 1978). Resources that are constantly in a state of movement provide problems especially if that movement is unpredictable. In the case of reindeer (which provide antlers for making osseous spear points), that movement is fortunately highly predictable (Friesen 2013). Perhaps that gap is not a consideration of resources, but how and why those resources were chosen and why they are suited to playing an important role in a hunting group's economy. Returning to reindeer during the Aurignacian, they were present in large numbers in NW Europe based on faunal assemblages (see figs. 37 & 39). The reindeer carried a number of resources that were used by Aurignacian people (antlers for spear points, bones for tools, meat and fat for sustenance and hides that people almost certainly used). There are some simple decisions over why to use resources like reindeer hides: they are very well-insulated, so ideal for clothing in cold climates (Stenton 1991). But reindeer antlers for spear points are perhaps a less obvious decision, and one which past literature tended to ignore (on this point and similar examples). Decisions were made by people who lived in a cold environment where resources could be very sparse, about whether to use an osseous material instead of a stone to make a spear point. But what does antler offer over stone that had led to that decision? Manufacturing methods could offer clues to this question, and they have been extensively explored by researchers for nearly 90 years.

Both Henri-Martin and Peyrony generally agreed the points were created and tapered by scraping and smoothing using lithic tools; the way the split was produced was, however, debated. Henri-Martin (1931) argued that the split was created by basal cleavage, while Peyrony (1933) believed the split was created by flexion after incision to regulate the length of the wings at the proximal ends (Knecht 1993). Knecht covered the research and discussions by both Peyrony and Henri-Martin in her thesis (1991).

Her account of many European sites that have yielded Aurignacian archaeology, excavated by Henri-Martin, Peyrony and others has been a starting point for later research. Her research (as part of her thesis and later papers) generally focusses on possible hafting methods for the osseous projectile points. Her belief was that Henri-Martin's theory was correct, reasoning that many SBPs did not show evidence of missing material between the wings which would support Peyrony's theory. She later developed this to suggest that the thin pieces of antler found within many assemblages, identified by Peyrony as tongued pieces or "*pièces à languette*" (Fig. 10) removed from the split during flexion, were instead a type of barb or armature hafted with the SBPs (Knecht 1993). Knecht's hypothesis was supported by limited experimental evidence, and by the observation that the distal cleft of many SBPs did not have a space where material could have been removed in the form of a tongued piece via flexion. Therefore, these pieces Knecht labelled as "shims" were separate objects, not waste material from SBP production, as suggested originally by Peyrony (Knecht 1993).

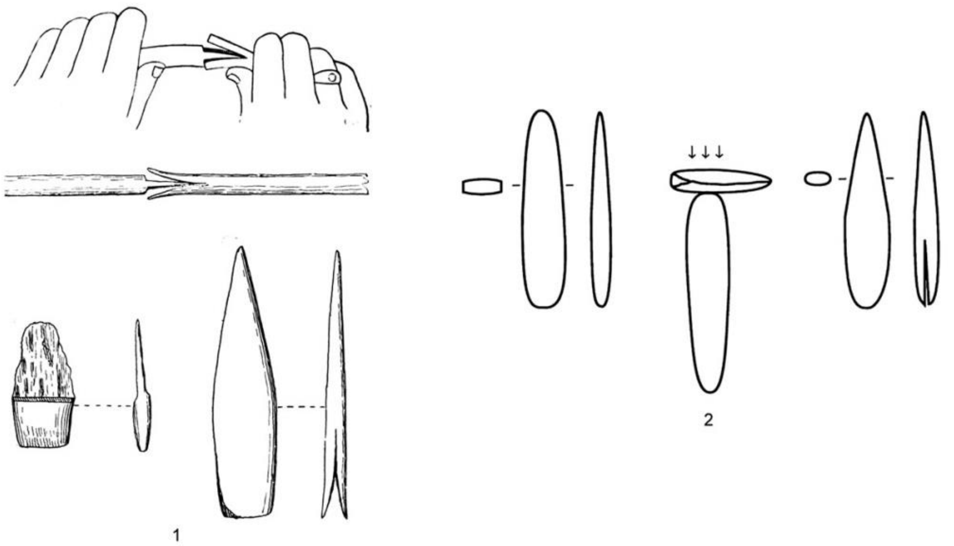

Fig. 10: Production of SBPs as theorised by Peyrony (1) and Henri-Martin (2). An example of a tongued piece, or *pièce à languette*, is shown in the bottom left. From Tartar and White 2013: 2724.

Later experimentation by Tartar and White (2013) indicated that Henri-Martin's hypothetical technique lacked splitting control, resulting in many failed attempts to replicate SBPs. They found that Peyrony's incision and flexion approach allowed greater control of the split with fewer failures. However, it was demonstrated by Tartar and White (2013) that often the split was not long enough when produced by this method alone. It was concluded that the procedure was most successful with a combination of the two methods. First, Peyrony's method was used to create a controlled split, followed by using cleavage (Henri-Martin's approach) to widen and lengthen the split. This approach proved successful for a number of reasons. First, the rate of failures decreased, as the initial split was controlled during flexion of the reindeer antler, so could not cause damaging splitting unexpectedly. Second, the observation made by Knecht regarding the lack of a gap in the split between both wings in many SBPs she observed could be answered using Tartar & White's (2013) technique; the lengthening of the split by cleavage would show little evidence of a tongued piece if the first step had only produced a small gap (as demonstrated during the experiments). This therefore fitted with Knecht's observations, while suggesting both techniques may have been in use separately at some sites or in combination (Tartar & White 2013) (see Figures 12-14 for Tartar and White's 2013 SBP production method).

Prior to the shaping and splitting of the osseous point, the two main methods for obtaining antler blanks have been discussed. Tejero (2016) proposed that blanks were produced by cross-segmentation of red deer antler beams, before splitting to create sub-triangular lengths or *"baguettes"*, based on waste material from Spanish sites such as El Castillo and Labeko Koba (see Fig. 15). This method utilises the 'grain' of the antler fibres produced during growth (Fig. 11). Tejero also indicated that this method may have been used to produce some of the longest examples of osseous points from Aurignacian deposits in both Spain and France. Previously, Knecht explored maximising antler blank size during her thesis to address the issue of SBP size variation, which ranged from a few centimetres in length to over 20cm (Knecht 1991).

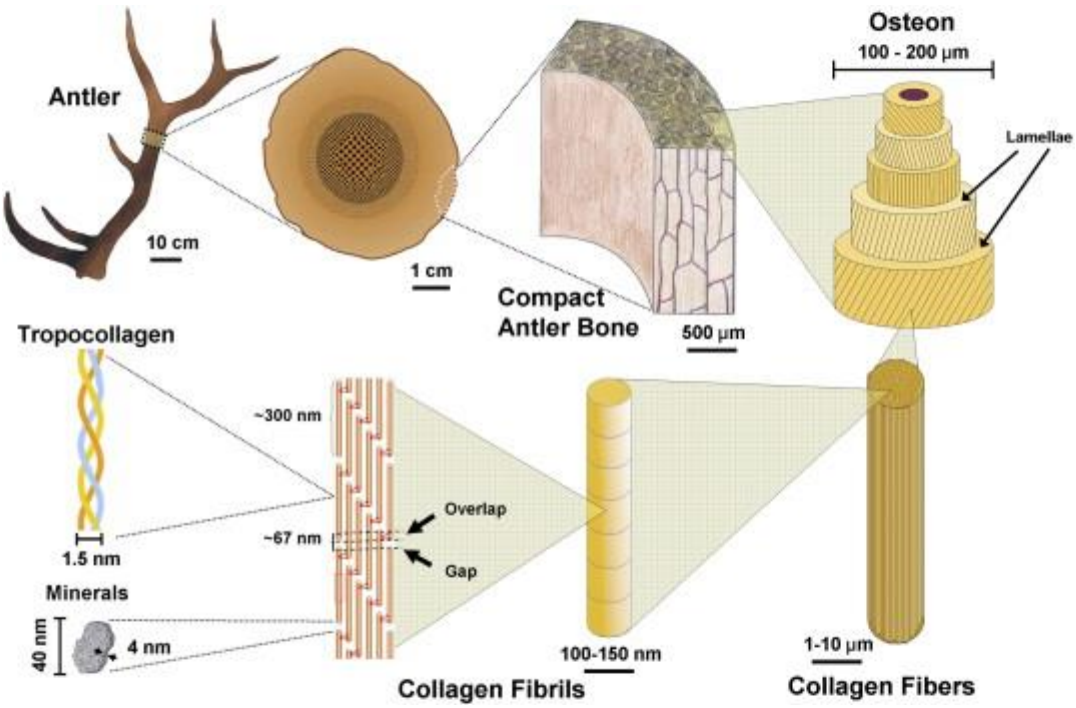

Fig. 11: Hierarchal structure of antler showing collagen fibres or 'grain' as discussed by Tejero (2016) in regards to splitting antler for blanks. Image from Kulin *et al*. 2011: 1031.

The alternative method is based on percussive flaking and breaking of antlers into useful sections (Tartar & White 2013), but the random size and shape of blanks produced demonstrate a clear downside to this approach. In comparison of the two methods, it may be possible to assume that time and effort could be a deciding factor. By flaking and breaking an antler, a number of blanks can be produced within a fairly short session of working. However, there is some potential for pieces produced to be too small. By cross-sectioning and splitting, there is still some risk, but essentially this approach would appear to be more efficient for material consumption. The downside is that to cross-section the beam, it would require a sawing action to the marrow around the outside in several places. This would certainly take a great deal more time and cutting/sawing tools before splitting. However, where more time and effort are invested initially, there is almost certainly a good return in the spear point's longevity in maintaining and re-sharpening. Tejero observed that climatic conditions were likely to be the reason for adaptation by early modern humans, seen in new tool forms. By using replica Aurignacian lithic tools to make osseous points, it will be possible to evaluate whether they were made specifically for manufacturing and maintaining spear points (research question 1b). The natural next step will then be to determine whether Aurignacian spear points were designed to improve the longevity of either the whole spear or certain elements (research question 2). This could demonstrate an adaptation by Aurignacian people seen in their tools and hunting equipment to curate scarcer raw materials such as wood under difficult climatic conditions (as inferred by Tejero). However, he admits the reasons linking specific aspects to deciding factors in adaptation are difficult to trace (Tejero 2016). Like other researchers, the main focus of interest is the use of antler for projectile points. The clear divide between Neanderthal spear points (of stone, or crudely-shaped bone/ivory) and early modern human examples seems to be the source of investigative curiosity by modern researchers. However, it would seem likely that Aurignacian people were using antler to suit their lifestyle, as it was readily available and potentially allowed the improved longevity of other spear elements (research questions 2 and 5).

Fig. 12: Production method used by Tartar and White (2013) to produce many blanks from one beam (2). However the risk of misshapen blanks due to a failed split is relatively high (From: Tartar and White 2013: 2732 and 2734).

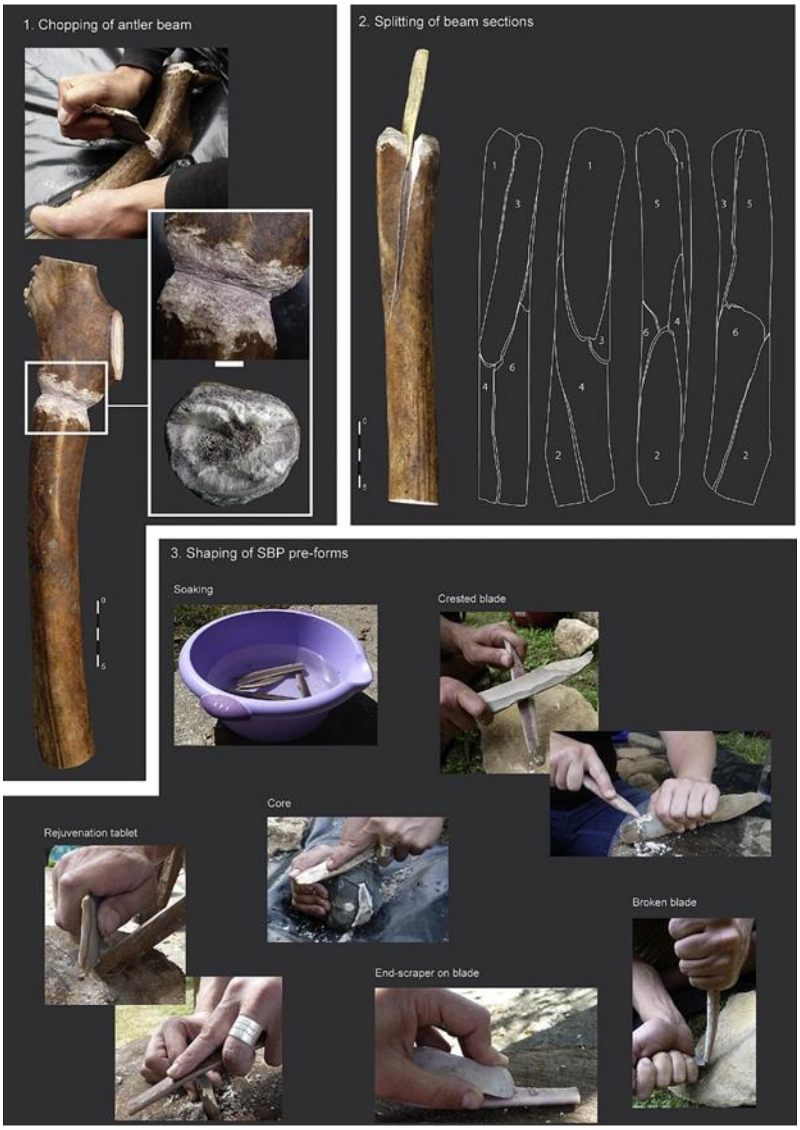

Fig. 13: Tartar and White (2013: 2731) used both Henri-Martin's (1931) method by cleavage (left) and Peyrony's (1933) method by flexion (right).

Fig. 14: After successfully creating the initial split by flexion, Tartar and White (2013: 2736) demonstrate the use of cleavage to lengthen the split. Therefore a combination of Henri-Martin's (1931) and Peyrony's (1933) method.

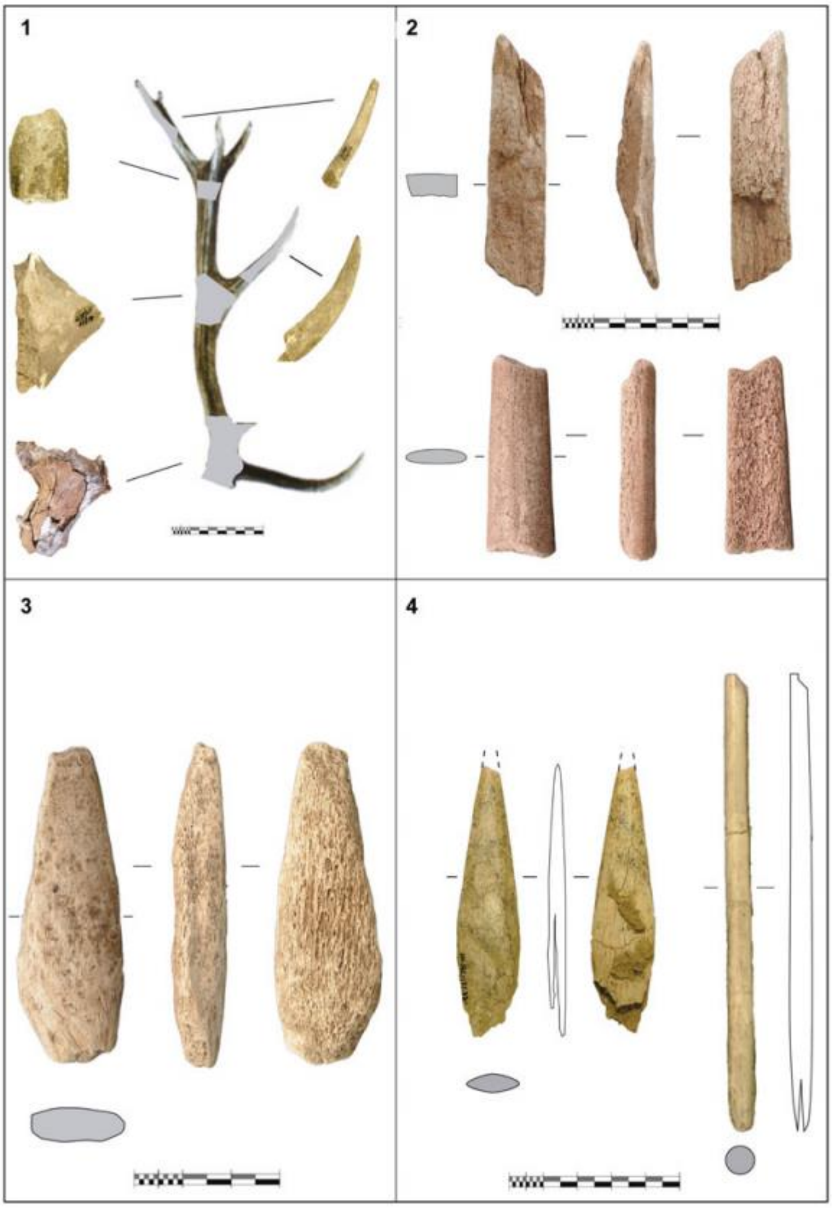

Fig. 15: Tejero's (2016: 57) method demonstrated using examples from El Castillo, Conde Cave and Labeko Koba. Cross-segmentation of the red deer antler (1). Split blanks or *"baguettes"* come from the straight beam sections (2). Split blanks are shaped to create a point (3). Split base point is created on an antler point from Labeko Koba (left) and an ivory point from El Castillo (right).

A smaller experimental study conducted by Nuzhnyi in 1998 addressed Knecht's theory (itself developed from Henri-Martin's 1931 theory) of production for split-based points. During the production of his own replicas (3) for testing, Nuzhnyi emphasised the usefulness of water in controlling the split, as the reindeer antler is softer after soaking, but did not specify the length of time required for soaking (Nuzhnyi 1998). He also suggested that following incisions to start a split (from

Peyrony), using a wedge of some kind would help to lengthen the split. This was later adopted by Tartar and White (2013). Nuzhnyi made some reference to the wooden spear shaft, by suggesting it could be used as the wedge to length the split before the SBP was fixed in place. However, he did not extend the discussion regarding the spear shaft any further. For Nuzhnyi's usage experiments, the replica points were shot from a bow at targets of freshly-killed boars. Neither the distance to target or draw weight of the bow was specified, and the velocities were not disclosed (therefore probably not recorded and examined), but Nuzhnyi did describe how the antler points were able to pass through soft tissue and even thin bones such as the ribs without showing any macroscopic damage.

In a focus on possible projectile barbs, Hays and Lucas (2001) investigated the role of Dufour bladelets, associated with the Protoaurignacian or Early Aurignacian (Bordes 2006). Their research did not aim to demonstrate that Dufour bladelets could be used as projectile barbs, but rather to try and match use wear after experimentation to originals. It was quite clear that the results were "random" and could not categorically demonstrate hafting systems or potential use as barbs. Notably, the protocol for the experiments included an outline for the materials used for hafting. Hays & Lucas (2001) referred to evidence from Le Flageolet I level IX (their main case study site for the bladelets), with regard to the absence of antler or wooden points. They then continued: "given the availability of hazel and beech, four hafts were fashioned" (Hays and Lucas 2001, pg. 112). It is not made clear whether the availability referred to the place the replica hafts were made or the palaeo-vegetation evidence from Le Flageolet I itself. Pollen evidence from levels K3-J at La Ferrassie shows hazel (*Corylus*), ash (*Fraxinus*) and lime (*Tilia*) were present during warmer phases, which coincides with Aurignacian occupation (Blades 2001). Hays & Lucas (2001) briefly discussed Palaeolithic mastic use more broadly prior to their experiments in relation to archaeological evidence from existing literature (Shea 1988). However, as identified by Knecht in her thesis and following research, no mastic has been identified on SBPs (Knecht 1991, 1995). As discussed by Knecht (1991), if any adhesives or mastics were used, it would likely leave some trace within the matrix of the softer marrow sections of the point. Hays & Lucas (2001) used a resin, ochre and beeswax mix as the mastic for replica hafting. This would seem an unusual approach after including literature that discussed birch tar, for which there is evidence from the Mousterian, and later at the Aurignacian site of Les Vachons, France (Dinnis *et al.* 2009). Instead Hays and Lucas (2001) chose to use a resin/wax-based resin, for which there is no evidence until later prehistory in Europe. Ultimately, it is difficult to suggest how the different mastics could have affected the results. Furthermore, Hays and Lucas's lack of consideration of tree species available during the Aurignacian or the requirement for mastics on spear tips is generally consistent with other existing experimental literature.

A Southampton undergraduate dissertation into Aurignacian points used an experimental approach to test the variation in design in a controlled experiment (Rees 2003). It was mainly based on Knecht's (1991, 1993) research, so followed her hafting theories (derived from Henri-Martin). Although only an undergraduate dissertation, Rees proved that osseous points hafted using Knecht's approach, and with an additional binding made from intestine, could withstand several impacts within highly-restricted motion along a rail against a static target. Although this had been briefly discussed by Knecht, it had not been demonstrated continuously. Tartar & White (2013) pointed out that Knecht's experimental work supporting her hafting and usage theories had little in the way of a clear methodology.

A recent experimental study into the types of wound trauma caused by osseous (bone), lithic and composite (inset microblade) projectiles in Alaska during the Pleistocene/Holocene transition was conducted on ballistics gelatine and on a reindeer cadaver by Wood & Fitzhugh 2018. Their aim was to investigate the archaeological implications of Alaskan projectile tips as well as develop a wider framework for future experiments with replica projectiles. The osseous points in their experiment were based on an ivory point from central Alaska; however, the decision was made to use the "long bone of a cow", rather than ivory (either from mammoth or elephant) or a polymer equivalent. There is no explanation for this material substitution; presumably the authors wished the reader to assume the ivory was not used on ethical grounds. This does not answer the question as to why a polymer substitute was not used, as it would have had more similar characteristics to ivory than would bone. The bone points were produced using an electric multi-tool cutter to shape and sand the blanks. The notch in the wooden hafts was also cut with the multi-tool. It should be noted at this stage that the arrow shafts were made from tapered poplar (*Populus*) and fletched with three natural feathers. Poplar timber is used in the manufacture of paper and can be split easily for chopsticks due to its tight grain (Schreiner 1959). Poplar timber also has a very high water content (Schreiner 1959), and such a characteristic would restrict its ability to grow in low precipitation zones such as those identified by the Stage Three Project (Huntley *et al.* 2013). Choosing poplar to make thin shafts seems unusual, although the authors note that artificial sinew was wrapped at both ends of the shafts to prevent splitting. There is no mention of shaft damage later in the research paper. It is worth considering the launching mechanism (a modern recurve bow) had a low draw weight of 18kg (or 40lbs, as bow draw weights are usually measured imperially). The authors assured the readers that the velocities generated by the bow (30-35 m/second) adequately compare to those produced by spear-throwers. The other types of projectile tip produced in the research were purely lithic and composite (lithic inset) types. The stone used to produce the lithic points and blades for inset was obsidian. The material chosen to hold the blade insets was reindeer antler with a birch tar mastic for all the points.

Returning to the issue of wound ballistics, the three main types outlined by Wood & Fitzhugh include puncture, incised and laceration wounds. Certainly these three main types are useful for categorising results in this type of experimental study (and this thesis). In the case of this thesis and previous experiments using osseous Aurignacian points, the most likely types of wound are puncture ones. It would be classified as a hole produced by penetration that lacks cutting or tearing (Wood & Fitzhugh 2018). During the experiments on the ballistics gelatine, the bone points created deep penetration channels (90-127mm in length), which were slightly longer than the lithic and composite points. However, the lithic and composite points created wider wound channels and disrupted the gelatine tissue, which would have caused greater incision trauma leading to quicker blood loss. A composite lithic point from the open-air Gravettian site of Les Prés de Laure (France) pushes back the earliest evidence for similar projectile points to those used in Wood & Fitzhugh's experimental study (Tomasso *et al.* 2018). The proposed hafting and lithic form are slightly different from that of the replica obsidian and antler points used, although some observational results can be used to infer the capabilities of the Gravettian example from Les Prés de Laure (Fig. 16).

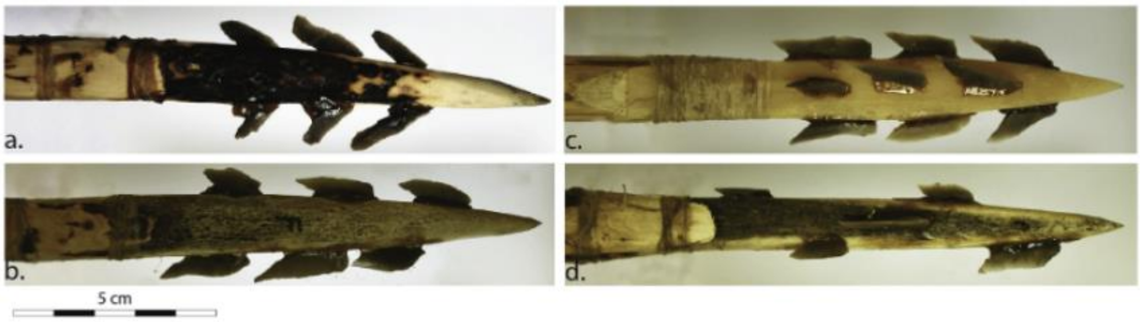

Fig. 16: Reconstructed designs of the Les Prés de Laure composite point (From Tomasso *et al.* 2018: 170)

Wood and Fitzhugh (2018) discuss in some detail the requirements for lethality in regards to hunting equipment that relies on making channels into the body cavity. It should be noted at this point that Pleistocene herbivores were larger than their descendants of today (Owen-Smith 2013; Saarinen *et al.* 2016), Wood and Fitzhugh don't specifically refer to this issue so it could be argued their estimate for lethal channel depths should be increased, though Hughes 1998 indicates a lethal wound depth for ungulates is around 20cm. For the experiment using a reindeer cadaver as a target, there are two angles used to test the lethality of their projectiles. The first angle is labelled as a "quartering away" shot; this angle is about 45˚ closer to the rear of the reindeer from a perpendicular "broadside" shot. They point out that a shot from behind (although slightly angled) prey will require a projectile tip to make a deeper channel into the body if it is to damage vital organs such as the kidneys or liver. If any of the vital organs are damaged, incapacitation of the prey could occur within an hour. If the projectile tip fails to damage a vital organ, the prey incapacitation will be much slower (5-24hrs) as bacteria and acids start to take their effect. Wood and Fitzhugh (2018) also point out that due to limited blood loss, tracking will be more challenging. Therefore, it is vital that attempted shots within a 90˚ space directly behind the prey have very high penetrative power. In the case of the bone points, 6 out of 9 failed to achieve a penetration depth of at least 280mm that would have been sufficient to damage vital organs (and probably slightly deeper for larger Pleistocene prey). Both the lithic and composite points were more successful in penetrating deep enough to cause rapid incapacitation with several of both types going past 280mm into the thoracic cavity (up to 400mm). Certainly, from this first experiment by Wood and Fitzhugh, it would be possible to question the likely effectiveness of Aurignacian osseous points as they create very similar types of puncture wounds. It would be reasonable to suggest hunters could have only made shots from a broadside angle, unless the prey was trapped within an area. Assuming that herbivores during the Aurignacian would have been larger than today's, it can be concluded that a lethal wound depth of 280mm as identified by Wood and Fitzhugh (2018) is more likely to have been a larger figure. According to their experiment, this could further call into question the effectiveness of osseous projectile points.

The broadside experiment proved far more successful for bone points but this is almost certainly due to the shorter distance to vital organs. Based on American bow hunting practice, it is necessary for hunters to attempt to pierce both lungs to ensure fast incapacitation and limited suffering of the prey animal (Wood & Fitzhugh 2018). At this angle the chance of the prey animal becoming incapacitated within a few minutes is much higher; an ambush hunter would clearly wait for a clear broadside shot to have the best chance of a successful (and rapid) kill. The composite points still proved to be the most effective in terms of penetration depth and trauma caused by incision of the inset lithic blades. Limited dislodging of the inset blades came as a surprise to the authors and calls into question why such tips were not used consistently. In the case of the composite point from Les Prés de Laure, it would be reasonable to assume it had a far more effective lethal capacity than Aurignacian osseous points, based on Wood's and Fitzhugh's experiments (Tomasso *et al.* 2018). Different split-based point sizes may have been more effective on different prey classes. This could then dictate their use, whether they were maintained and shortened over time, or whether they were intentionally made at the outset to that size (Doyon & Knecht 2014).

The much later hunting and butchery site of Stellmoor in the Ahrensburger tunnel valley (Schleswig-Holstein, Germany), offered an interesting view on hunting strategy that is similar to Wood and Fitzhugh's observations. Lesions on reindeer bone created by the tips of flint projectiles were plotted to indicate the most frequent angle at which the projectiles impacted the reindeer (Bratlund 1991). Within the valley at Stellmoor is a bottle-neck between the side of the valley and what would have been a lake. Based on the angles of impact, hunters waited until migrating reindeer were passing their position. At this point they began launching projectiles; the hunters appeared to be at the same height as the passing reindeer (Bratlund 1991). Based on the reconstructed layout of the valley and lesion angles, it is likely the reindeer came towards the position of the hunters at a slight angle so their right side was partially exposed. As the reindeer passed with the hunters at a perpendicular angle, a true broadside shot was available (and thoroughly utilized by hunters). The reindeer then angled away from hunters as the valley side narrowed and the herd fled from the hunters, here the "quartering away" shots were available (Bratlund 1991; Wood and Fitzhugh 2018). The final opportunity for a similar shot but from a higher angle was when the reindeer tried to escape across the lake; here the lesions are clearly angled (Bratlund 1991). Although not an Aurignacian site, such hunting strategies in environments such as narrow valleys work well when ambushing migrating reindeer. This could indicate split-based points were less useful in an open landscape unless the prey was driven into a corral or trap.

There was one final partial experiment by Wood and Fitzhugh which focused on the vertebrae. It was a partial experiment, as many of the replica projectile points were too damaged for use so lithic points were not used at all. However, from evidence at Stellmoor it is clear that the lithic tips used were able to pierce vertebrae (Bratlund 1991). Interestingly, bone points proved very effective at causing small punctures into the thoracic vertebrae. This is significant, as sufficient shock to this area can cause "spinal shock," which can temporarily incapacitate a prey for a period between a few minutes to an hour (Boddington & O'Keefe 2002; Wood & Fitzhugh 2018). Where there are drawbacks in using osseous tips in terms of penetration and incision trauma, their durability against impact on bone and effectiveness for spinal shock offer unique advantages over lithic projectiles (whether totally lithic or composite). The evidence and discussion raised by Wood and Fitzhugh add interesting angles to the investigation of Aurignacian osseous points. It seems likely that a compromise must be made (as highlighted by Wood and Fitzhugh, but only referring to penetration) when using osseous tips in production, use and maintenance. Climatic pressures almost certainly played a role in this compromise, where durability and opportunities for tip re-use were paramount.

Perhaps the most interesting point made by the authors in connection to this thesis is during the observations section. Here Wood and Fitzhugh discussed the hafting method, and noticed that the "clothespin" design (or notch) at the top of the haft in which the spear/arrow point fits created a problem: the weakness created leading to a shorter lifespan of the projectiles in experiments, which was "one of the top reasons data can be lost" (Wood & Fitzhugh 2018: 10). They did not make it clear whether data were lost during their experiments, or whether this passage was in reference to other experimental research. They followed by saying a bevelled haft end will last much longer and allow a “higher overall shot count” as they are more “efficient” (Wood & Fitzhugh 2018: 10). This observation suggests there were problems with split hafts during their experiments that have not been made clear in the results. As discussed, the timber used for the hafts (poplar) can be susceptible to splitting, which would make it an unsuitable choice for hafting with a notch. However, if there are few other options to choose from, it may be necessary for the manufacturers to utilise a different hafting method (such as a bevelled tip to the haft) to drastically reduce the chance of haft splitting. Combining a projectile tip that is highly resistant to impact, and which carries the weakness of a split or notch instead of the haft (yet is still resistant to splitting), and a haft that is bevelled will almost certainly offer hunting equipment that will have very high longevity and a high chance of re-use with little or no maintenance These traits would fit into Bleed’s (1986: 739) characteristics of reliable and maintainable systems for the optimal design of hunting equipment (full characteristics on page 61) as there are overdesigned components that are stronger than minimally required and the overall design is easily serviceable. Slow-grown wood that has become distorted as it grows has a greater resistance to splitting as the wood fibres are twisted, preventing a split that creates a clean cleavage (Fredriksson & Lindgren 2013). Wood with these characteristics would be ideal for resisting high impact forces, though the extra mass from the denser wood could cause greater strain on the other components. Later Aurignacian points that revert back to the traditional style of hafting in which the notch or split is in the haft to accommodate the tip may have had one of these highly resistant slow-grown foreshafts. Determining why SBP projectiles were relatively short-lived in comparison to their simple-based point counterparts (in lithic and osseous material) may simply come down to manufacturing logistics. It may be more efficient to source and manufacture a highly split-resistant wooden foreshaft (with the tip facilitating notch), instead of sourcing a long shaft and making tips with the notch to facilitate the shaft.

Research question 2 (Are Aurignacian osseous points over-engineered?) will at least begin to answer some of these questions, and allow answering of research question 5 about how they would suit the hunting strategies discussed by Tartar and White (2013).

A haft for a spear

As with other experimental research of Aurignacian points, there has so far been little consideration of the wood used to haft them, probably because it was assumed it would have been readily available (research question 3a). This of course leaves a large gap in the understanding of projectile spears in the Palaeolithic; arguably the haft/spear shaft is the most important component. Wider experimental research focussing on other types of projectile points from the Palaeolithic also glossed over issues surrounding projectile wood (Wilkins *et al.* 2012; Shea *et al.* 2001). Generally, the main research focus with thrusting spears or projectiles is the efficiency or penetrative power of the tip or armatures. One of the few considerations for haft characteristics was by Théry-Parisot (2002). However, her approach focused on considering hafts for Palaeolithic tools suitable for felling trees to obtain firewood, rather than on spear hafts. She did point out that a suitable haft would need to be "solid enough to support important and repeated mechanical constraints" (Théry-Parisot 2002: 245). These would certainly be necessary traits for a good spear haft, but there are certainly many others. More interest has been shown in the case of entirely wooden spears that have been found, such as fire-hardened ones. In Thieme's interpretation of the 400,000-year-old wooden spears found at Schöningen, he describes the wood used for the spears and notes the wood itself grew slowly in cold conditions (Thieme *et al.* 2005). The exceptional preservation of these wooden spears has allowed a rare insight into hunting equipment from the Palaeolithic; however, besides a description, Thieme has not expanded on the advantages or disadvantages of the type of wood (spruce) used to make the spears. His interpretation suggested the spears would have been thrown, but does not consider the limitations attached in using slow-grown spruce wood. In theory, wood that has been growing slowly in a cold climate will be denser and heavier (Schweingruber 2007), therefore making it unsuitable for use as a thrown projectile. However, if this were the only wood available, it would have been the only option. Certainly, in the case of osseous-tipped projectiles, this type of wood would not be suitable, as the extra weight may cause damage to the tip. Nevertheless, this will be tested to answer research questions 4 and 2. Wilkins (*et al.* 2014) experimentally compared wooden spears based on those from Schöningen to lithic-tipped spears, by shooting them into ballistics gel. The wood used for all the spears was dowelled poplar; Wilkins et al. (2014) reasoned that it displayed a similar hardness to spruce (based on the Janka timber hardness scale). However, it was not mentioned whether the comparison was to slow-grown spruce, which would clearly be denser (Wilkins *et al*. 2014).

The two major activity stages in the valley are represented from the Hamburgian and Ahrensburgian, both yielding dwelling and kill sites (Tromnau 1975). Based on the environmental data from the valley, the climate was fairly cool and restricted tree species to a similar selection to those seen in NW Europe during the Aurignacian (birch and pine mainly) (Bokelmann 1991). The previously-mentioned hunting equipment from the valley comes in the form of wooden arrow or dart shafts made of pine wood. Importantly the arrow shafts are two-part: a foreshaft with the arrow tip and a rearshaft which would likely have been fletched (though no fletching survives). The join between the two parts can be best described via comparison to slightly earlier osseous points with a notched base from the Magdalenian, from sites such as Isturitz in the Pyrenees (Bokelmann 1991). The arrows and/or darts had lithic tips rather than osseous tips, which lessens their usefulness to this thesis slightly, but demonstrates *Pinus* offers timber that was used for hunting reindeer. As pointed out by Bokelmann (1991), separate fore- and rear-shafts can reduce overall damage to equipment, as the (probably) fletched rear-shafts would detach before they were trampled or crushed. By using two-part arrows or darts the required lengths of suitable timber for shafts is shorter. This is important when sourcing raw materials from timber that either has a slow replenishment rate or the trees themselves are relatively scarce in the landscape (Bokelmann 1991). Experiments using replica two-part arrows loosed from a replica Mesolithic bow have demonstrated the useful feature these arrows offer in being able to easily retrieve the rear-shaft (the fore-shaft would be retrieved once the hunt had finished). Reattaching another fore-shaft is relatively straightforward, and allows for quick reuse. This is certainly an interesting consideration in regards to earlier Aurignacian spears, which may have had fore-shafts, but certainly offered the opportunity for rapid reattachment of a fresh antler tip.

Resource management and procurement in early Upper Palaeolithic Europe have previously been investigated to demonstrate possible group movements and population connectedness (Féblot-Augustins 2009; Schmidt & Zimmermann 2019). Generally, lithic raw material has been the focus of such research, as it survives far better than any other resources and can pin point specific source areas (Blades 2001). Schmidt & Zimmermann (2019) focus on three areas that provide reasonable amounts of data (N Spain/SW France, Belgium and the middle Danube/Moravian region). They identify core areas or "CAs" of Aurignacian activity and point out that raw material sources are "overwhelmingly often located within CAs" (Schmidt & Zimmermann 2019: 11). Extended areas (EAs) are identified as areas that include at least one CA and sources of lithic raw material that might fall outside a CA. Using this model, they attempt to demonstrate how certain regions might be demographically connected via lithic raw material movement (see Fig.17). Specific raw material transport models, such as those created by Schmidt & Zimmermann, provide evidence of human movement and exchange over a geographic area. In their research they also tackle the movement of personal ornaments such as beads, as Schmidt & Zimmermann (2019: 14) believe they offer insights into social interaction and play a role in the researchers observed "social carrying capacity" in a landscape. Arguably beads and objects of personal ornamentation are likely to consistently travel further than lithic raw materials (as they are generally smaller and lighter), especially if the case study region only covers coastlines in limited areas, such as the extended area of map A in Fig. 17. In comparison to lithic raw material, which can have many sources, such as those included in Fig. 17(a), environment-specific resources would become more valuable as that source environment became more limited in an extended or catchment area for a human group owing to climate change. If inferred resources could be considered in such a raw material movement model, how would timber fit in? Based on Fig. 36 (the charcoal and pollen sample map), both maps in Fig. 17 would cover areas which offered different tree species. The larger EA shown on Figure 17(b), in particular, includes the greatest variety of tree species if compared to Fig. 36. It would be irrational to suggest that as people moved and exchanged lithic raw material, they did not at the very least opportunistically procure suitable lengths of wood for spear shafts as a form of embedded procurement strategy (Binford 1980).

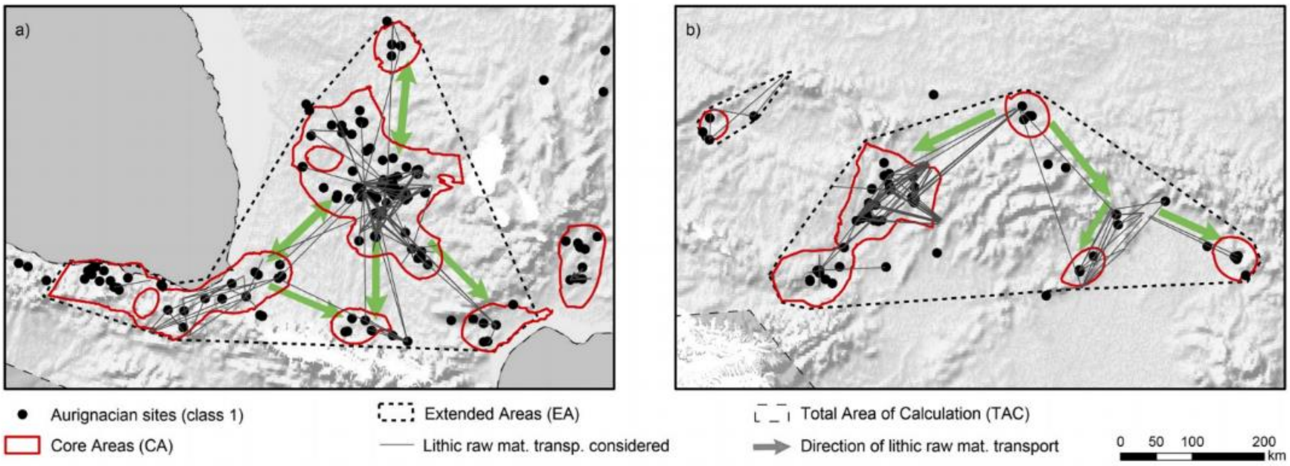

Figure 17: Direction of repeated lithic transport between core areas. Map (a), left, shows the N Spain/SW France area, while map (b), right shows the middle Danube/Moravian region (from Schmidt & Zimmermann 2019: 11).

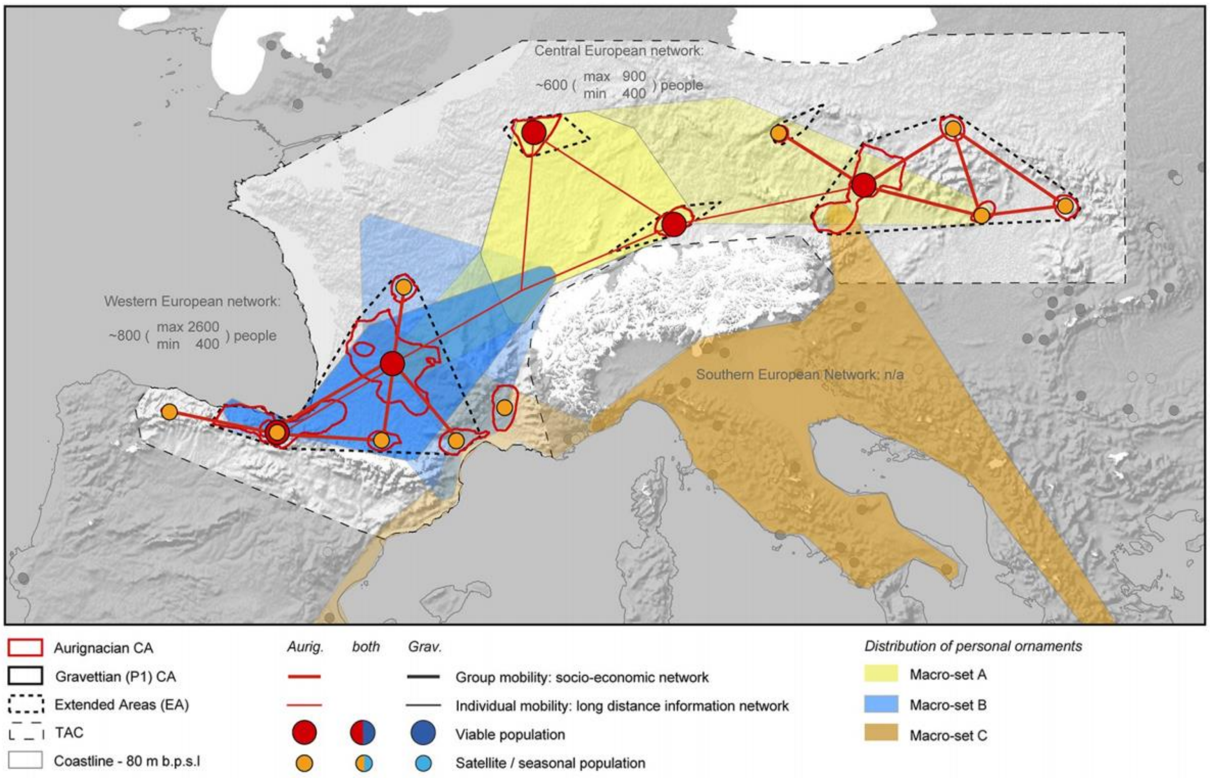

Figure 18: Socio-spatial organisation and group mobility during the Aurignacian with population estimates, from Schmidt & Zimmermann (2019: 13).

Schmidt & Zimmermann attempted to plot possible spatial organisation during the Aurignacian (and Gravettian), showing estimated population in the two main regions and networks based on lithic and ornament movement (Fig. 18). By overlaying spatial occurrence of personal ornamentation, it is possible to show that raw materials could be moved hundreds of miles across the European continent. It is unlikely timber resources were moved over the same range as personal ornaments, due to the greater size and weight of timber, but it is very possible they were transported along the same routes over shorter distances, even as finished items to save transport costs. Exchange of spear shafts for specific characteristics has been observed in hunter-gatherer groups in the 20th century, such as those in Tasmania (see following section). The orange dot satellite/seasonal populations in Fig. 18 could have existed for a number of reasons, such as raw material procurement or exchange, hunting activities or climatic pressures. It is likely a combination of factors contributed to decisions about group movements. It is within these factors that we would probably have found the need to obtain spear shafts as an added aspect of landscape “attractiveness”, as noted by Schmidt & Zimmermann (2019: 14). By testing replicas in semi-controlled experiments, it will be possible to determine the viability of spear shafts from certain tree species. If shafts from species that occurred widely over Europe during the Aurignacian, such as silver birch, performed well in the experiments, it could be concluded that long-distance trade for shafts from more suitable species such as hazel or ash was not necessary (research questions 3a & 3b).

Within the Upper Palaeolithic of NW Europe, there is a clear gap in the understanding of hafting technology and potential problems. This is mainly due to the lack of preserved spear shafts; however, lack of physical evidence does not make it acceptable to completely ignore the issues and strategies Palaeolithic hunters adopted to source suitable shafts and use them effectively. To address the issue, this PhD will evaluate the potential problems in sourcing viable wood for projectiles in a boreal environment such as that in NW Europe during MIS 3 (research question 3). As well as testing the quality of available wood in such an environment, it will also look at potential alternatives that may include transporting wood from more temperate regions for use in hunting in colder areas.

A view to a kill

Knecht (1991) and Rees (2003) made limited attempts at demonstrating the effectiveness of Aurignacian points. Knecht used a goat carcass as a target to show the points were adequate for causing significant trauma when thrown. Rees used a static rig that moved shortened spears along a rail at a plant-based putty target; this demonstrated the points could be used several times without maintenance. Beyond the ability to penetrate a soft target from very close range, the full process (excluding flight and range), descent, impact and maintenance have not been investigated (Shea *et al.* 2001, Churchill 1993). It has not been considered what effect an osseous tip might have in comparison to a lithic-based tip in terms of flight trajectory. The arising issue concerns the weight of the projectile tip: if an osseous tip causes trajectory problems due to a lack in weight at the tip in comparison to a lithic-based point, is there a need for flight stabilisation (research question 4a)? This stabilisation may come in the form of fletching at the back of the spear. It has been observed during ethnographic studies that lighter spears can be thrown further with greater accuracy. This was in comparison to heavier spears with a sharpened wooden point that would resemble the types of spears found at Schöningen (Ellis 1997). However, within the Aboriginal groups observed by Ellis using these lighter throwing spears, there was a clear lack of "killing power" due to their light weight. This problem was met by the use of heavier lances to deliver finishing strikes to injured prey (Ellis 1997).

Interestingly, as described by Meyer (1952), ivory-tipped arrows used by hunters in Trinidad Bay were able to bore through the body of prey. This, however, was likely to have been facilitated by the spinning of the arrow as it flew through the air which is caused by fletching feathers from the same wing side (Bergman *et al.* 1988). Such an action could be created by the correct technique when thrown from the hand, as observed by Noetling (1911) of Tasmanian Aborigines using wooden throwing spears. Such observations may not relate to the flatter Aurignacian points such as the SBPs, but may relate to the later bevelled or spindle points.

Contrary to Ellis' observations, Tasmanian groups using light, reed-shaft, wood tip spears demonstrated that light spears could be highly effective when used by experienced hunters (Allen & Akerman 2015). The original account from Spencer (1914: 359) noted, in particular, that the spears could be "hurled with great speed and accuracy of aim, and with wonderful penetrating power". Interestingly, the reed spears were also traded for heavier hardwood spears (Spencer 1914). This clearly cannot be used as evidence that Aurignacian people traded spears or shafts for their different characteristics, but it is a tantalising possibility which remains difficult to prove. As observed by Spencer, the reed spears were highly standardised, which implies careful manufacture to fit an approved design (through social selection). That approved design may have been reached over many generations of spear development, which was likely directed by changes and access to raw materials and prey. Can parallels be drawn to Aurignacian projectile technology? There is certainly a clear standardisation of Aurignacian spear tips (Knecht 1991, 1993), but can the same be proposed for the spear shafts? A further potential complication is though split-base points have a standardised style, their size can vary. As explored by Doyon and Knecht (2014), this is probably caused by use and maintenance/re-tooling, but did the spear shaft change with the spear tip? Keeping in mind the likely high value of spear shafts during the Aurignacian, it seems more likely that spear tips may have changed spear shafts as they reduced in size rather than the shaft alongside the spear tip.

If this was a problem faced by Aurignacian hunters, it will be tested and addressed to answer research question 4a. This is not something that has been considered by either Knecht or Tartar and White.

Their research aims were clear, although perhaps too confined to broader considerations into resource management and maintenance. Verpoorte (2015) discusses the maintenance and storage of (mostly) bone and antler points from Potočka zijalka cave, Slovenia. The quantity of broken points and variation in size gave a strong indication of retooling and maintenance that could be pin-pointed to a specific part of the cave. Interestingly, the back of the cave appeared to serve as a point caching site which Verpoorte (2015) interpreted as a measure for future visits (a strategy previously suggested by Davies in 2001). Evidence of caching for future use can be linked to ethnographic evidence, discussed later). Verpoorte (2015) also refers back to Knecht (1997) who points out that collagen-rich antler would serve as a better material for spears, as it is not as brittle as bone. This may be the reason for strong evidence of retooling and caching at Potočka zijalka, as the breakage rate is reasonably high. Faunal evidence from the cave indicates red deer was present, as well as many other herbivores, so the reasoning behind choosing bone may simply be down to its availability (Verpoorte 2015). There were small usage experiments by Knecht, which proved little beyond her replicas having the ability to pierce through a stationary cadaver target at very close range (<5 metres) from a calibrated crossbow (Knecht 1991). This was not too dissimilar in method to Rees' (2003) later dissertation experiments. Guthrie (1983) demonstrated that osseous tipped darts propelled from a compound bow could penetrate up to 28cm in a moose carcass. However, as Wilkins *et al.* (2014) points out, the limited statistical data from Guthrie's research limits the solid conclusions that can be drawn out. For Tartar and White, their research focussed on hafting systems, but like that of Knecht and Rees there was no comparison to ethnographic evidence of groups using spears or osseous-tipped projectiles for hunting activities. A recent paper by Borodovsky and Tabarev (2016) investigates the deformation of early Iron Age bone points from Denisova Cave using experimental and ethnographic evidence. The significance and consistency of the damage observed on original bone points could be replicated by shooting the replica arrows at hard surfaces. It was from here that Borodovsky and Tabarev (2016) were able to draw upon evidence from a Native American site at which people has been intentionally shooting arrows at a high rock crevice with the aim of lodging the arrows there. The function of this activity was regarded as originally having a ceremonial purpose that later became one of competition (Borodovsky & Tabarev 2016). There is currently no evidence for such a practice in Aurignacian assemblages, but it is worth noting that considering ethnographic studies can sometimes encourage wider thought on the role of equipment that appears to be fairly one-dimensional at face value. On the other hand, it is important to remember that ethnographic studies are not necessarily evidence of how other (past) groups lived their lives.

This issue of "killing power", with regard to Aurignacian projectiles, will become apparent during experimentation. If the osseous tipped javelins can be thrown accurately to a distance within which wild herd animals would roam before fleeing (unless trapped), but lack sufficient penetrative power to kill outright (from distance) or injure prey to immobilise them, there would be a requirement for alterations to the replicas tested or a heavy lance such as those described (Ellis 1997). Hughes (1998: 351) highlights earlier research: "primitive weapons kill by cutting and bleeding". The wound depth required to fatally injure large ungulates is about 20cm (Hughes 1998). This was also discussed earlier in reference to Wood's & and Fitzhugh's 2018 research into Alaskan projectile points. For this research, a severe wound with a high chance of lethality will be set between 20cm and 30cm as a benchmark. Certainly in the case of megafauna, the required wound depth would clearly be higher. Alternatively, Ellis suggests that if lighter spears required extra mass to cause greater damage, this may have been improved by using a foreshaft made of denser, heavier wood such as those described in some of the anthropological accounts collated by Ellis (Driver 1939, Latta 1949). This would imply that slow-grown, wood from a cold-climate could have some value in spear construction if used as a foreshaft (as discussed previously).

Use of poisons to weaken prey may be a possibility, although sources of fast-acting toxins in Europe are relatively rare (Borgia *et al.* 2017). One exception is *Aconitum*, also known as monkshood or wolf's bane, which is exceedingly poisonous and has been used in hunting by the Ladakh to hunt Himalayan ibex (*Capra ibex sibirica*) (Peissel 1984). *Aconitum* prefers to grow in mountainous regions with well-draining soils, so could suit regions Aurignacian people occupied, such as Potočka zijalka (Peissel 1984, Verpoorte 2015). Interestingly, some of the bone points from Potočka zijalka appear to have been incised (Jéquier 2016). This may have been to facilitate poison delivery, either in retaining it on the tip surface during throwing and penetration, or to apply it more easily to the tip's surface. Jéquier (2016), seems uncertain as to the purpose of the incisions, but suggests they may play some role in hafting or establishing ownership (Fig. 19).

Fig.19: Some of the bone points from Potočka zijalka showing a variety of incisions across the faces and sides (From: Jéquier 2016: 54)

One of the few examples in which experimental research into Palaeolithic projectiles used ethnographic evidence is presented by Iovita et al. (2014). In a similar experiment to Rees' (2003) investigation of Aurignacian points, Iovita and colleagues used replica glass Levallois points against a bone plate target. The aim was to try and produce damage patterns on the replica points and bone plates that could then be compared to archaeological examples. In Iovita et al.'s 2014 paper, there is a short section on on the spear shafts that mentions the wood used as "6cm-long homogeneous wood foreshafts" (page 75). Like the other research, species relevance is ignored; however, Iovita *et al.* do add that extra weight was attached to the shafts to match those from ethnographic examples of throwing spears and spearthrower darts (Iovita et al. 2014). The mastic binding agent used was beeswax: Iovita used archaeological evidence from Border Cave (South Africa), along with local South African ethnographic evidence, to justify its use (d'Errico *et al.* 2012). Recent analysis of a barbed bone point from Bergkamen (Westphalia, Germany) has shown the presence of beeswax with charcoal powder at the proximal end. This is the oldest evidence of beeswax used for mastics in Europe, at approximately 13,000 years old (Baales *et al.* 2017). The issue with beeswax alone as a binding agent is that it has poor cohesive properties; generally, beeswax is used to improve the ductility of a resin-based mastic glue. The reasons for Iovita et al. not using birch tar as a binding agent are unclear, as it would fit with existing evidence of tar remains on Middle Palaeolithic lithics such as at Königsaue, where impressions of a wooden haft were left in the pitch mastic (Shea 1988, Koller *et al.* 2001, Boëda *et al.* 1996). Rees' dissertation demonstrated that within his experiments, a binding agent (intestine) improved the life span of the shortened spears before major repairs were required as the joint between tip and shaft were covered. It remains to be seen if any sort of binding agent or mastic is required for hafting Aurignacian osseous points to make them more effective under different testing conditions. A number of different glues (made of materials/ingredients available during MIS 3) will be trialled to determine their value in hafting to answer research question 1a.

A hardwood foreshaft also has the advantage of preventing splitting (improving longevity of the spear shaft), something that lighter spear shafts are liable to do (Ellis 1997). This would certainly be a consideration for Aurignacian hunters; reducing the likelihood of shaft splitting while on hunting expeditions into resource-sparse areas would avoid high transportation costs of extra materials and time spent on maintenance (unless expeditions were supported by assessable exchange networks). If an imperfect spear shaft is chosen due to raw material limitations, it could have significant effect on penetration or cause overall tool failure (Wilkins *et al.* 2014). However, it is worth noting at this point that some hunters who used lighter throwing spears tended to carry a large number of them. An example of this was the natives of Admiralty Island. In 1877, Moseley stated that "natives possess an enormous store of these weapons" and "men commonly carry two or three in their hands" (pg. 409).

This would not be an unrealistic scenario for Aurignacian hunters, and certainly if spear hafting wood was not available further north in hunting grounds, it would be sensible to carry several spears complete, or in parts with tools for maintenance. As an alternative strategy, hunters could have carried a selection of detachable fore-shafts that could be quickly attached to the main spear shaft once the initial foreshaft had been used to dispatch an animal. It would have been left in the animal until the hunting engagement was complete (Nelson 1899). If reindeer were being corralled in a basic enclosure or natural bottleneck, Aurignacian hunters could have created a stockpile or cache of tools and points similar to those observed by Moseley (1877) and discussed by Verpoorte (2015) and Davies (2001). This would have allowed hunters to quickly dispatch a number of reindeer (by bludgeoning or thrusting spear blows) without having to waste time on a full reattachment process (Frison 1991). It was noted by Ellis (1997) that stone tipped spears could be problematic if multiple thrusts were required, due to their fragility such as in the scenario above. Certainly, in the case of hunting in cold environments, accounts exist (as discussed by Ellis 1997) that indicate hunters avoided highly siliceous rocks due to their increased brittleness; instead hunters used slate (though still brittle in cold seasons). This observation was later raised by Pétillon *et al.* (2016) in reference to the phenomenon of osseous projectile tips in the Palaeolithic. Osseous tips may have offered better reliability and longevity, but it was noted by Khlopachev and Girya (2010) that ivory also becomes considerably more brittle in temperatures below -25˚C, which would presumably also be problematic for the mammoths themselves. During the manufacture of any stone tools in cold conditions there seems to be a detrimental effect on the raw material, which becomes far more fragile (Ellis 1997; Pétillon *et al.* 2016). This would result in a much greater level of risk when producing projectile points, which have to be thin and standardised enough to fit into a shaft. Raw material that is opportunistically collected on the surface will have undergone damage from freeze-thaw processes (unless it is extracted from a sufficient depth below permafrost). Stone for flintknapping that is exposed to frost and sub-zero temperatures during the winter is a problem faced by flintknappers today, they will keep raw material indoors or under insulated covering. If such damage from weathering is a problem for flintknappers in NW Europe today; it is likely the problem during MIS 3 would have been much greater (due to the harsher cold seasons over wider areas).

As pointed out by Ellis (1997), another issue would be the transport costs and problems faced when relying on stone for tools and projectile tips. In the case of transporting raw material so it can be used to produce fresh edges and tips, the energy expenditure in carrying such material is very high. If extra spear shafts (or fore-shafts), glue and bindings are also being transported, the overall equipment burden is even higher. It would be possible to cache or stockpile raw materials (similar to earlier discussions) in natural or prepared shelters for seasonal visits, although this could pose problems for soft organic materials (unless frozen), which would otherwise degrade. Where good raw material was available (particularly for stone), it seems more realistic to reduce the mass to lessen transport costs (as discussed on page 54). It is likely that sites such as Maisières Canal offered opportunities to prepare lithics for both immediate and later use (Moreau *et al.* 2016). A problem, rather than cost, in the use of stone for projectile points goes back to the material's fragility in cold climates. As mentioned, producing fine projectile points is challenging enough in favourable condition, but even more so in cold conditions below 0°C, due to the higher risk factor of breakage. This risk would continue after production immediately into transportation (Ellis 1997). If lithic points are set into a shaft, care would have to be taken to not knock the spear as a whole and cause shock or vibrations into the lithic tip. Extra tips that are being transported (not yet hafted), they may have required cushioning to prevent knocking against each other, which could otherwise result in blunting or more severe damage. Occupation sites or hunting camps, such as those in SW France, contain assemblages of lithics that must have come from a great distance, though it is also clear people made use of local stone types (Blades 2001). This suggests people were either travelling great distances to obtain good quality resources because local sources were poor or hard to access, or they were acquired *en* route to occupation sites.

Experimental research into the re-use and reliability of osseous points is discussed further in chapter 4. The question of whether the Aurignacian osseous-tipped spears were thrusting spears (lances) or thrown spears (javelins) (research question 4) will be best answered during the throwing/flight experiments in a sports field. If the spears fly poorly, or display a high frequency of irreparable damage, it is possible the spears were lances. In regards to the reliability and maintenance of the Aurignacian spears, Bleed (1986: 739) constructed two lists to outline the factors that contribute to the reliability of maintenance requirements of hunting equipment:

Reliable systems:

- A1. Over-designed components (parts made stronger than they minimally need to be)
- A2. Under-stressed (system used at less than full capacity)
- A3. Parallel subsystems and components (redundant and standby)
- A4. Carefully fitted parts and generally good craftsmanship
- A5. Generalized repair kit, including basic raw materials (to effect any repair)
- A6. Maintained and used at different times
- A7. Maintained and made by specialist

Maintainable systems:

B1. Generally light and portable

B2. Subsystems arranged in series (each part has one unique function)

B3. Specialised repair kit that includes ready-to-use extra components

B4. Modular design

B5. Design for partial function

B6. Repair and maintenance occur during use

B7. User-maintained

B8. Easily repaired, overall: “serviceable”

Bleed makes it clear that compromises are very likely (if not certain) when producing hunting equipment. On the macro scale, something like a spear might have a tip or shaft that is thicker (“A1. Over-designed”) than is necessary, which increases the “Under-stressed” (A2) capacity. However, this can have a detrimental effect on other aspects, such as A5 (“Generalized repair kit, including basic raw materials”), as more raw material is required to produce a thicker component. Or it could have an effect on the B1 (“Generally light and portable”) of maintainable systems, as thicker components will be heavier and larger. These aspects do not consider the performance of the equipment. In the case of a thicker spear tip that will be “under-stressed”, it may have poorer penetration potential, so may require greater velocity to cause adequate damage. Wood and Fitzhugh (2018) found that the different projectile tips produce different types of damage, and thus were better suited to different angles of shot. Once a serviceable compromise is found (as suggested by Bleed), the most efficient way of using the hunting equipment will therefore follow (i.e. shots at certain angles, which could be achieved through hunting strategies such as ambush hunting).

To better understand any kind of implement that engages in high impact scenarios, it is critical to understand the types of damage they can exhibit. Localised stress caused because the impacting material has inadequate mass to distribute the loading force will result in material failure. Damage caused by impact on different surfaces can cause consistent breakage patterns, sometimes on different parts of the implement (not always at the point of impact). Generally, major non-post-depositional damage to projectiles is attributed to impact on hard surfaces such as bone or stone (Pokines 1998). Existing experimental assemblages can be very useful in understanding how and why certain objects and materials break under certain stresses. However, it has already been discussed how it is difficult to fully replicate the scenario in which archaeological material was created, especially for projectiles. Variables such as wind speed, direction, throwing force, velocity, distance, trajectory, prey size and orientation can all play roles in endless combinations to affect the appearance of a used projectile tip. To answer research questions 4 and 2 adequately, it is vital to compare my own experimental assemblage to archaeological material. Such comparisons will enable more robust discussion on the timeline of these artefacts, from creation, maintaining and final damage/discard. They will also demonstrate whether the experimental testing methods used are similar in action to those in the past. If similar damage occurs to that seen in archaeological examples, then similar force loading and material failures can be extrapolated from replica examples. This will therefore show the experiments are reliable reconstructions of how these artefacts were used in the past.

A large number of Aurignacian points from the Dordogne region are kept at the Musée National de Préhistoire in Les Eyzies-de-Tayac-Sireuil, France. The largest assemblage on display comes from Abri Castanet (55 split-base points), Abri Blanchard (51 SBPs), Isturitz (75 SBPs) and La Ferrassie (first addressed in chapter 2 at the start of Peyrony's Aurignacian stages) (Knecht 1991). A range of different sizes and forms are displayed, giving a good impression of variation and examples that have been re-tooled over several episodes (Fig. 21). The SBPs from La Ferrassie in Fig. 21 show the level of re-sharpening that osseous points receive before they are deemed too small or were lost. While attempting to answer research question 4 and 2, it will be necessary to use replicas of different sizes that may represent osseous points at different stages in their life span. This will generate a performance-based dataset that can assist in understanding whether the function of osseous points changed as their size decreased. It is possible that smaller osseous points (once re-tooled to that size) may have been used to hunt different prey, or that they were used at a different stage of the hunting process. Smaller, lighter spears may have been more useful for launching from a greater distance, while larger-tipped spears were used at closer quarters. Alternatively, smaller osseous points may have derived from smaller sections of antler, either because it was an offcut or an unintentionally smaller break (Knecht 1991). In different regions, antlers of different average sizes would be available. Larger reindeer with larger antlers were generally found in the higher latitude regions of Europe, while smaller specimens were found towards the south (Weinstock 2002). This in itself would be a contributing factor in the average sizes of SBPs, while manufacturing approach and access to antler working tools would be other factors. Tartar and White's (2013) production method for blanks used cleavage to create a series of blanks from the antler beams (see Fig. 13). From their description and challenges in splitting discussed in chapter 5, it is easy to see that smaller sections (that were intended to be bigger) broke from the main beam prematurely. The smaller blanks would have already been a suitable thickness and had taken time and effort to produce. It would be logical to suggest that some of the smaller points were created from small blanks.

Presumably there would have been a time when the osseous points were simply too small to be worth re-sharpening. If their shape was approaching an equal balance between width (towards the proximal end) and overall length, the penetrative power would have started to diminish. By observing archaeological examples, such as those from La Ferrassie, it is evident that the points may become redundant after being re-tooled down to only a few centimetres in length (Doyon & Knecht 2014).

Fig. 20 – Split base points from Abri Castanet (above) and La Ferrassie (below), side-by-side. Both appear to have been damaged, although the point from La Ferrassie is more likely to have been damaged post-depositionally, as it has been refitted. The example from Abri Castanet is missing the tip, which may be from use during the Aurignacian.

Fig. 21 – Simple base and split base points from La Ferrassie (two left and two top right), showing a range of sizes. It is likely that the smaller tips had greater penetrative power, due to their narrow width (although this will be tested in research questions 4 and 2). The two examples on the left show the clear difference between spear points that had limited usage and those in the top right of Fig. 21 which have been worked down to stubs. The damaged nature of the two smallest examples may be evidence of a decision to not reuse them.

Fig. 22a (left) – Narrow simple-based points from La Ferrassie. Fig. 22b (right) – 3 simple-based points of different sizes and broken sections (top) are also from La Ferrassie. Other variations of Aurignacian osseous point are displayed, such as the simple-based points shown in Figs. 22a & 22b. As demonstrated by Rees (2003), there is some variation in re-usability of simple-based points without re-sharpening. The damaged sections in the top right of Fig. 22b will be compared to any replica points damaged during experimentation. This will give some idea of how they may have been damaged (see chapter 4). The small points at the bottom of Fig. 22b are clearly going to perform very differently to their larger counterparts. However, smaller points could be more useful when hunting small game that is too large to trap.

Fig. 23 (left): Damaged SBP from La Ferrassie, (middle): Damaged SBP from Abri Castanet, (right): Damaged SBP from La Ferrassie. The damaged SBPs in Fig. 23 will be used to compare against those made and used during experimentation. The points in Figs 23. (left and middle) may have been damaged post-depositionally, or during production of the split. As identified by Tartar and White (2013), controlling the split could be difficult and result in broken wings. If these points were damaged during use in hunting

activities, it is more likely a part would be missing through spalling upon impact. The simple base point in Fig. 23 (right) may have been damaged during hunting activities. Detachment of such a large spall from the proximal end is likely to have been caused by a high degree of sudden shock. Such shock may have been caused by impact into an animal, or hard target such a tree or rock (i.e. a missed shot).

Fig. 24 – Highly polished split base point from Abri Pataud. The polish may have been applied by conservators (consolidant/varnish), though it is not apparent on other points. A highly smoothed or even polished surface would reduce air resistance and almost certainly provide better penetrative power.

Fig. 25 – Tongued piece (left), or *pièce à languette*, and broken split base point (right) from Abri Pataud.

Tongued pieces, or *pièces à languette*, (Fig. 25) were the subject of debate between Knecht (1993) and Tartar & White (2013). Knecht believed they were not a result of creating the split of a split base point, but instead a separate process in which the aim was to produce these tongued pieces, or "shims" as Knecht labelled them (see Fig. 26). These shims were barbs that would be fitted between the split base point's wings as it was hafted. The shim would stick out from the proximal (closer to point of attachment) end of the point to create a sort of armature (Knecht 1993). However, as pointed out by Tartar & White (2013), her theory relies on 27 pieces from Abri Castanet, and does not explain their absence at other sites that contained SBPs. Nuzhnyi (1998), demonstrated experimentally that, by incision and flexion, SBPs could be produced to match archaeological material, including waste products such as the tongued piece. Tartar & White (2013) also proved that flexion followed by basal cleavage produced tongued pieces, while maintaining a reasonable success rate of producing SBPs. A relatively blunt armature on the side of the spear would probably not have improved its function (more likely worsened it). Her experimental tests were not clearly described, and so cannot be used to demonstrate their effectiveness. Perhaps the only advantage of using this hafting method is that adding a shim into the proximal end of a SBP will force the wings apart. This would wedge the SBP into the wooden notch, but puts more pressure on the haft.

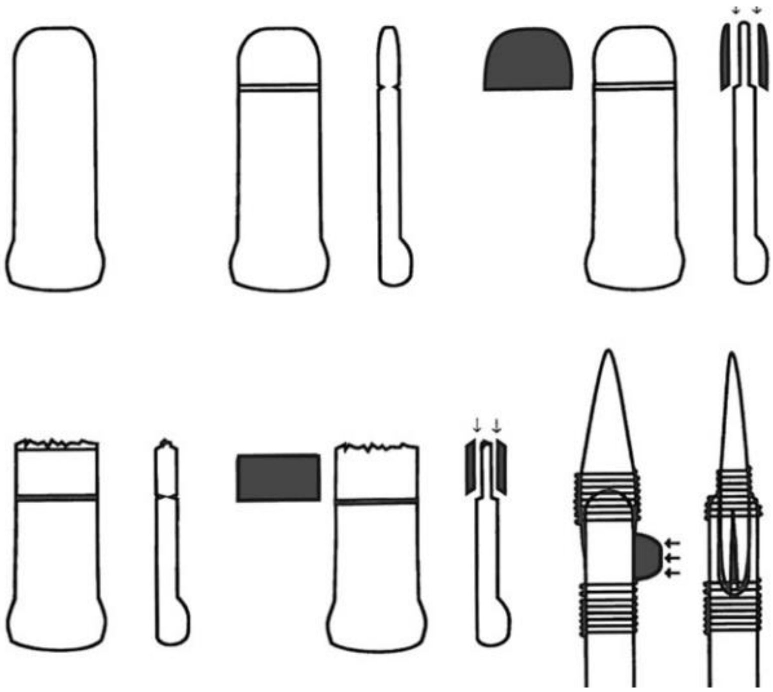

Fig. 26: Knecht's (1993: 40 and 41) *chaîne opératoire* of producing shims (dark grey rectangles) and their possible hafting method.

One of the displays in the upper gallery of the Musée National de Préhistoire shows some replica spear points that have pierced vertebrae from a cow (Fig. 27). The replica points were part of an experimental study conducted by Pétillon in 2003 at the musée du Malgré-Tout (Belgium). His aim was to record breakage patterns (discussed later) using replica points propelled from a bow and spear thrower at a male calf cadaver. Perhaps unsurprisingly the projectile tips suffered no damage when impact was made with soft parts of the cadaver target. When the projectile tips made impact with harder body parts with thick bones, the tips began to show consistent breakage patterns that Pétillon (2003) compared to points from Isturitz (where 371 Magdalenian points were found). Between the projectiles that had been propelled from a bow and spear thrower; the bow-shot tips suffered less damage. Pétillon (2003) attributed this difference to the greater mass of the spear thrower darts which would put greater stress and strain on the tips upon impact. These tips tended to suffer damage at both the proximal and distal ends, whereas the bow-shot tips suffered damage at the distal ends only. Though the focus of this study was on later points using different propulsion methods to those of Aurignacian projectiles (as far as evidence currently suggests), the observation by Pétillon (2003) about the projectile mass having an effect upon impact is interesting. As discussed previously, most experimental approaches utilise methods that are not accurate to the way the hunting equipment was originally used i.e. calibrated crossbows or modern bows for testing Palaeolithic spear tips (Knecht 1997; Nuzhnyi 1998; Shea et al. 2001). Based on Pétillon's (2003) work, this would mean such studies by previous researchers created unreliable data as the experiments did not truly test replica projectile tips with the same stresses and strains they would have undergone in the Palaeolithic.

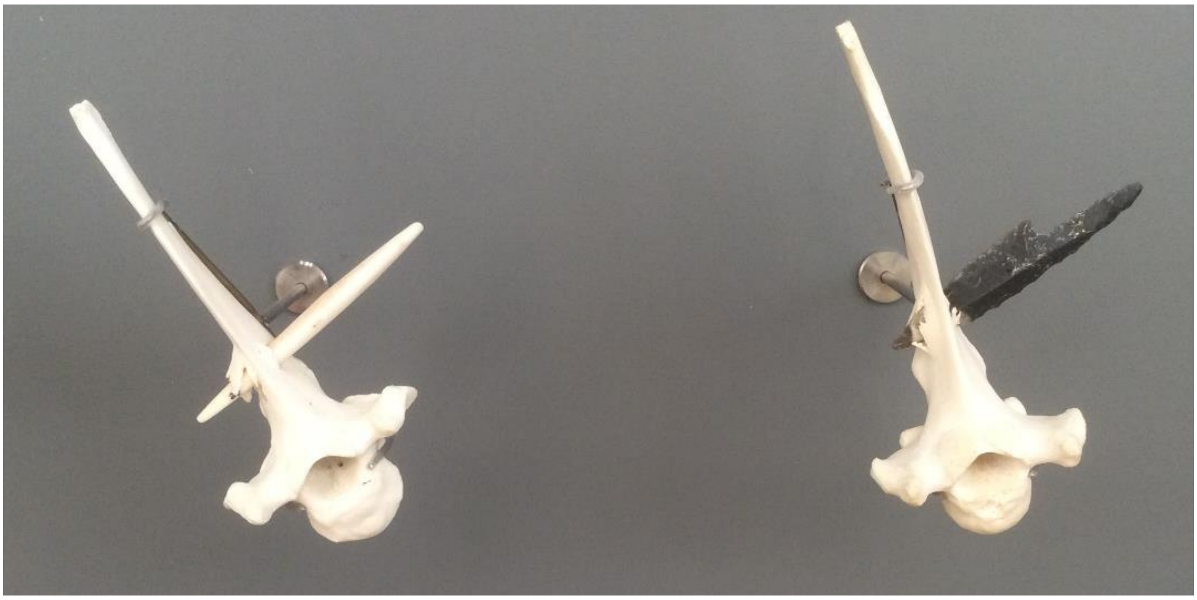

Fig. 27: Osseous and lithic points that have both pierced cattle thoracic vertebrae. Created by Pétillon (2003) who tested Magdalenian and Gravettian osseous and composite lithic tips. Displayed at the Musée National de Préhistoire, Les Eyzies.

Fig. 28: An osseous and a lithic point that have both been damaged in use (Musée National de Préhistoire). The osseous point shows a "bevelled break", discussed by Pétillon *et al.* (2016) as damage caused by hard impact.

Pétillon *et al.* (2016) give an overview of experimental research of osseous points over the last 30 years. Different types of break are outlined, using a selection of archaeological material compared to experimental material. Projectile points covered include both bone and antler from the Aurignacian through to the Magdalenian. Pétillon *et al.* (2016) note that there has been limited experimental research into ivory points. The main types of damage discussed by Pétillon *et al.* (Fig. 29) include bevelled breaks, crushing or "mushrooming", splitting, shattering and breaks at the base. The most common types of damage identified in experimental examples were bevelled breaks and tip crushing. This can be seen on the experimental osseous tips in Figs. 27 and 28 quite clearly. Pétillon *et al.* also refer back to previous experimental research, during which bevelled and crushing damage were frequently observed (Pétillon 2003).

Fig. 29: Experimental points showing different impact damage. 1: Bevelled break; 2: Bevelled break with rounding; 3: Bevelled break; 4: transversal jagged break at the limit of the hafted part; 5: multiple bevelled break with rounding; 6: Bevelled break with spin-off (From: Pétillon *et al.* 2016: 60)

A number of the archaeological examples discussed earlier also show damage that could be identified as bevelled breaks or crushing (Figs. 20-23b). Arndt and Newcomer (1986) discussed damage to osseous points from NW Europe that sound very similar to that described as bevelled or crushing by Pétillon *et al.* (2016). Such damage could be caused by hard impact on bone or stone (a "missed shot"); however, in many cases observed by Pétillon *et al.* the damage was limited, even against hard surfaces.

If an osseous tip were to impact onto flesh or soil, the damage was likely to be only microscopic. It is likely therefore that throwing experiments to test Aurignacian spear flight will result in extremely limited damage (research questions 1 and 2). Arndt and Newcomer (1986) noted that a rounding effect can occur on a broken edge (Pétillon *et al.* identified these breaks as bevelled). The rounding at the edge was hypothesised to occur once the tip had broken and the break surface ground against the impact surface. Arndt and Newcomer also observed that bone points do not appear to gain a crushed tip (or "mushrooming") in the same style as antler tips. It was more likely for bone tips to splinter if damage occurred; this trend is almost certainly caused by the more brittle nature of bone (Arndt & Newcomer 1986). Greater damage to bone points was recorded by Bergman (1987), in this case longitudinal damage from the tip, resulting in a complete split, was present on bone but not antler points. The survey by Pétillon *et al.* (2016) came across only a couple of incidents where antler points shattered or split in a way that made repair impossible (Stodiek 1993). Such damage (both to bone and antler points) only appears to have occurred when the experimental shot was made onto hard surfaces, either intentionally or as a misplaced shot (Pétillon *et al.* 2016). Breaks at the proximal end of the spear point are not impossible, according to the number of studies surveyed by Pétillon *et al.*; however, they are unlikely. Almost all the studies discussed that used replica antler tips had at least one break at the base, or more specifically at the intersection between haft and antler tip. Two particular studies demonstrated the longevity of antler points before destruction when thrown with spear thrower:

1. Pokines (1998) – 249 launches at goat cadaver – only 2 of 20 antler points broke at the haft end;
2. Pétillon *et al.* (2011) – 74 launches at deer cadaver – only 1 of 34 antler points broken at the haft end.

Though particularly good results in terms of a longevity investigation of osseous points, it is worth noting that the points used in both studies were Magdalenian in style and launched from a spear thrower. Whether this impressive longevity trend would be reflected in Aurignacian examples when thrown by hand (with a heaver shaft) remains to be seen (research question 4 & 2).

Fig. 30: Cellier point A

Fig. 31: Cellier point B

Fig. 32: Cellier point C

A small collection of Aurignacian point fragments in the stores of the Museum of Archaeology and Anthropology had been recovered between 1930 and 1940 at Cellier, Dordogne by H. Noone. Unfortunately there was very little additional data associated with the collection.

Out of the collection, three broken osseous points were found. Points A and B (Fig. 30 and 31) were flat in profile, while point C (Fig. 32) was conical. The relatively clean truncations of points A and C are quite consistent with other breaks seen in osseous points such as in Fig. 20. This type of damage should appear during experimentation and may be highlighted as a common issue with this type of projectile point. Point B, on the other hand, displays a more unusual break pattern. It is a much longer split, with a tail much like those in Fig. 3 from Torralba and Ambrona. Their production began with an incomplete truncating cut across the ivory beam. Once the ivory beam was broken by bending and percussion the incomplete cut would hinge the tail-like break (Villa & d'Errico 2001). No cut was visible on point B; instead the break may have been caused by some kind of flaw in the antler grain.

Summary

The summarise, it is clear that a greater understanding of Aurignacian hunting equipment and resource management is required to build on major gaps in existing literature. Narrow focus on the production of hunting equipment only gives a partial view of the possible implications of usage and maintenance. This issue will be addressed by this thesis (research questions 1-4) to give a broader understanding of how these objects perform and are maintained. By comparing observations and findings with archaeological data, it may be possible to gain a better understanding of how Aurignacian groups operated when hunting or moving across a landscape (research question 5). As well as a focus on production, only the spear points have received any great attention by past experimental researchers (Knecht 1991, Tartar & White 2013, Nuzhnyi 1998, Guthrie 1983, and those summarised by Pétillon *et al.* 2016). Some discussion has been made on possible hafting methods and use of mastics, but very little consideration has been granted to the spear shafts. Evidently the spear shaft is a hugely important element of a spear, arguably the most important. Archaeological and ethnographic examples of wooden spears that do not rely on a lithic or osseous tip have already been discussed. A spear tip alone could not be used as a spear; therefore, it is reasonable to suggest the wooden shaft is the more important element. But why not even consider the type of wood used? Is it due to the lack of direct evidence of an Aurignacian spear shaft? Presence of charcoal and pollen remains indicate that much of northern Europe would have only had limited tree cover, populated by genera such as *Betula, Pinus, Picea* and dwarf species of *Salix*. These are not the classic sources of throwing spear shafts (assuming the Aurignacian spears were for throwing), and certainly in colder environments they may be highly unsuitable. Their characteristics (density, flex etc) will be compared to those of more temperate genera such as *Corylus* or *Fraxinus* which were present in Europe during MIS 3, but only in the south and east (Willis & Van Andel 2004). If the species present in northern Europe during MIS 3 are clearly unsuitable for yielding acceptable spear shafts, it will demonstrate a much wider raw material management and procurement than previously attributed to Aurignacian groups in Europe (research question 3a and 3b). As discussed by Ellis (1997), there are disadvantages in using stone for projectiles in cold environments. This, combined with almost certain problems sourcing suitable timber for spears, will have made the production of a reliable, effective spears challenging. It would not be unreasonable to suggest that where there were problems in creating high performance hunting tools, hunting strategy could have filled gaps. Bleed (1986) made it clear that compromise must have been a major factor in determining how hunting equipment was made (and what it was made from). Decisions on how those compromises are made must have been influenced by a number of factors including climate, prey specialisation, cultural tradition (in regards to manufacture), resource availability, prey specialisation (which may be influenced by culture or ecology), and hunting strategies or group size. Ultimately, if appropriate resources are not available to produce serviceable equipment, group strategy has to change to make it possible to source those resources. The alternative solution is that group hunting strategy itself has to change, so that there is not a reliance on those resources.

Chapter 3: The Aurignacian World

The climatic conditions during the Aurignacian (~44 - 30 ka BP; MIS 3) would have posed some limitations and difficulties for people aiming to move west and north. As discussed previously, a warm phase around 37 ka BP would have opened opportunities for people "surfing the ecological tide" (Mellars 2002: pg. 497). Determining a passive expansion in this warm phase over one of a more opportunistic character is unclear, as gentle and equal dispersal progressively north and west is not evident, but certain areas remained preferable (Figs. 4 and 5). This would indicate opportunistic use of the landscape where natural shelters exist, raw materials are available and abundant sustenance will not be exhausted. Open-air occupation sites cannot be ignored as a part of Aurignacian strategy but they may play roles as raw material source sites or lithic workshops such as the Maisieres Canel in Belgium (Miller 2014), sites around the Bergerac area of the Dordogne such as Barbas, Cantaloutte II and Vieux Coutets to name a few (Anderson *et al.* 2018). Certainly the lithic raw material rich region of the Dordogne would have been an attractive pull factor to Aurignacian people. Determining whether groups stayed within that region or reused it as part of a longer migration remains challenging.

It has been suggested in some literature that much of northern Europe would have been a combination of boreal and arctic tundra, with northern fringes under ice (Barron *et al.* 2002; van Huissteden *et al.* 2003). Organic samples from central Scotland at Balglass Burn have suggested that between 34,480 and 28,050 ^{14}C BC (c. 39.8 – c. 32.8 ka BP, based on Fairbanks *et al.*'s (2005) calibration curve) the landscape would not have been covered by ice sheets (Brown *et al.* 2007). The landscape at that time appears to have been open grassland with some permafrost; a mean temperature of 8-10°C in warmer months and −26° to −10°C during colder months has been indicated by Coleoptera fragments from the sample (Brown *et al.* 2007). An earlier paper by Guiot (*et al.* 1993), indicated that around 40 ka cal BP the annual temperature at Le Grand Pile (Vosges, France) was about 4-6°C based on raw pollen data and beetle remains. Between 40 and 35 ka cal BP, there was an annual temperature rise to 6-15°C, before a sudden drop around 33 ka to 1-5°C. A sharp rise back to 6-15°C around 32 ka cal BP is presented by raw pollen data, but not beetle remains, which indicate only a small rise to about 4°C. However, this assumes the climatic tolerances of species used in the reconstruction have not changed since MIS 3. Pollen shows a drop back to 5°C before a rise to 15°C between 32-30 ka cal BP. Beetle remains on the other hand show a similar a trend at the same time, but with a tighter temperature fluctuation (Guiot et al. 1993). Le Grand Pile offers samples from a very long pollen record, so has been extensively researched (Van Andel & Davies 2003). The fluctuations in temperature that remain at and below 15°C indicate that, even during warm phases in NW Europe, vegetation must have been limited to colder species. From North West Germany, pollen samples from MIS 3 have also indicated several warm phases which can be associated with those from Le Grand Pile (Van Andel & Tzedakis 1996). Pollen core locations are presented in Fig. 35 with simulated biomes.

Based on simulated biomes of aggregated plant functional types (PFT) compiled from pollen data, precipitation and temperature simulations, northern Europe would have mostly been covered in dwarf shrub and tundra with some barren arctic zones in cold intervals: see Figs. 33 and 35 (Huntley et al. 2003). During warmer phases, cold forest would have been present, but this was likely to have been discontinuous and restricted to sheltered areas (Huntley *et al.* 2003). It was noted that temperate "summergreen" trees were only present significantly in southern Europe, while cool coniferous trees were present only in moderate quantities in north mainland Europe (Huntley *et al.* 2003). Examples of species present, based on pollen evidence include *Betula nana* (dwarf birch), *Salix* (willow) and *Juniperus* in northern Germany, *Picea* (spruce) in the Netherlands and eastern Baltic, while *Pinus*, *Picea* and *Betula* made up woodland in eastern France and across to the alpine foothills (Behre 1989). Behre (1989) observed that other deciduous species were not present north of the Alps at this time. It is only further south into central and southern Italy that species such as *Quercus* (oak), *Corylus* (hazel), *Fagus* (beech), *Tilia* (lime) and *Ulmus* (elm) are present in pollen or charcoal (Follieri et al. 1988). Both boreal summergreen and evergreen trees were low scorers in terms of presence in the northern European sites sampled from warm intervals, which further suggests sourcing timber for spear shafts during the Aurignacian in N. Europe would have been a problem (see research question 3). Cold herbaceous species, temperate grasses and woody desert plants (shrubs) scored highly, indicating very open landscapes with limited cover, as shown in Fig. 35 (Huntley *et al.* 2013). This presumably would have resulted in a fairly hostile environment during the winter in the warm intervals. An interesting point made regarding charcoal by Huntley et al. (2003) is that its presence at a human-occupied site cannot be used as good evidence for woodland. The reason is that the charcoal might not represent the main local species if it was selectively chosen by people. If people carried firewood great distances into higher latitude regions which had low firewood resources, charcoal remains could suggest an artificial abundance. However ethnographic and archaeological evidence suggests groups tended to use locally available sources as a "principle of least effort model" (Pryor *et al.* 2016: 3). Certain parts and species of tree offer better firewood than others for heat output or ease of lighting, etc (Marquer et al. 2010; Théry-Parisot 2002). However, it is likely that people followed the least effort model as described by Pryor *et al.* (2016), and used whatever was available rather than focussing too much on the specific firewood types and their burning properties. Research by Binney *et al.* (2009) identified that late Quaternary charcoal remains from northern Eurasia were a mix of shrub and tree remains from a range of species. This would indicate opportunistic collection, rather than that focussed on species or firewood type. Certainly, when referring to faunal evidence (both macrofauna and microfauna), it seems clear that in NW Europe the landscape was mostly cold and open, with a limited variety (and quantity) of tree species, except in sheltered areas (Discamps *et al.* 2011; Willis & Van Andel 2004). It is also possible that hearths were present, but not in the excavated occupation zones. Their purpose may have been to act as smoke screens to biting insects during butchery, and therefore would have been placed outside a main occupation zone (Théry-Parisot 2002). Riehl *et al.* (2014) suggest firewood was probably made up of small branches, with any charcoal found representing local availability rather than human choice, which is in line with Binney *et al.*'s (2009) research and Pryor *et al.*'s (2016) model. This availability was likely to be scarce, based on the presence of burnt bones in Aurignacian hearths such as at Abri Pataud, where bone made up a large proportion of burning fuel (Pryor *et al.* 2016, Marquer *et al.* 2010).

Later species distribution work by Binney (*et al.* 2009) in northern Eurasia appears similar (in terms of species presence and distribution) to Behre's regional species summary based on latitude, especially for Eastern Europe. Here there is a presence of several species that could be suitable for spear shaft production. Within an age range of c. 45,000 – c. 20,000 years cal BP (calibration by Willis *et al.* 2004 using IntCal04), *Salix, Corylus, Fraxinus* (ash) and *Ulmus* have been identified from charcoal remains (Willis *et al.* 2004). From the charcoal samples tested by Willis *et al.* (2004), most were from *Pinus, Picea* or *Betula* species. However, from Stránská-skála and Bohunice (Czech Republic), samples of *Corylus* and *Fraxinus* were identified. The sample of *Corylus* dated to around 38 ka cal BP while the *Fraxinus* sample to around 44 ka cal BP (Willis *et al.* 2004). Both species could certainly provide suitable lengths of wood for spears, and have been used for such in much later time periods for both javelins and lances (Anderson 2011). It is likely that other species could provide wood of an acceptable form for spears, but may not be as effective as hazel or ash. Interestingly, Willis *et al.* (*ibid.*) suggested the food resource carrying capacity of Eastern Europe during MIS 3 for both mammal herbivores and humans would have been adequate, though no population estimates were suggested. However, it seems more likely that this referred to an abundance for food for mammals for humans to exploit, rather than availability of raw materials for tools (Willis *et al.* 2004).

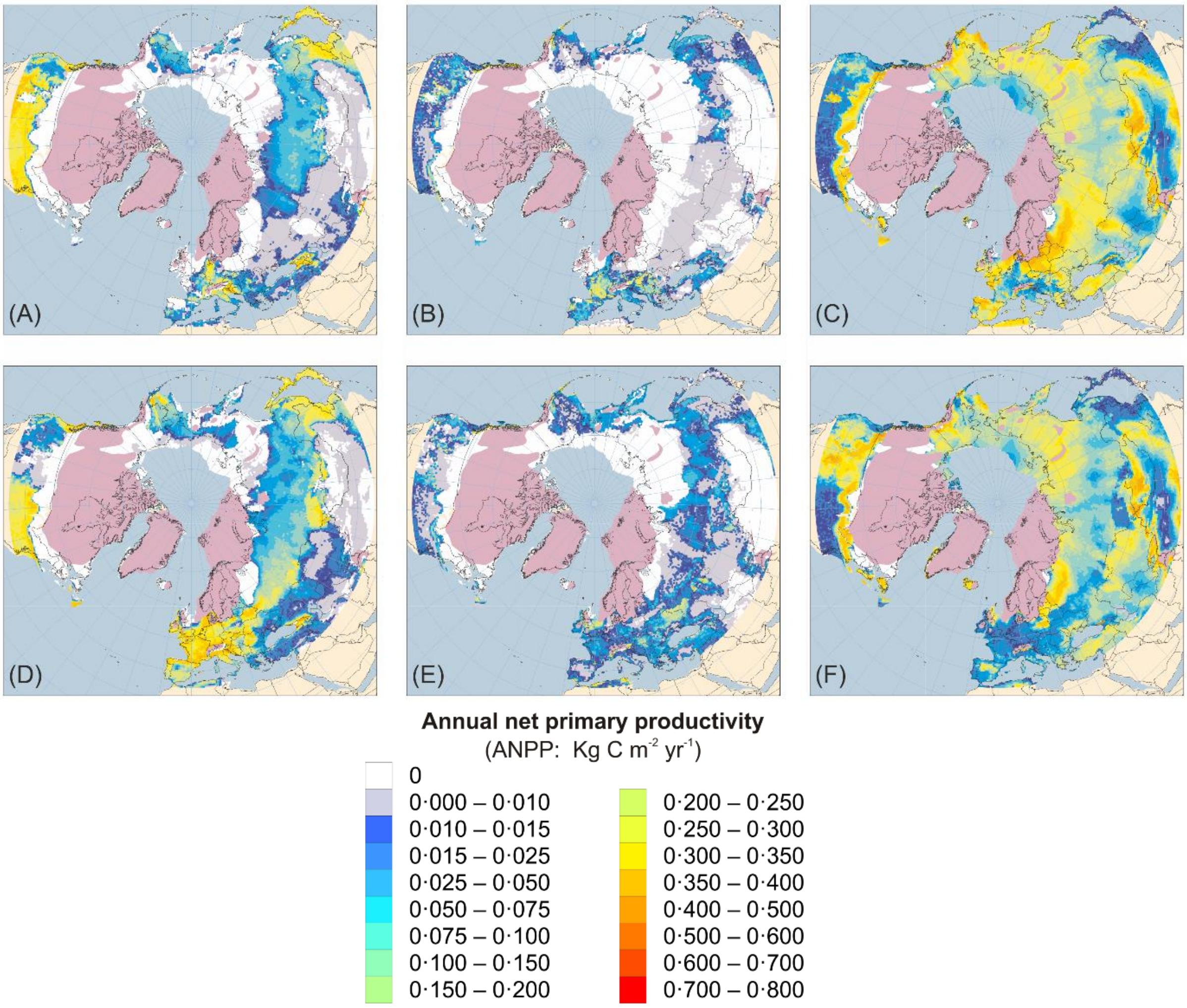

Fig. 33 – From Huntley et al. (2013) pg. 5: Tree, shrub and herb plant functional type ANPP: Heinrich Event 4 hosing experiment compared to 38 ka cal BP normal experiment. ANPP for the aggregated tree (A and D), shrub (B and E) and herb (C and F) plant functional types (PFTs) simulated for the palaeoclimates generated by the Heinrich Event 4 hosing experiment (A–C) and the equivalent 38 ka cal BP normal experiment (D–F). Lilac shaded areas indicate the extent of the ice sheets mapped for the mid-Weichselian; land area is shown for sea-level lowered by 80 m in comparison to today's sea level. In both experiments, productivity of aggregated trees (A & D) is generally limited in the northern hemisphere (even more so in NW Europe). It can be assumed that the highest productivity out of that group would be limited to species resistant to colder climates and short growing seasons.

The topography of a landscape clearly plays a major part in vegetation distribution; it can generate micro-climates in harsh, exposed areas, through to sheltered, nutrient-rich areas with a longer sun exposure (Chapin III *et al.* 2006). The boreal forest of Alaska is a good example of what a landscape could have looked like during warmer parts of MIS 3. North-facing slopes tend to have a greater presence of herbaceous genera and lichens with permafrost (Chapin III *et al.* 2006). Where there is tree cover, it is dominated by softwood genera (black spruce) and dwarf species of birch. South-facing slopes tend to be far more productive, with a greater variety of both soft and hard woods (see Fig. 34). Further down onto steppe and floodplains, where the ground is not saturated by water, there is floodplain forest: see Fig. 34 (Chapin III *et al.* 2006). In Europe during MIS 3, the most likely source of timber for spear shafts would be the margin between the higher areas of south-facing slopes and the floodplains/bog or fenland. This would certainly indicate that topographical zones in the landscape could be recognised for yielding certain valuable resources (research question 3a). It could be suggested that some sites were chosen for occupation, not only because of their obvious opportunities (i.e. a cave, next to a flint source etc), but also the more subtle opportunities such as lying within a south-facing zone with good drainage; therefore providing more timber and wider variety (research question 3b).

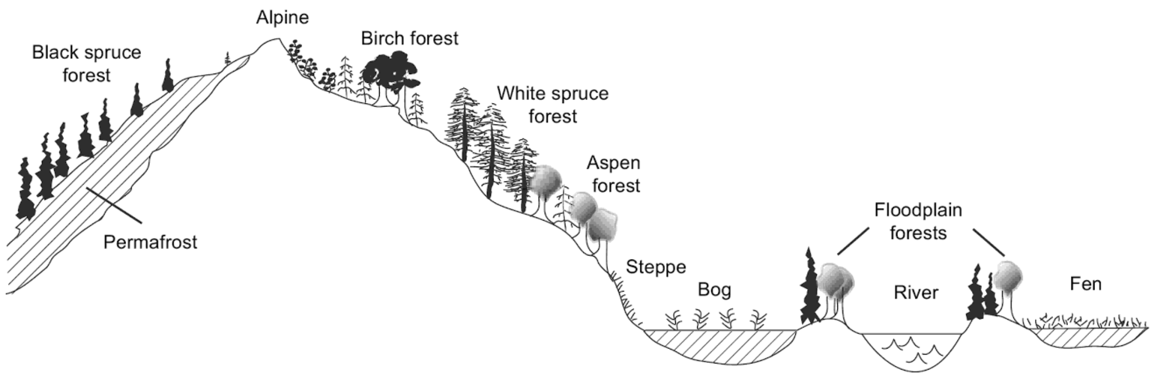

Fig. 34: A cross-section of topography through Alaskan landforms (from Chapin III *et al.* 2006: 88).

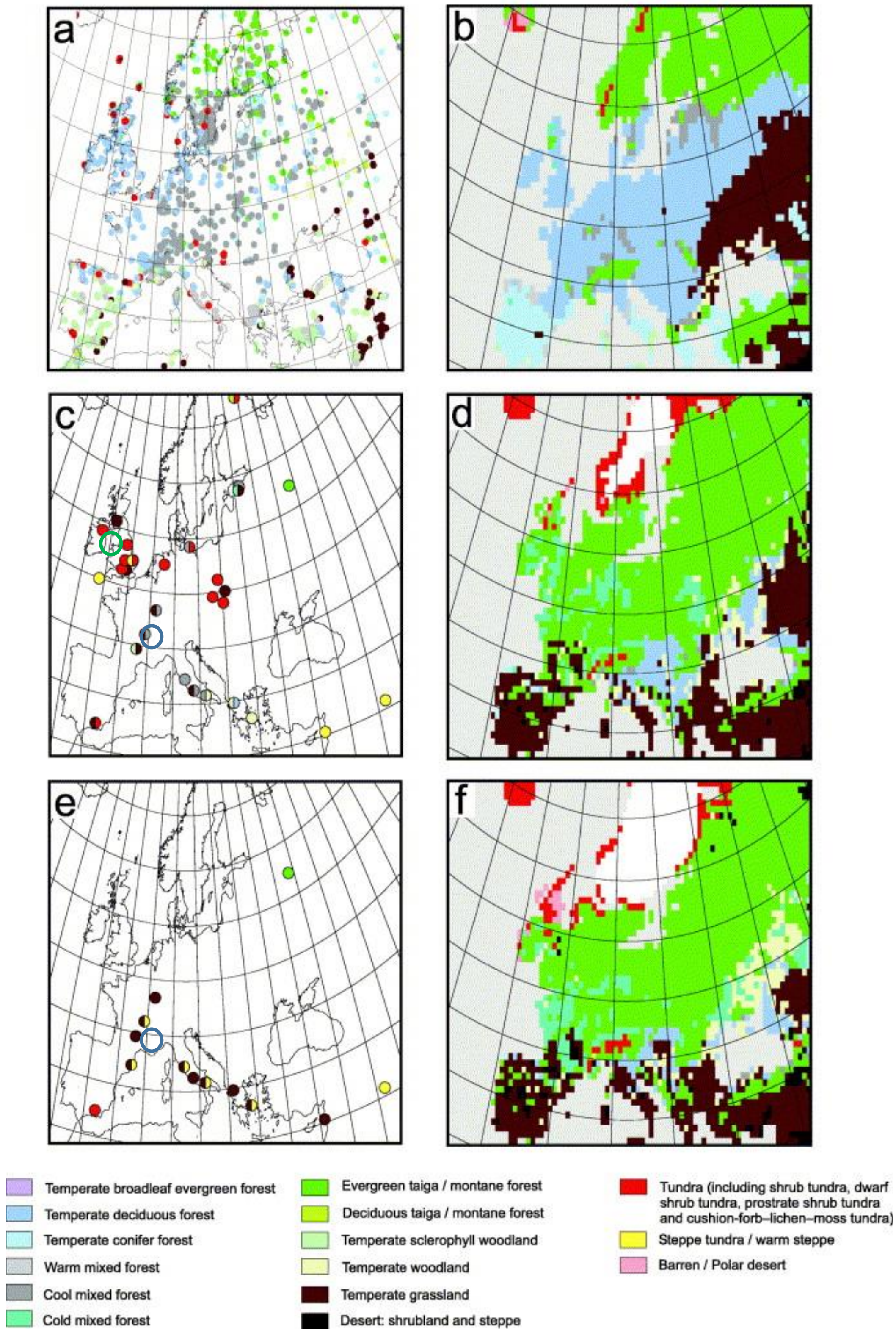

Fig. 35: Inferred and simulated biomes based on pollen data (from Huntley *et al.* 2003: 208). Biomes a, c and e inferred from pollen data, while b, d and f were simulated using BIOME 3.5; a-b show present day, c-d show MIS 3 at a warm stage, e-f show a cold stage of MIS 3. Le Grand Pile is circled (blue) in c & e; Balglass Burn circled green in c.

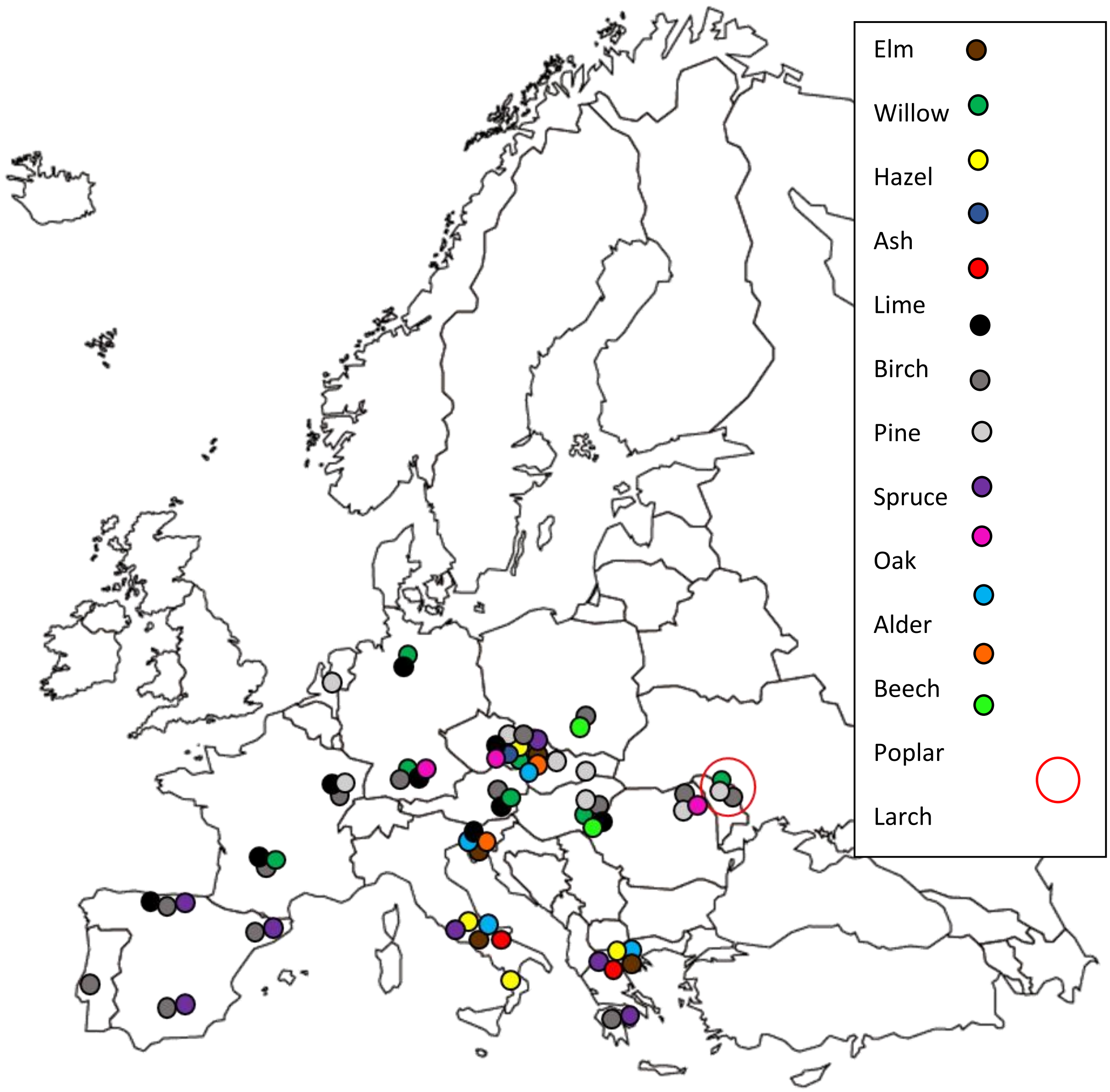

Figure 36: Charcoal samples of species considered viable options for spear shaft production have been identified via coloured dots (each colour representing a different species). The date range for these samples is 45,000-20,000 years cal BP, so slightly younger than MIS 3 for some samples (Van Andel & Tzedakis 1996, Willis & Van Andel 2004, Uzquiano 2008, Figueiral 1995, Marquer et al. 2010, Follieri et al. 1989).

It is clear from the map (Fig. 36) that these suitable species (especially ash and hazel) were not present in NW Europe, but remained in the south and east. It has been postulated that that any trees within NW Europe would be limited to dwarf species (Willis *et al.* 2004). The presence of *Salix* (willow) further north may be evidence of a dwarf or shrub species such as *Salix arctica* or *Salix reticulata*, rather than a tall tree species such as *Salix alba* (Willis *et al.* 2004). Likewise, generic attribution of samples to

Betula sp. and *Alnus* sp. may conceal the possible presence of dwarf species, indicating the extent of tundra in NW Europe during MIS 3 may have been greater than boreal zones (Riehl *et al.* 2014). Pollen grains from MIS 3 found in an organic deposit in Scotland are from deciduous species such as *Corylus*; however, the worn condition of the grains indicate they almost certainly came from further afield (Brown et al. 2007). Huntley *et al.* (2003) do admit there are mismatches and issues with the simulated vegetation that may be affected by sea surface temperatures, sea ice and wind movements. Certainly, pollen grains found in a deposit that have come from a great distance to the find location could add another problem to vegetation simulations as indicated by Huntley *et al.* (2003). Genera such as *Pinus, Picea* and *Larix* are potential sources of spear hafts, although not the preferred species, due to the presence of resin canals making them harder to work (Back 2002). In more limited growing conditions, they are likely to be very poor sources of spear hafts, and this will be tested during this research. Based on Aurignacian charcoal remains from El Castillo and Cobrante, the most strongly represented genus is *Betula* (Uzquiano 2008). This is probably down to local availability, burning qualities, and the source of tar that birch wood is (Théry-Parisot 2002). Another scenario is that the charcoal may have derived from trees some distance from its find context. Timber brought by natural processes into an area with limited trees, such as driftwood, before being burnt, could easily influence an environmental reconstruction (Marquer *et al.* 2010). Certain sections of rivers or water courses can be particularly abundant in driftwood; it would be reasonable to suggest this would have some influence on decisions made about settling for a short stay or seasonally (Marquer *et al.* 2010). Certainly, if availability of viable firewood were limited, it would not take long for a community to exhaust an area, requiring decades for replenishment (Pryor *et al.* 2016). An alternative strategy would be to supplement the limited quantity of wood for burning with bone (Théry-Parisot 2002). As dead wood will burn easily and quickly, it would be important to try and extend that burning time per kilogram of fuel. Bone burning requires an initial source of strong ignition that green wood cannot adequately provide (Théry-Parisot 2002). Once a mixture of wood and bone is burning without extra assistance, the two can then provide a longer-lasting fire, as seen at Abri Pataud (Théry-Parisot 2002; Marquer *et al.* 2010). Abri Pataud provides an interesting case study of people managing resources in climatically challenging conditions. Aurignacian charcoal remains from levels 6-14 at Abri Pataud indicated a consistent presence of *Pinus, Betula, Salix, Rhamnus* and *Juniperus;* the latter two falling into a category of dwarf trees or shrubs (Marquer *et al.* 2010). However, in most sample locations, burnt bone fragments were more frequent than wood charcoal. This alone indicates the limited quantity of wood than is suitable for burning (Marquer *et al.* 2010). Management of available timber resources would play a key role in the relationship of a group to a potentially new area (research question 3). They would therefore have to move to a new base location, or travel further in wider sweeps to collect firewood, or rely on alternative fuel sources such as bone or sub-fossil wood (Théry-Parisot 2002; Marquer *et al.* 2010; Pryor *et al.* 2016; Fladerer *et al.* 2014). This would ultimately lead to deposition of burnt wood remains in an area far from their original growth. Sourcing of spear shaft woods could have forced people to travel even further afield to obtain suitable wood (or exchange materials with other groups to obtain it). Obtaining timber that is reliable and well-suited for use as a spear haft would influence group movement strategies in collecting raw materials, as a greater reliance rests upon such a tool to provide sustenance, potentially over several episodes. This would make the antler spear tip more expendable, as it is an easier resource to obtain locally (Knecht 1991). The advantage of such antler tips is that they should be easy to re-sharpen, in a similar approach to their initial creation; this should provide some answers to research questions 2 and 5 (Tartar & White 2013).

Modern studies would suggest a preference for *Corylus* when identifying suitable types of wood for light spear shafts, specifically *Corylus avellana* (Common Hazel). Growth of straight shoots with a relatively consistent width and flex makes it ideal for throwing spears, darts or other projectiles with a shaft. Seasonal coppicing can improve the quality and yield of such shoots, resulting in large areas of hazel coppice in more recent times for making wattles. The temperature and drought resistance of common hazel would suggest it could expand ahead of *Ulmus* and *Quercus* species across Europe, as climate improved and more herbaceous species retreated (Finsinger *et al.* 2006). However, this was not the case in the early Holocene, according to Finsinger (*et al.* 2006), and did not appear to be the case earlier during MIS 3, as discussed above. It is possible that a limited growing season and competition prevented *Corylus* sp. from expanding sooner during the early Holocene (Finsinger *et al.* 2006). This may well be the case during MIS 3, as the limited established woodland of *Pinus, Betula, Juniperus, Larix* and *Salix* species simply outcompeted other species such as *Corylus* when more viable growing space became available.

Faunal evidence from the Ardennes (Belgium) shows montane taxa would certainly have been present (chamois, marmot), and probably with some temperate species such as boar and roe deer (Stewart *et al.* 2003). However, temperate species were almost certainly restricted to warmer phases when present in northern Europe; they did not encroach into Britain (Stewart *et al.* 2003; Currant & Jacobi 2001). Simulated summer marine surface temperatures for northern Europe range between 0°C and 2°C in warm phases and -2°C to -5°C during cold phases (Huntley *et al.* 2003). Combined with limited precipitation (around 0.5-1mm per day), vegetation and tree species would have been limited to the hardy, slow-growing and cold environment species (Huntley *et al.* 2003). An environment such as this would have been an obvious pull factor to reindeer herds, hence why pursuing hunting groups would have made their way into northern Europe for short spells (Stewart *et al.* 2003). Other large mammals such as Mammoth (*Mammuthus primigenius*), Woolly Rhinoceros (*Coelodonta antiquitatis*) and horse

(*Equus ferus*) were exploited by Aurignacian groups in northern Europe, giving further indication of the type of climate they operated within (Niven 2007). It is well-known that reliable and safe hunting strategies would be required for hunting both mammoth and rhino, indicating the types of hunting equipment found at sites such as Vogelherd and Hohle Fels were effective (Niven 2007, Wolf *et al.* 2016). The narrow, tapering tips of osseous points from Hohle Fels and Vogelherd could be an effort to improve the penetrative power of these tools (Fig. 38). As some of the common prey included Mammoth and Woolly Rhinoceros, attempts to improve the ability of hunting tools to pierce thick hides is understandable (Niven 2007). This is supported by Hughes (1998): deeper penetration into skin requires a projectile tip with as small a cross-sectional area as possible. The cross-sectional profile behind the tip would also have to remain narrow, or with a smooth and gradually thickening transition to the join with the projectile shaft (Hughes 1998). Experiments to answer research questions 4 and 2 will demonstrate the effective penetrative power of osseous tipped spears. It will be obvious if narrower spear tips provide the extra penetration required to hunt larger, more dangerous prey as suggested by Niven (2007) and Hughes (1998).

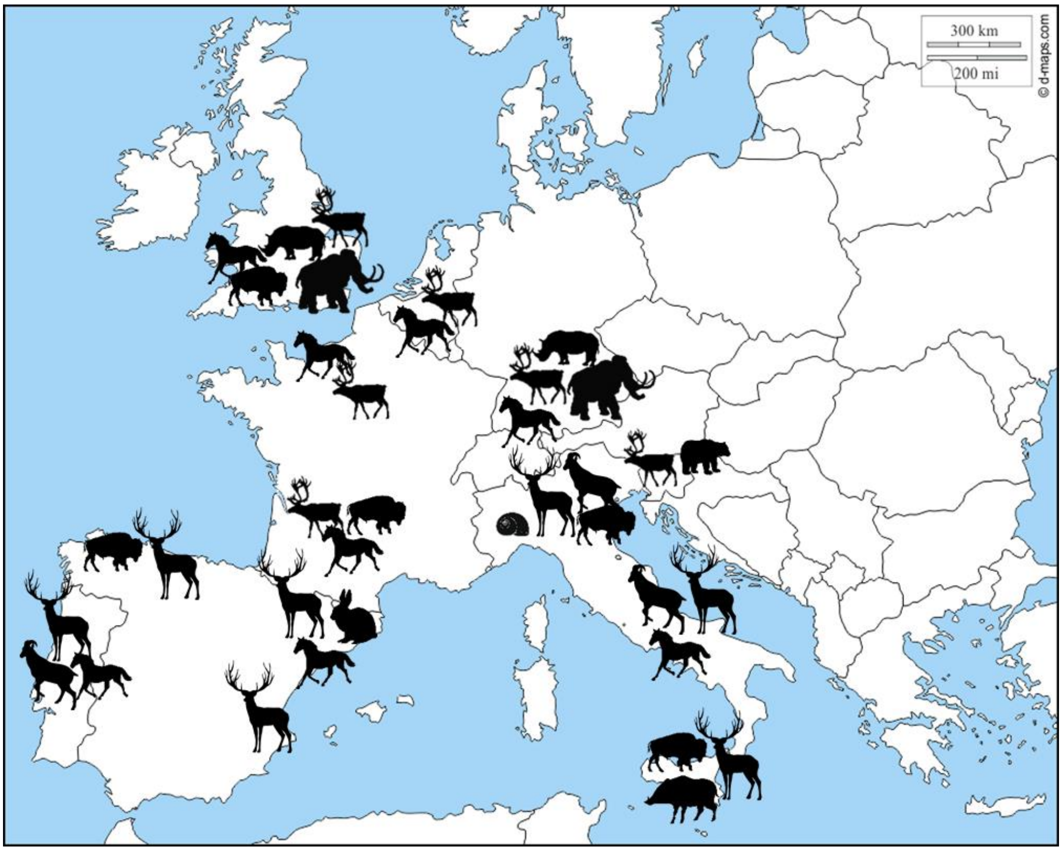

Figure 37: Map generated using following sites (by country): Britain: Goat Hole cave, Kents Cavern, Cresswell Crags. Belgium: Trou Walou, Spy. France: Mauran, La Ferrassie, Abri Pataud, Grotte du Renne. Germany: Hohle Fels, Geissenklösterle, Vogelherd. Slovenia: Potočka zijalka. Italy: Riparo Mochi (Balzi Rossi), Riparo di Fontana Nuova, Grotta di Castelcivita. Spain: L'Arbreda, El Castillo. Portugal: Pego do Diabo Cave (Data from: Discamps et al. 2011; Gutiérrez-Zugasti et al. 2013; Fa *et al.* 2013; Dinnis 2011, 2015,; Dinnis and Flas 2016; Flas 2015; Álvarez-Lao and García 2011; Chilardi *et al.* 1996; Mussi *et al.* 2006; Mannino *et al.* 2011; Verpoorte 2015; Niven 2007; Zilhão, J. and d'Errico 2003).

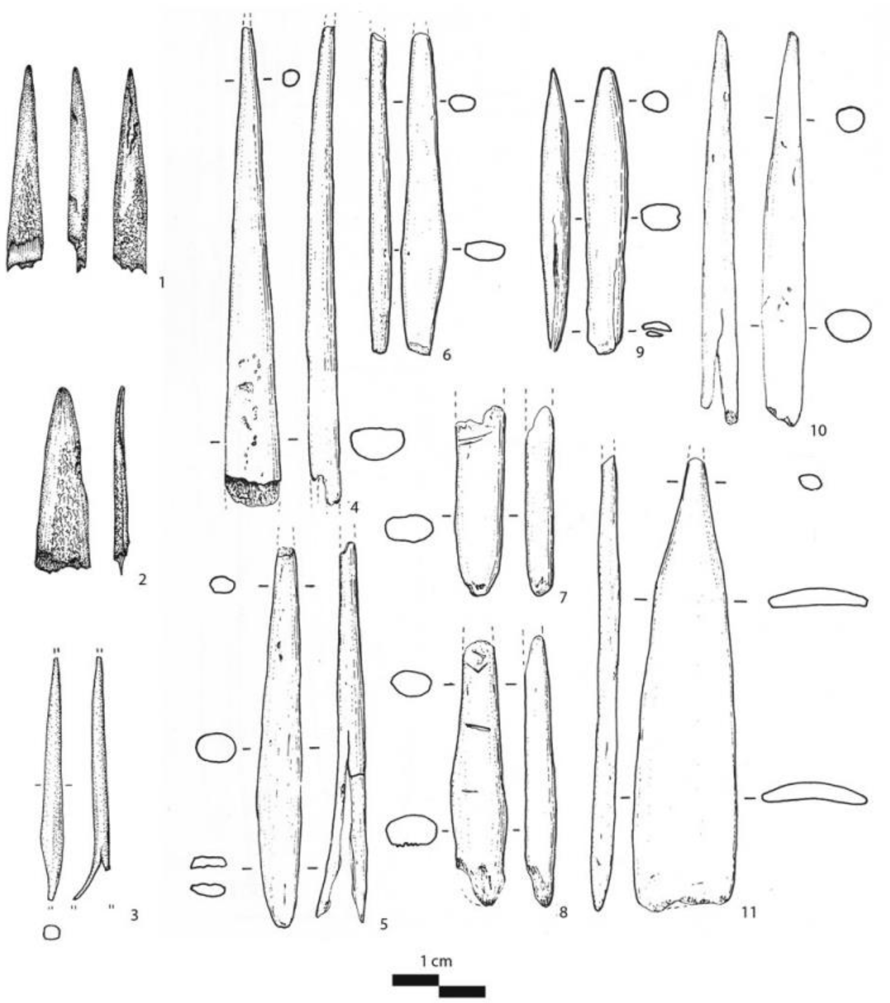

Fig. 38: (1–2) spear tips from Hohle Fels IV, (3) split-based point from Hohle Fels Vb; Vogelherd V: (11) massived-base point, possibly unfinished; Vogelherd V: (4, 5, 9, 10) split-based points, (6) massive-based point; Vogelherd IV: (7–8) massived-base points. From Wolf et al. (2016: 76).

Further south, into Iberia, groups preferentially exploited red deer (*Cervus elaphus*), probably due to the warmer climate (Straus 1992). This is supported by the presence of tree genera that only thrive in warmer conditions, such as Oak (*Quercus)*, Juniper (*Juniperus)* and Olive (*Olea)* (Carbonell et al. 2000). Further east, into the central Mediterranean, deciduous woodland was present alongside cool woodland species and grassland, based on charcoal and pollen remains (Stewart *et al.* 2003, Willis *et al.* 2004). The palaeo-environmental setting of NW Europe during MIS 3 would direct researchers to study groups living in the modern day in similar environments, such as boreal forest or the grass and dwarf-shrub rich steppe of Siberia (Řičánková *et al.* 2014). However, as discussed later, few researchers have taken ethnographic and anthropological studies into consideration. In trying to find a catalyst for technological change from the bladelet-focussed proto-Aurignacian to split-based point-producing early Aurignacian, Banks *et al.* (2013) suggested climatic changes may have been a factor. It was highlighted that the proto-Aurignacian occurs during a period of climatic improvement based on Greenland interstadials 10 and 9, 41,460 ± 817 – 38,220 ± 724 ^{14}C BP (43,019 ± 940 – 40830 ± 702 cal BP via CalPal 2007 HULU) (Anderson *et al.* 2006). This hypothesis would rely on a consistent development from the proto to early Aurignacian either side of this climatic change. However, the presence of early Aurignacian material at sites such as Willendorf II and Geißenklösterle (at around 43 ka cal BP) which pre-dates these climatic changes sheds doubt on Banks *et al.* (2013) (Falcucci *et al.* 2017). However split-based points from proto-Aurignacian sites have been found at Trou de la Mère Clochette dating to between c. 38.12 and c. 41.222 ka cal BP (Calibrated using Calpal HULU from 33 750 ± 350 ^{14}C BP and 35 460 ± 250 ^{14}C BP), making Banks *et al.*'s (2013) technological transition unfeasible (Szmidt *et al.* 2010). It was also argued by Ronchitelli *et al.* (2014) that Banks et al.'s (2013) model did not fit with the Italian evidence regarding a lithic-based distinction between the proto-Aurignacian and early Aurignacian. Banks et al. (2013) concluded that a variety of factors may have affected technological change from the blade and bladelet rich proto-Aurignacian (41.5-39.9 ka cal BP) to the early Aurignacian (39.8-37.9 ka cal BP) in which retouched bladelets were less common (Falcucci *et al.* 2017), although Banks *et al.* (2013) suggested Aurignacian people may have used the climatic changes to their advantage. These possible advantages (or indeed disadvantages) were not discussed by Banks *et al.* (2013), though it would have been an interesting avenue to pursue and hopefully this thesis will go some way to fill that missed opportunity. It can be assumed that not all Aurignacian groups would have had the same advantages, due to different location and time of existence (possibly one group replacing another).

Based on a sample of Aurignacian sites across Western Europe, it is possible to grasp some idea of the dominant prey species (Fig. 37). Regionally it appears there are consistent appearances from some species. For example, in France and Belgium there is a consistent presence of reindeer, horses and bison. Further south into Spain and Portugal, there is a consistent presence of red deer and horse; sites in Italy show a similar selection, though ibex species are more common. Either side of the Pyrenees and Alps there appears to be a divide in dominant prey species. This is almost certainly down to the environment, as some species have a low tolerance to extreme conditions. Red deer, for example, cannot live in open, cold environments for extended periods, so a stronger presence of reindeer would indicate the environment was indeed cold and open. Likewise, south of the two mountain ranges, the greater presence of red deer would indicate milder conditions with more woodland. Horse species on both sides of the mountain ranges indicate that grassland was present as far north as Britain, as even the hardiest of equids need a reasonable amount of sustenance (Discamps *et al.* 2011). A geographic boundary, such as mountain ranges, appears to have an effect on ungulates and where they can live, which has a knock-on effect on humans (who hunt them). It would therefore be reasonable to suggest such an effect could influence hunting strategy on the smaller scale in terms of hunting equipment, and larger scale in terms of hunting strategy. Both the topography of the landscape and climatic conditions may have played the greatest role in the way human groups operated, and affected their strategic or opportunistic decisions about which resources to follow, manage or incorporate into their seasonal movements.

Wood samples collected in high latitude and high altitude regions in Europe will be used to identify any issues that arise from using slow-grown and cold environment timber for spears. We can never know the true quality of timber available during MIS 3. It is certainly possible to identify species present through charcoal remains; however, this will not give an accurate indication of what the timber sources looked like. It is important when selecting timber for spear production to seek a length of wood that is relatively straight (certainly for thrown spears), with the correct weight, balance and thickness (Ellis 1997). In cold conditions, areas with limited topsoil overlying solid rock, exposed or windy areas, or dry areas, trees will grow slowly, often resulting in the dense, twisting trunks and branches that are seen today in such conditions.

Primary Prey

A detailed view of the raw material used to produce Aurignacian spear points has been extensively explored by Knecht (1991, 1993), Nuzhnyi (1998) and Tartar (et al. 2013), determining the functional advantages of antler. The faunal presence of reindeer at Aurignacian sites has also been documented and discussed previously. The issue of reindeer movement in NW Europe during MIS 3 has received some interest, but generally only in specific regions or later than the Aurignacian (Bahn 1977; Fontana 2017). This is probably due to the limited quantity of preserved faunal remains from NW European sites (Bignon-Lau 2014). Bone and antler preservation at open air sites in NW Europe prior to the Magdalenian is frustratingly poor. It is these sites that would fill gaps in our understanding of human interaction with fauna in regions that have fewer caves and rock shelters in comparison to the Dordogne and others (Bignon-Lau 2014). This means only a few locations such as the caves of Arcy-sur-Cure in Burgundy can be relied on to make implications about possible hunting strategies (Bignon-Lau 2014). Certainly in the case of the Grotte du Renne (level VII), there is a dominant presence of both reindeer (*Rangifer tarandus*), at 47.6% of the number of remains (NR), and horse (*Equus caballus gallicus*), at 34.39% NR, suggesting a targeted strategy on prey animals that prefer cooler, open landscapes (Bignon-Lau 2014; Stewart 2004). 87% of the early Gravettian faunal remains from layer V at Grotte du Renne were reindeer (Schmider *et al.* 2004, Bignon-Lau 2014). Based on the dental series and presence of shed female antler, these remains suggest a winter occupation by early Gravettian hunters (Schmider *et al.* 2004, Bignon-Lau 2014). Regarding sex ratios of reindeer exploitation during the Upper Palaeolithic, Weinstock (2002) determined two methods of procurement: a non-selective as wolf-kills approach, and a female-dominated, but with male presence approach. However, Weinstock (2002) makes it clear that a typical form of reindeer exploitation in the Upper Palaeolithic of NW Europe cannot be highlighted. Interestingly in relation to hunting technology, Weinstock (2002) points out that the slightly bolder and more curious nature of male reindeer would make them more likely prey to hunters wielding lances or short-range throwing spears. As they yield more meat, fat and have larger hides and antler in peak condition, male reindeer would be preferable if a hunter was focussed on wider raw material procurement than meat (Weinstock 2002). A male reindeer dominated hunting approach is seen at the middle Palaeolithic site of Saltzgitter-Lebenstedt and the Ahrensburgian site of Stellmoor which indicated a 9:1 male-female hunting strategy (Gaudzinski & Roebroeks 2000).

Sturdy (1975) suggested three possible options for human groups hunting migratory reindeer: herd-following, migration hunting or single-season exploitation. Arguably the first two options are fairly similar, or can overlap; certainly in the case of Stellmoor and Salzgitter the hunting was single season (autumn) and used interception on a migration route (Gaudzinski & Roebroeks 2000; Price *et al*. 2017). Out of the three, Bahn (1977), and previously Clark (1967: 64) suggested herd following was the most likely option for Palaeolithic hunters of SW France, and offered "a walking larder". However this strategy has its own risks, as carcass quality can vary through the year, and the human party can suffer alongside their reindeer prey herd if their population starts to collapse (Hoare 2009). Burch (1972) also outlines the potential productivity problems for groups that might attempt to follow herds,and suggests even human hunters in peak physical condition would struggle to keep up. Bahn noted that migration hunting only works through routes that restrict deviation, therefore making migration predictable. He continued by stating this predictability would have been unlikely in SW France for a number of reasons, including pasture exhaustion. However, as herds moved north into central France, through the Dordogne, it would seem likely that herds travelled through natural pathways such as the limestone gorges, in which Palaeolithic habitation is often concentrated due to the natural shelters available. However, as concluded by Fontana (2017), it is possible that during the Aurignacian reindeer were not migrating from the Dordogne area (based on her research which analysed slightly younger remains). The evidence from Amvrosievka suggests non-migratory herds of herbivores were still strategically manipulated by exploiting their prey behaviour and driven into gorges or ravines, rather than relying on them to pass through such features during migration (Julien 2011). As discussed previously, the high proportion of reindeer remains in faunal assemblages found within the cave and rock shelter sites of the Dordogne would indicate reindeer migration, or at least presence in the local area (Mellars 2006). Bay-Petersen (1975) highlighted that many sites in the Périgord were located in natural topographic bottlenecks. These potentially could have been used by hunters as bottlenecks or corrals to make mass-kills (Bahn 1977), though again Burch (1972) observes that certain sites would not work as kill sites over successive years, due to herd movement irregularity. It has already been briefly mentioned how reindeer would have probably migrated up and down through North Western Europe seasonally, as they do today outside Europe in herds of several thousand to several hundred thousand, travelling up to 5000km (Hoare 2009). Therefore encounter/intercept hunting at natural bottlenecks during long migrations would seem a viable strategy. However, Burch (1972) again points out predicting reindeer migration routes is unrealistic. What appears to be a migration route that has suffered annual damage and wear could instead be a route through ground that is taking many years to recover. Making that critical decision over which gorge or pass to settle one's family group and wait is as Burch (1972: 346) puts it, "literally a matter of life and death". In times of large herd population, small satellite or straggler groups may be some distance from the main herd, following alternate routes. In this scenario, the impact of making that wrong base location decision is less severe, as it is likely a splinter group will pass through. When the reindeer population drops, an incorrect decision can be catastrophic (Burch 1972). Reindeer population fluctuations can also have a disastrous effect on hunting groups that rely upon them. Burch (1972) refers to the Nuataqmiut of Alaska who suffered starvation when reindeer herd fluctuations became more extreme over a 30 year period.

Herd interception will be discussed later with regard to caching hunting equipment at prepared corral areas. In the areas along the Vézère and Dordogne rivers, it would seem highly unlikely that herds would travel above the gorges, instead favouring the natural pathways they offer (Hoare 2009), or that humans would choose to live far from reindeer migration routes if herds avoided the gorges and limestone cliff-rich areas. Single-season exploitation was ruled out by Bahn as it would not have been enough to sustain local human populations (and does not fit with faunal remains proportions). When discussing regional movements in the south west, Bahn points out that the Pyrenees offer an area that could accommodate short range migration of herds (within 50km). However, it is unclear whether this is based on the assumption that adequate foraging ground would have been available seasonally within such a small area. Bahn mentions issues about over-grazing and the time required for reindeer pasture to recover: "After two days of feeding, reindeer pasture is useless for a year, while pasture used for three or four consecutive years needs to rest for five or six" (Bahn 1977: 245). Considering that some modern herds of reindeer number into the tens of thousands (Burch 1972), and that pasture can take such a long time to recover, it seems unlikely that a migration range of 50km (compared to modern ranges of up to 5000km) could support a herd of even a few hundred. However, if simulated biomes are to be believed, it is likely far greater areas of suitable pasture would have been available (Huntley *et al.* 2003, 2013). While smaller herbivore populations are generally regulated from the top of trophic networks (by predators), larger herbivores are regulated from the bottom (by availability of forage in quantity and quality) (Hopcraft *et al.* 2010).

Stable Isotopic evidence from reindeer teeth dating to the late Pleistocene indicates an east-west migration route across the central European plain rather than a north-south pattern (Price *et al.* 2017). The reindeer remains from Stellmoor and Meiendorf studied by Price *et al.* (2017) dated to between c. 15 and c. 11.4 ka cal BP. The strontium isotopes indicated herd movement was within the European plain, presumably taking advantage of flatter ground over uplands (Price et al. 2017). This observation was also seen in Middle Palaeolithic reindeer from Jonzac (SW France), which appeared to have avoided highland areas (Britton et al. 2011). It seems unlikely, therefore, that Aurignacian reindeer herds would have moved through areas such as the Pyrenees, as suggested by Bahn (1997). When comparing faunal assemblages from SW France and northern Spain, a suggestion such as Bahn's (1997) does not seem unreasonable. Between reindeer and red deer, there is a clear divide in faunal dominance either side of the Pyrenees and Alps (Fig. 39). It is likely that this divide is down to a geographical barrier in terms of migration routes and climatic zones, as discussed previously (Bahn

1997; Discamps et al. 2011). Nevertheless, Discamps *et al.* (2011) point out that despite there being dominant species that are good indicators of climatic and environmental conditions, there are still species present that cannot tolerate extreme cold or food sparsity for example. In the case of reindeer-dominant Aurignacian deposits, such as those in many south-western French sites, remains of ungulates that cannot tolerate the environmental preferences of reindeer (cold, open landscapes), such as red deer, are still present (table 1). Discamps *et al.* (2011) suggest that in the case of most ungulates there are species individuals who might stray outside their preferred environment for a number of reasons. This can lead to them appearing in deposits that would generally seem unsuitable for their environmental preferences. Based on the faunal assemblages from SW France, it would be reasonable to assume the environment was a cold, open one with few trees that had snowfall for a significant proportion of the year (Discamps *et al.* 2011; Willis & Van Andel 2004). Fontana (2017) presents post-Aurignacian results from La Madeleine levels 25 and 27, which indicate year-round hunting of reindeer based on antler morphology, presence of foetal bones and tooth eruption stages. Fontana (2017) suggests the view of annual migration to follow herds or intercept them should be revised in the case of sites such as La Madeleine. However outside SW France, sites such as Pincevent (layer IV) and Verberie indicate strong autumnal hunting (Fontana 2017, Enloe & David 1997). Autumnal hunting is perhaps the optimal time of year to be obtaining reindeer carcasses. The hollow-hair insulated skins are at peak condition in the autumn, and it is a near-certainty that Aurignacian groups made use of this highly valuable resource for clothing and shelter covers (Burch 1972; Friesen 2013). In addition, a reindeer carcass taken in the autumn has optimal fat content. This is yet another valuable resource for many reasons beyond simple sustenance (e.g. lighting, tool maintenance, pigment binding) (Friesen 2013). Besides resources, it is possible reindeer herds during MIS 3 made their migrations during the autumn, like prehistoric herds in the Canadian Arctic (Friesen 2013). To fill other gaps in the year, Fontana (2017) refers to Canecaude cave (level II) – November to May hunting and Le Blot (southern Massif Central) showing April to October hunting. Fontana’s sites are clearly much later than the focus of this thesis, but such a variation in hunting strategies and timing indicates it is possible for groups in Europe during the Upper Palaeolithic to employ different approaches to hunting reindeer.

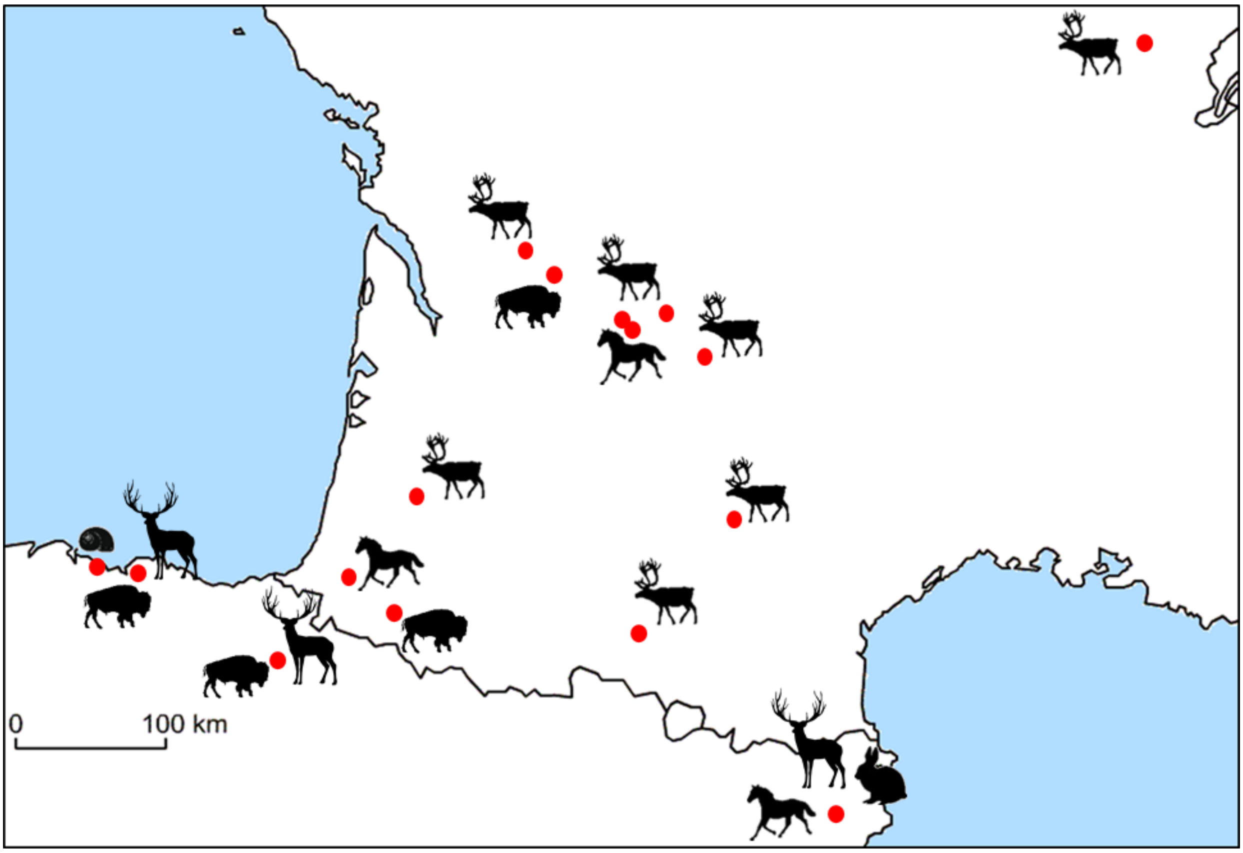

Figure 39: Map generated using following sites: El Castillo, El Cuco, Labeko, Arbreda, Isturitz, Gatzarria, Mauran, Battuts, Brassempouy, Roc-de-Combe, Ferrassie, Castanet, Abri Pataud, Bourgeois Delaunay, La Quina and Fontaury/Hauteroche

(Data from: Discamps et al. 2011; Gutiérrez-Zugasti et al. 2013; Fa *et al.* 2013; Álvarez-Lao and García 2011).

Table 1: Common Aurignacian prey characteristics. Adapted from Discamps *et al.* (2011) & Burch (1972)

	Snow tolerance	**Feeding strategies**	**Environmental preferences**
***Rangifer tarandus* (Reindeer)**	Well-adapted to movement and foraging in heavy snowfall (to a maximum depth of 50cm) which is required for their ecology.	Grazers of grasses and sedges in summer, lichens in winter. Broad food habits. Woodland species can graze lichen on trees.	Open, treeless areas in cold and high winds. Will live in spaces uninhabited by other ungulates.
***Bison bonasus* and likely to be very similar to *priscus* (Bison)**	Reasonably well adapted to snow cover but not for extended periods. Access to food in snow is a limiting factor.	Grazers and browsers, mainly short grasses	Mainly open grassland but can live in woodland.
***Equus ferus* (Horse)**	Like Bison, can only tolerate snow for a short period and lacks adaptation.	Grazers, can live in areas of low quality vegetation	Mainly grassland or habitats with limited snow cover
***Cervus elaphus* (Red deer)**	Similar to equids, lacks adaption to snow.	Highly adaptable mixed grazer on grasses, leaves, shrubs, fruits, nuts	Wide range of grassy, woodland, highland and moorland. Cannot tolerate tundra.
***Capreolus capreolus* (Roe deer**	Less tolerant than red deer, but can walk on crusted snow due to smaller body mass.	Very selective, soft high nutrient parts of plants. More selective than red deer.	Mainly woodland but can live in grassland. Can tolerate long winters.

Different researchers have proposed a variety of movement or migration patterns for reindeer and other ungulates in Palaeolithic Europe. Some of these hypotheses have been based on observations of herds in the present day in regions such as Alaska, with application to the European landscape (Burch 1972; Bahn 1977); others have been based on tooth enamel isotopes and faunal remains (Willis & Van Andel 2004; Discamps *et al.* 2011; Fontana 2017). Within the regions of NW Europe during the Aurignacian, it is reindeer that are the dominant species represented in faunal assemblages (see Fig. 37) (Discamps *et al.* 2011). Occasional sites, such as Solutré (layer II), yielded a huge amount of faunal remains; over 60% of the individuals represented were *Equus ferus* (Olsen 1989; Bemilli & Bayle 2006).

Based on antler morphology, Palaeolithic reindeer in Europe appear to be most similar to tundra reindeer (*Rangifer tarandus tarandus*) (Piskorska *et al.* 2015). Other ungulates tend to favour similar ecologies to reindeer, though it is clear that reindeer are better adapted to colder and harsher conditions (Burch 1972). Broadly speaking, both by looking at the simulated biomes and organic samples at the start of this chapter and faunal assemblage discussion that follows, NW Europe during the Aurignacian appears to be grassland-dominated, with pockets of woodland in sheltered areas. The species in those areas would typically have included *Betula, Pinus, Larix* and *Picea* which would have offered shelter and grazing to ungulates who either eat bark or the lichen which grew upon it (Burch 1972; Discamps *et al.* 2011). As demonstrated by Fontana (2017) it is possible that reindeer during the Aurignacian were almost always present (based on isotopic data from slightly later samples). This is contrary to suggestions by Bahn (1977) and Hoare (2009), who suggested the migration of reindeer would have played a major role in hunting strategies. This potentially less risky availability would indicate Aurignacian groups may not have had to move as frequently or as far to intercept herd groups. Risk management is an essential part of any strategy, and making decisions over hunting camp location can essentially determine the success or collapse of a community.

Burch (1972) addresses suggestions that reindeer are easy to kill (Clark 1967). He agrees that in comparison to other herbivores, reindeer are easy targets which may explain their dominance in Palaeolithic assemblages. Burch discusses the wariness of reindeer in different scenarios, which would clearly be an important factor in Aurignacian hunting strategy. In mid-winter when groups are scattered and in smaller numbers, reindeer are especially wary and in particular notes that groups fled upon visual contact at least 400m away (1972). This would clearly be problematic for hunters if they attempted to approach groups in open grassland. This is perhaps where herd driving tactics, such as those seen at Amvrosievka with bison or Solutré (horses), may have been employed (Julien 2011; Olsen 1989). However, Olsen (1989) points out that due to the nature of wild horse groups (small bands of bachelors or families with a single stallion), it would be very difficult for a small group of human hunters to drive these groups of horses any reasonable distance, because of stallion aggression. These small equine groups are somewhat dictated by their ability to quickly digest low quality plants, such as tundra grasses (Berger 1985). Larger groups of equids existing within an area with only low quality plants would quickly exhaust food supplies and potentially cause population collapse (Berger 1985). This adaptation to process lots of low-nutrition plant matter in a short space of time (via a monosacculated stomach) would mean frequent group migration was vital (Berger 1985). If reindeer were not migrating over great distances, as suggested by Fontana (2017) (and affecting Aurignacian hunting strategies), it is possible bison and horses were (Berger 1985). Though evidence from Amvrosievka and Jonzac suggests bovids tended to be relatively sedentary, while evidence from Payre (SE France) shows horses were not necessarily migratory (Julien 2011; Richards *et al.* 2008; Bocherens *et al.* 2016). Based on observations of when reindeer are travelling in very large groups that can run into the thousands, Burch states that they can be "practically oblivious to all dangers from an animate source (1972: 361). During these times hunters may have had a better chance of easy kills in open grassland. Burch (1972) also highlights the problems in predicting reindeer movement patterns annually, though it is almost a certainty that hunters would have observed specific foraging areas and their replenishment. These observations would have been important in making some predictions of movement. Though reindeer are on high-alert during the winter, they will be searching for lichens, so these locations must have been likely ambush sites or starting points for drives (Burch 1972; Piskorska *et al.* 2015). Bison and horses, by comparison, would appear to be much trickier challenges to a lone hunter or to a small hunting group. Horses are easily spooked, and can flee quickly while being protected by a stallion (Berger 1985). Bison, in comparison, are perhaps not as swift as horses, but can offer a formidable opposition to any hunting party (Arthur 1974). During the rutting season, large groups of bison congregated on the northern Plains of North America. Large groups of humans from a variety of tribes would mirror this gathering for the purpose of hunting (Arthur 1974). It is here that high-risk hunting to demonstrate prowess against prey that is perhaps more aggressive than normal would occur before the bison herds split away into smaller groups for the winter (Arthur 1974). Such cycles and seasonal herd gathering would have provided Aurignacian hunters with good opportunities to socially and culturally network, while engaging in hunting activities (Schmidt & Zimmermann 2019).

Chapter 4: Making the point

To answer the main questions of this thesis, it is necessary to outline the approach into the hypothesis for each question, how it will be answered, and the expected outcome. The collection of materials, production of tools and equipment and methods for producing data to answer questions is discussed in more detail later.

Table 2: Hypothesis, Methodology and Outcome

Hypothesis	Methodology	Outcome (expected)
Osseous-tipped spears fly cleanly (in an arc) in semi-controlled flight conditions when thrown by experienced javelin throwers without the need for extra stabilisation. See research question 4.	Replica spears will be thrown in a sports field by experienced javelin throwers. Their flight and condition upon impact will be recorded. Flight recording via video camera will demonstrate stabilisation during flight.	Replica spears will fly in a clean arc without extra stabilisation. Some damage will be expected on the spear points although only minor as they will be impacting turf.
Aurignacian spear points are engineered to improve the longevity of the spear shaft while offering adequate penetration power and resistance to sudden impact damage. See research question 2.	Replica spears will be tested in a drop shaft. Ballistics gel will test the spear's penetration power and impact resistance. A drop test will also show whether in high impact scenarios the spear tips will consistently break before the shaft does.	Replica spears will be able to penetrate soft and medium gels to a depth considered a potentially mortal wound (20cm). Spear points will break upon impact onto hard surface before significant damage to the spear shaft.
Some mastics and binding combinations improve the composite	The spear throwing tests will demonstrate the viability of using mastics (birch tar) with binding	Certain mastics such as birch tar can be produced to have a good adhesion while not being brittle

strength of Aurignacian spears. See research question 1a.	materials (tree bast cordage). The drop shaft tests will push the components of the spears to destruction indicating the weaker elements.	like pine resin. Therefore birch tar will perform better and improve the composite strength of the replica spears. It is likely that there will only be a limited difference between the binding materials following the throws and drop tests.
Aurignacian lithic tool types play a clear role in the *chaîne opératoire* of spear production. See research question 1b.	Replica spears will be made using authentic materials (reindeer antler for tips and several different species of wood for the shaft. These components will be produced using replica stone tools based on Aurignacian examples. An observational analysis of the effectiveness of these tools will be made and recorded and various stages of production and discussed.	Due to inexperience in making these spear tips, it may take several attempts to find the best tool types and method for using them. The spear shafts will be relatively easy to prepare. Almost all the main lithic tool-types will have a clear effective role.
Species of wood in cold or high latitude regions are not suitable for spear production. Sources of viable timber would have to be sourced in warmer, temperate regions. See research question 3.	Personal observation in higher latitude regions and drop shaft tests will show: A – whether suitably formed timber grows in such regions. B – whether such timber is not too dense or inflexible for spear shafts which would create high levels of impact load on the spear tips.	Finding timber that grows suitably straight to make a spear shaft will be extremely challenging. Even in only cool woodland such as in Scotland. Drop shaft testing will show higher latitude timber is too heavy (dense), creating a higher frequency of spear tip damage due to lack of spear shaft flex.

Production of replica osseous points

Replica osseous points will be required for most of the experiments as part of this thesis. Therefore it is necessary to produce accurate replicas that will perform closely to originals; a full account and discussion of the production can be found in Chapter 5. Experiments determining the method of production have already been discussed in the literature review (Chapter 2). A combination of the two original theories by Peyrony and Henri-Martin will be employed to produce the points. Tartar & White (2013) have already demonstrated that this combination provides a method of production that is relatively risk-free, while maintaining a reasonable success rate for good quality points. Experimental work by other researchers will also be used for specific stages in production, such as Nuzhnyi (1998), as useful observations and suggestions were made regarding production efficiency.

Reindeer antler from Scandinavia will be used as the material to reproduce these osseous points, along with a variety of replica stone tools made of flint, chert and sandstone to finish the points. The tools used to produce the osseous points will be closely based on Aurignacian examples. It is therefore necessary to observe examples first-hand in the same fashion as original osseous points (Chapter 3). Recording will be conducted at all stages when producing these replicas, by photograph, video and written notes. This will generate a huge amount of information that will be useful later in determining whether the osseous points are in fact over-engineered or not, as per question 4 (and partially question 2) of this thesis.

Glues and bindings

A number of different glues and bindings will be used when producing replica spears for testing. Rees' (2003) dissertation research indicated the effectiveness of both when applied to an osseous spear point in a shaft. The spear shafts will be de-barked, cut and bevelled with replica stone tools to provide further information regarding research question 1. The mastics (apart from distilling birch tar) and bindings will also be prepared using non-modern procedures. The plant fibres used will be lime bark/bast (under-layers of the bark) which will be harvested and turned into cordage. The lime bast must be submerged in water for several weeks to encourage the bast layers to delaminate. It can be removed from the water once the bast layers separate easily so it can be split into thinner strands before twisting; this is known as "retting". Once retted it can be made into cordage in the same way as the nettle cordage, by twisting a length until it kinks and starts to wind around itself.

The birch tar will be obtained by dry distilling bark packed into a metal container in a fire. This will force the tar to vaporise, and drip out once the fire starts to cool. Until recently, viable aceramic methods for extracting birch tar have been uncertain. Schenck and Groom (2018) have shown the effective use of sand structures within a fire in the extraction process. They highlight similarities between Middle Palaeolithic burning areas and their experimental methodology as evidence of a possible method used by Neanderthals (and later humans).

Testing the replica Aurignacian spears

A number of replica spears were produced to better understand the relationship between the different material elements. A large number of spear points were produced as it was assumed this element would suffer the most damage during experiments. When thrown from experienced hands, the spears were observed in flight conditions (not loosed from a calibrated crossbow for similar).

As stated, the spears will be tested by experienced hands, in this case sports javelin throwers. They will throw the spears down range to gain a better understanding of these spears performing in a closer to real-world scenario. These tests will demonstrate whether the spears can fly and land without the need for fletching or air resistance at the distal end of the spear to improve stability (research question 4a). Experienced javelin throwers will be able to give their opinion (and demonstrate) whether problems with stability could arise (research question 4b). They will take turns to stand in the same position. They will then throw their javelin down the field. The throw and flight will be recorded by a camera close to the thrower and another halfway down the track with a perpendicular view of the flight path. This will record the way the spear flies (see Fig. 40). The results will be recorded after each throw on a recording sheet (example shown in table 3). Clearly this type of experiment is semi-controlled. Some variables and elements can easily be controlled, such as the replica spears, while other variables such as wind speed, soil hardness and thrower ability cannot be controlled within reasonable means. When used during the Palaeolithic, such spears would almost certainly have been used in a variety of conditions by hunters with varying skill and experience. Therefore, to fully control all variables would actually move the results further away from 'real-world' conditions. Essentially it is important to strike a balance between controlled conditions and factors that may affect the spear effectiveness if used in a hunting scenario. If time and finances were no issue, it would be sensible to test the spears with a large number of throwers with varying experience in a facility in which weather and ground hardness/conditions could be simulated. A very large set of individual throws could be performed and measured using a variety of sensors and processed to produce results. However, such a study would require huge investments of time and finances which was not viable. In this instance it was enough to test the spears using a small number of throws to provide observational data. If there were elements of these composite spears which were weaker (engineered or not), they would become apparent after only a few throws. If the data set had provided inconclusive results, it may have been a necessity to revaluate the time investment of the experiments and whether more resources and time were needed. The spear throwing experiments in particular relied on the good will of the sports club and javelin throwers. A further request of their time and experience without compensation (at significant expense to the researcher) for this thesis would have been unreasonable. The engineering laboratory were also kind enough to offer their time, experience and equipment in the creation of an impact experiment. The setup of equipment and software required several days preparation and safety checks by laboratory technicians. Their efforts were hugely appreciated and the experiment could not have happened without their assistance. Once setup was completed, each test series (see table 6) took a whole day to conduct. With 5 series of tests, the time investment becomes apparent from the researcher and technicians who were required on several occasions to resolve issues with the equipment and software it ran on. As the lab was used by engineering students and researchers who had their own studies, it was important not impede on their work or that of the technicians. Pioneering experimental archaeologist John Coles recognised that an "archaeologist cannot possess all scientific processes or theories involved in an experiment, but that it was necessary to appreciate limitations" (Coles 1966: 1-2). The experiments were not the sole focus of the thesis research, but instead provided observational data that could be used in combination with data from other sources such as the Stage Three Project.

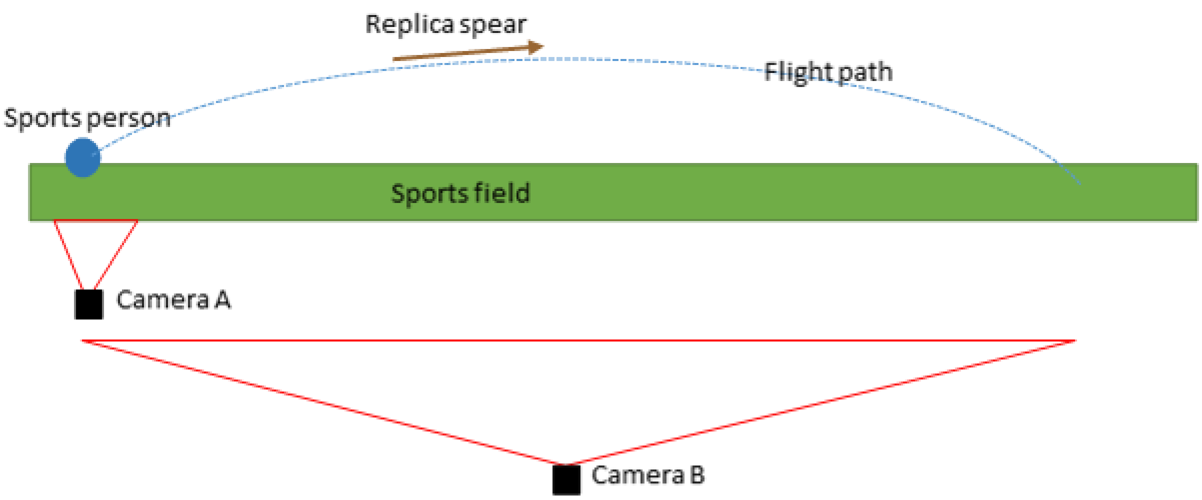

Fig. 40: Throwing of replica Aurignacian spears at a sports field. Camera A will capture the throw, camera B will capture the flight path.

Table 3: Example recording sheet for spear throwing experiment with examples of likely observations.

Example recording sheet for spear throwing **Date: 09/01/2017** **Location: Sports ground**					
Javelin throw	**Javelin thrower**	**Distance of throw (metres)**	**Footage number**	**Observations of spear throw during flight**	**Observations of spear after throw**
1	**A**	**xx m**	**001**	**Clean arc, spear descended and penetrated ground**	**No damage**
2	**A**	**xx m**	**002**	**Clean arc, spear descended but landed flat**	**No damage**
3	**B**	**xx m**	**003**	**Relatively clean arc although steep descent and penetration into ground**	**Some damage (small chips) to tip of spear**
4	**B**	**xx m**	**004**	**Non-clean arc, spear turned over in the air on descent before landing flat**	**No Damage**
5	**C**	**xx m**	**005**	**Non-clean arc, spear turned partially at highest point before descent and penetration into ground**	**Spear point broken and detached from spear shaft**
6	**C**	**xx m**	**006**	**Clean arc, but landed flat**	**No damage**
7					

The next phase of testing the spears will be in a drop test onto surfaces of different hardnesses (see Fig. 42). This will demonstrate the material failure points (whether it be the wooden shaft, antler tip or binding agents) under increasing stress. As only short lengths of wood will be required for this test, the wood samples from northern Scotland (Chapter 6) can be used by dowelling them to consistent widths. If samples are heavily twisted or bent, sections to dowel will be selected where a short, straight length can be obtained (see Fig. 41). In the case of a twisted sample having to be dowelled where the grain does not follow the line of the dowelling, it will be highlighted that this could cause adverse effects during testing. However, such problems highlight the difficulty in attempting to create a fully controlled experiment using natural materials. Unlike the spear throwing experiment which was subject to weather conditions and thrower ability, the drop tests will be controlled other than the natural variation in the raw materials and small differences in SBP size. It would be possible to use dowelled hardwood from a timber specialist, though this would not be an accurate means of attempting to fulfilling a 'real world' scenario. Past experiments have used dowelled timber, though it is notable that the focus of such experiments was the effectiveness of the point, rather than spear as a composite object.

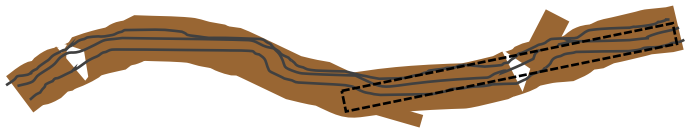

Fig. 41: Obtaining straight dowelled length from twisted or bent sample. Dotted rectangular rectangle shows potential position of dowelling.

The short spear shafts will have an osseous point attached in a variety of combinations (in the same way as with the spear throwing experiment). The short spear will then be clamped into a railed vice in the drop shaft (see Fig. 42). This will be raised and the impact hammer weighted to increase travelling velocity, and therefore impact stress on the short spear. The surface at the bottom of the drop shaft will be two different materials: ballistics gel and a block of 80 gsm paper. The choice of impact materials means there is a control: a hard impact can thus be observed (paper block), likewise a medium/soft material that can simulate a tough-skinned animal with dense muscle structure (mammoth or woolly rhino), and finally a soft impact material that can simulate an animal with thinner hide and muscle structure, such as a deer. Each drop will be recorded for later analysis and discussion; the recording table will be very similar to the example in table 3. These drop tests will push the spears and the elements that make them to breaking point. This will show whether the osseous points were over-engineered, or if they were carefully designed to improve longevity of certain elements (research question 2). The drop tests will also create damage patterns that can be compared to archaeological examples (see Chapter 3). This will start to give some impression of how some of the material in the archaeological record became fragmented, and whether distinct break patterns can be seen. The drop tests will also demonstrate the regularity and severity of spear maintenance required, certainly for the spear tips. Research question 1a could also be answered during these tests, as the presence of mastics will almost certainly make a difference to the results upon impact. The combined results from the experiments will provide evidence to begin answering research questions 3 and 5. The existing simulations and biomes from Chapter 2 will assist in demonstrating the challenges and implications of hunting and making effective hunting equipment during the Aurignacian in NW Europe.

Fig 42: Instron drop tower ISO 6603. (From Instron.co.uk)

Production of stone tools

Replica stone tools made for spear point production were created from flint extracted near Norwich (Norfolk). The choice of flint is mainly down to availability, as it originates from a quarry that has often been visited by the researcher to collect fresh nodules (and dispose of flint waste responsibly). The quality of the flint and nodule form plays a role in selection for blade core production. Glassier flint will generally produce a greater frequency of consistently sized blades that do not snap when detached or step fracture on the core. Flint that is poorer quality will generally prevent shock from a strike at the platform travelling through the core predictably. This typically results in blades of an inconsistent form and thickness; breakage on detachment is also common. A good nodule for easy blade production is relatively cone-shaped; these can occur naturally, or be produced with relatively simple flaking to prepare a flat platform.

The flintknapping tools used included several different hammerstones for preparing and maintaining the core, a rough abrasion stone for working on the platform edges, two antler tine punches and a heavy wooden mallet for detaching the blades by indirect percussion. A very basic outline of reduction and production of blades is as follows (see also Fig. 43):

1. Nodule is selected and first flakes detached with hammerstone to create platform.
2. Platform is checked and abraded where necessary.
3. First detachments are made from platform down the face of the core (heavily cortical removals.
4. Repeat step 2, and isolate platforms above scar edges (ridges).
5. Detach first non-cortical blades with antler punch and mallet.
6. Repeat step 4.
7. Repeat step 5 until core is depleted/requires rejuvenation or maintenance.
8. Retouch of blades to produce heavily-backed and strangulated blades.

	**Blade core platform preparation and large flake removal** The flint chosen comes from a surface source, as part of a gravel and sand system. It is probably similar to opportunistically-obtained flint by Aurignacian people, or to "drift flint" as noted by Dinnis (2015).
	**Blade detachment with antler punch and wooden mallet** The production of replica Aurignacian blades for previous experiments has either been omitted or mixed between hard and soft hammer removal (Knecht 1995; Nuzhnyi 1998; Tartar & White 2013).
	**Continued removal of blades until core is exhausted** To compare different tool types, it was necessary to produce more than might be typically required by an Aurignacian tool maker. It is highly likely they were far more conservative in the amount produced, and curated existing blades for longer timescales (Blades 2001).
	**Retouch of blades to produce replica diagnostic types of lithic tools** Care was taken not to produce a long scraping edge. Though scraping tools are useful in the working of osseous material, it is likely blades were used over several stages of use and re-

	sharpening (with steepening edges), until they were effectively scrapers.
	**Retouched blades (3, left) alongside unretouched blades (3, right)** One strangulated blade on the far left and two heavily backed (or well-used) blades on the inner left. The three blades on the right were fresh, and represent removals in the use stages before those on the left.

Fig. 43: Flint blade and tool production.

A quantity of fresh, un-retouched blades were produced from a couple of blade cores. Some were retouched to produce replicas of Aurignacian tools from a typical assemblage from NW Europe (such as strangulated and backed blades). As stated earlier, the aim of using replica stone tools based on those from Aurignacian assemblages was to determine their role in the *chaîne opératoire* of Aurignacian osseous spear points. By using unretouched blades, it may be possible to demonstrate their evolution (through use) from freshly-detached, clean-edged blades to well-used, steeply-retouched blades. Blades that could be considered 'well-used' are likely to be those that are steeply-retouched much like classic Aurignacian blades (Blades 2006). It seems a waste of a good working edge to destroy the razor-sharp, clean edge of a blade simply to create a specific blade type. It would be more efficient to use a fresh blade (not necessarily for tasks related to spear point production) until blunt, then retouch it to change its effective function from cutting/slicing to scraping. This would certainly make sense in a scenario where obtaining good quality material is challenging because it does not occur in the local environment.

Production of antler split base points

Reindeer antler was obtained from a trophy rack to produce some of the replica spear points. It was decided that it would be best to try breaking up some of the antler in a similar way to Tejero (2016) and Tartar and White (2013) on a couple of pieces. This would commence after the antler would be divided into lengths using a modern saw. This was purely to make effective use of the antler, which was in limited supply as it is hard to obtain in the UK. Cutting sections also made it easier to soak the pieces of the antler in a smaller trough. The first pieces of antler were soaked in cold water for approximately two months. This length of time would act as the extreme maximum. After soaking, the first piece to be worked on for the first antler point was a tine. Using flint blades, two ring cuts were made 5cm and 17cm from the modern saw cut (Fig. 44).

Fig. 44: First cuts made with flint tools after soaking.

Fig. 45: Antler "baguette" after cutting and breakage by percussion

It was noticed quite quickly that although the antler was much softer, the clean un-retouched blades did not effectively cut into the antler. A mildly retouched blade proved far more effective, as it offered a sawing function that cut through to the antler marrow in a matter of minutes. Once the ring cuts reached the marrow, the antler could be easily broken with a pebble or by manually-controlled flexion until breakage. Once the section of antler or “baguette” had been cut (Fig. 45), it needed to be split to create at least one blank. Initially this task seemed to be relatively straightforward. It was hypothesised that the antler would split cleanly along the weakest axis, through the marrow. However this was not the case. Achieving a clean and equal split through the baguette proved to be extremely challenging. Once the split had been started using a thick flake, the split tried to run out to the sides of the baguette. Several baguettes did not split cleanly, and only produced a flake from the main section (Fig. 46 & 47). The latter then had be split from the opposite end to produce a least one half. Some of the flakes were large enough to produce small spear points, but others were too small or thin.

Fig. 46: First incomplete split that produced a spall rather than a baguette half.

Fig. 47: Second incomplete split.

Fig. 48: First successful split (11.5cm in length), though still not perfect.

For the proximal end of the tine, there was an opportunity to attempt Tartar and White's (2013) flexion approach to creating a split and a tongued piece. However, creating the parallel splits via flexion was extremely difficult, as there was a constant risk of breaking the blank off at the ring cut. This would not be a devastating problem, only that the split would then have to be made via cleavage instead. An increase in leverage was required to try and force the parallel splits up the blank. This extra leverage caused enough strain on the first blank for it to snap from the potential tongued piece.

Fig. 49: Attempted tip blanks with attempted tongued pieces

Fig. 50: Attempted tongued pieces via flexion from Isturitz level A (From: Tejero 2016: 57)

Tejero (2016) noticed this as a problem faced by Aurignacian people at Isturitz (level A). Here there were points which displayed clear evidence of sawing before attempting to create an opening in the base of the point blank (resulting in a tongued piece). However, as with the attempts in this research, the maker found it difficult to run the split, leaving them with a very short tongued piece.

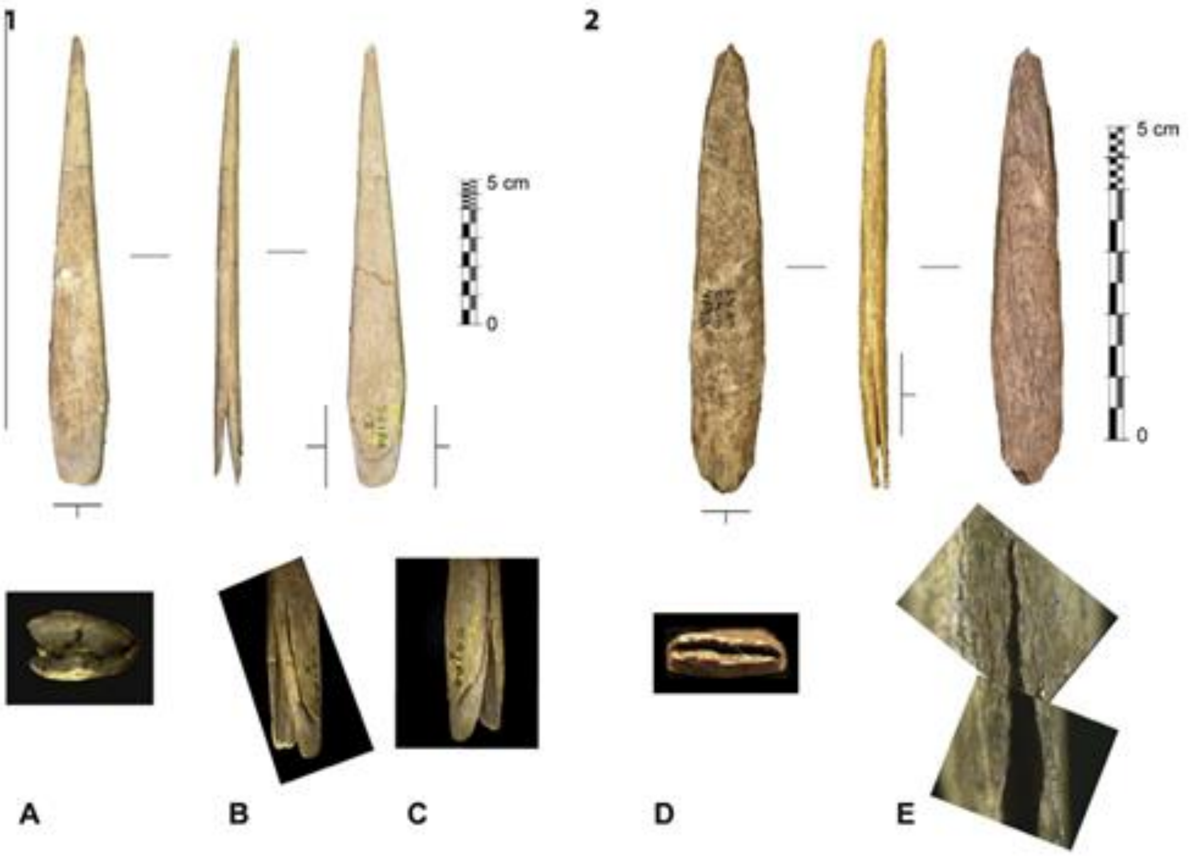

Fig. 51: Attempted splitting via cleavage at Abri du Poisson (From: Tejero 2016: 61)

Cleavage was the next option for creating the full split. This was created by placing a flint blade against the freshly broken base and gently striking it with a piece of wood. Surprisingly, the antler resisted splitting until higher levels of force were applied to the flint wedge. Tejero (2016) points out splitting problems in antler points from Abri du Poisson (Aurignacian level), where there is clear evidence of poorly placed/directed splits from the base.

Fig. 52: Splits have been lengthened and pulled appart to facilitate spear shaft hafting.

Once a split had been started and enlarged to around 10mm in depth, it was possible to start opening the split further using a combination of pulling apart the sides and using a thin piece of antler or wood to lever them apart. When attempting the same approach on a blank that had not been freshly soaked, it was noticeably much harder to run the split. The same can be said when scraping and shaping the blank following the split (to be discussed later). It is therefore essential for the blanks to be soaked before shaping if the base is to be split. If a simple-based point is to be produced, soaking the blank results in an easier task, as the antler is softer. However, it is not essential to achieve the objective. While running the split, it was noticeable that the direction of the split would easily run to the edge, causing a wing to eventually break off. Careful control was required to hold the blank while running the split. Sharpening the tip to a rough point, before forcing it into a relatively soft log acting as a basic vice, allowed both hands to run the split unhindered.

Fig. 53: Flint used for splitting showing clear damage, especially on its medial margin.

The flint blade suffered noticeable crushing damage from the wooden mallet. Such bifacial damage to the blade is quite different in appearance to the heavy retouch of Aurignacian steeply-flaked blades, which is unifacial and clearly determined (Fig. 53). The damage to the blade wedge showed bifacial flaking (or at least detachments) with step fracturing and edge crushing. Such obvious macro use-wear can be strongly linked to sharp, direct percussion directly onto a blade edge, using the blade as a tool (for splitting) rather than attempting to retouch the blade.

With the split complete, the tip of the blank could be shaped. This was conducted using a combination of fresh, sharp blades and blunt, retouched examples. The most effective method of using the sharp blades was to drag and scrape the surface of the blank when the blade was perpendicular to the blank surface. This prevented the blade digging into the antler, but allowed thin layers of antler to be removed with limited effort required. Essentially, the same approach was most effective with the retouched blades. However, it was quite clear that the fresh blade was more effective at the task. Generally, the whole process of scraping a blank to the correct shape took around one hour with the sharp blade, while using the retouched blade required nearly two hours: quite a noticeable difference in completion time, but this does not show that the retouched blades are ineffective. Replacement blades were not required during the shaping process of one blank for either fresh blades or the retouched ones. After shaping a second and third blank using the original fresh blade, it became noticeable that the edge was starting to blunt. The edge blunted far quicker when used on an un-soaked antler blank. The retouched blade edge lasted for a slightly longer period of working time against the fresh blade, but also became less effective during work on the third blank. This suggests that a single fresh blade could be used to shape a large number of antler points before the edge became too steep to be effective. The thickness of the replica blades meant they could be used in a similar action to a spoke shave. The prominent ridge on the back of the blades could also be used effective to scrape the blanks. If the angle of the ridge was very acute, it provided a very useful scraping edge. If the angle was too obtuse, it did not have enough bite to be effective.

Fig. 54: Completed replica split-based point, showing both faces and side profile.

A breakdown of the production sequence of a split base point:

1. Detach “baguette” from antler (either by cutting rings or breaking);
2. Split baguette into two halves which are the blanks;
3. Begin split using blade;
4. Run split using leverage of blade or hands;
5. Scrape tip of blank using blade.

Blade stage and usage can be broken down into the following stages (see also Fig. 55). There are several stages that are worth expanding upon. A “fresh blade” is one that has been freshly removed from the core and holds a razor-sharp (but fragile) edge. It would not be suitable for sawing or cleavage as discussed. A “sharp blade” is one that will still cut easily, but no longer has its original razor-sharp edge. A “blunt blade” is one that could cut, but with significant effort. It is also worth noting that blades could be (and were) discarded at all stages during the Aurignacian. However, in theory a blade would be discarded after being used for cleavage, which is most damaging to the blade edge. The stages below are also not an exact sequence, as blades can either last longer than expected or break prematurely. In areas that can yield more raw material, this sequence could be shorter, and *vice versa* in areas with limited raw material (i.e. more re-use of material).

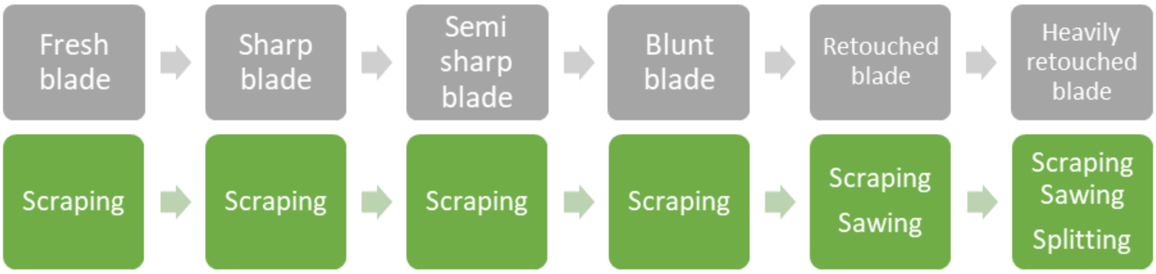

Fig. 55: Flow chart of stone tool condition alongside activity.

When the spear point was completed, it was left to dry out (Fig. 54 and 56). While waterlogged, the wings of the split were very flexible and required little effort to encourage the split to run further. This generated concern that when hafted and thrown (or dropped in the impact tower), the haft would act as a wedge and cause the spear point to split apart. However, after 24 hours the finished spear point had noticeably started to dry out. The wings of the split were much firmer, and required great force to even start encouraging the split to run. After 24 hours, the spear point hardened up sufficiently that it should not split apart easily, although this will be tested in later experiments. This firmness led on to thoughts of hafting the spear points. The main action of hafting these points would be to insert a bevelled length of wood into the split. If the wings of the split were firm, it would result in greater force required to insert the bevelled haft. This greater force could result in damage to the spear point; the lack of flexion in the wings would potentially result in them breaking off or causing the split to run. On the other hand, the firmness of the wings will likely result in a good bind to the wooden haft, as they would pinch the bevelled tip. Re-soaking the split end of the spear point before hafting would likely make it easier to insert the bevelled haft. However, this would probably sacrifice the aforementioned pinching effect of the firmer split wings.

Fig. 56: Replica split base point ready for hafting.

Production of replica spear shafts

Where possible, wood samples and wood staves from Scotland were used to make the spear shafts (see Chapter 6). However, due to time restraints in searching for suitable wood lengths, some spear shafts were made from trees growing further south in England (with kind permission from Berrycroft Farm, Wiltshire). Trees were chosen that matched those species identified in MIS 3 organic samples, such as *Betula pendula* (Silver Birch), *Pinus sylvestris* (Scots Pine) and *Larix decidua* (European Larch). With a suitable specimen identified, it was cut with a folding saw at an angle, close to the ground. This would encourage future growth and stop tree stand/stump rotting in line with common coppicing practice (TCV Practical Conservation Handbooks, 2017). Despite a key part of this thesis focussing on spear shafts, their procurement and maintenance, none survive from the Aurignacian (as discussed). This means that unlike the SBPs, which offer some insight into production (though that has been debated), there is next to no evidence of how they were produced, other than the inferred evidence that the proximal end fitted to the SBPs. A production method therefore is based on the researcher's own experience. Once cut with a saw, the wood staves were trimmed using some of the replica stone tools. The heavily retouched blades were effective at sawing through the wood enough to weaken it before snapping. Once the sawn ends were truncated, they were trimmed and shaved using unretouched blades. As the wood staves were still green (not seasoned), the stone tools cut easily and the process of truncating then trimming took approximately an hour per stave. The next stage was to trim off any small branches and shave off the remaining bark or excess surface material. Based on the researcher's experience of making replica spears, the rough diameter for the staves was 2-3cm in width (variable down the length of the same stave). Some of the staves were already at or close to this thickness, so only required bark removal. Others required more surface material removal which required a greater investment of preparation time. The step ranged from approximately 20 – 50 minutes. At this stage, the replica stone tools showed little evidence of wear and retained a sharp, usable edge. The final stage was to shape the proximal end of the stave to create a bevelled tip to accommodate the SBP. Like the previous step, unretouched stone tools were used to trim the stave. Following this, the faces of the bevel were abraded with a flat piece of sandstone. This additional action was considered and deemed necessary to refine the bevel to allow a better fit to the split base of each point. It was found that a bevel purely scraped and cut with sharp lithics did not achieve the same 'bind' from the clothes peg nature of the SBP. This final step that transformed the wood stave into a true, usable spear shaft took approximately 45 – 60 minutes. Even after this step, the sharp lithics used showed little evidence of wear or blunting, suggesting they could be used in the production of a large number of spear shafts. Six full size replica shafts were made for the spear throwing experiments, while a further six shortened spear shafts were produced for the drop tower experiments (though only 5 were needed).

Table 4: Replica spear shaft length and weight

Spear shaft	Length (centimetres)	Weight (grams)
Silver birch A	201cm	714g
Larch A	198cm	668g
Scots Pine A	199cm	640g
Silver birch B	200cm	723g
Larch B	204cm	781g
Scots Pine B	202cm	775g
Short spear A	30cm	89g
Short spear B	37cm	100g
Short spear C	31cm	91g
Short spear D	36cm	97g
Short spear E	33cm	95g
Short spear F	31cm	92g

Chapter 5: Spear testing

Spear throwing experiment

A component of this experimental research was to put replica Aurignacian spears through different stages of use. It has already been discussed that testing the spears under true conditions (hunting live animals) would be unethical and difficult to measure for reliable data. Therefore the process of hunting with spears had to be broken down into manageable analytical stages. The first of those stages was production of the spears using the same materials and tools used by Aurignacian people. The second stage was to record the flight and impact of the full-size replica spears when thrown by experienced javelin throwers in a sports field. Two types of throw would be encouraged: a 'normal' throw and a flat throw. The normal throw could be considered similar to the type of throw performed by a javelin thrower that focussed on distance rather than on a target. It was decided that including this style of throw would encourage a more familiar action from the throwers, and put the replica spears under increased stress upon impact. This increased stress is down to flight arc angles. A higher arc would increase the chance of a spear point embedding itself into the ground rather than deflecting or sliding. The second type of throw was a little different to one performed normally, but would be closer to a throw made by a hunter at a target. This type of throw would have a greater chance of the spear deflecting or sliding, as the flight arc is lower. A comparison between the two throw types would provide interesting observations as to how Aurignacian spears would fare if their user missed the target. To put replica spears through a scenario where they were neither thrown for distance scoring or at an upright target could be likened to a situation in which a hunter has missed the target. This is the most likely time a spear will be damaged, as huge amounts of loaded movement energy is brought to a sudden stop. This will of course cause a huge amount of stress to pass through the spear head and shaft. It is at this point that the weakest element of the spear will break. Consistent breakage of one element will demonstrate it is the weakest component. This may be an intentional overdesign to reduce the chance of other elements breaking by keeping them "under-stressed" like modern fuses in a circuit (Bleed 1986). If too much electrical current passes through a circuit, the fuse will break. This break will prevent the circuit and parts from becoming damaged. This allows for easy replacement of one part in the event of excessive current.

The location for the throwing experiment was Marlborough College sports field. This was an ideal location, as it was private land and surrounded on one side by a high bank which significantly reduced the chance of someone walking onto the space unexpectedly. Normally the field would be white marked for javelin and hammer throwing, but as this had not yet been done, the throws would be measured with a measuring tape. The three throwers who took part in the experiment were all experienced, with one competing at national level. They were advised to go through their normal routine of warming up before the experiment to avoid injury. It is worth noting that the weather on the day of the experiment was cold, cloudy with a strong wind. It was commented that such conditions could have an impact on the spear flight. The sports ground floor was a flat grassy surface with sand rich soil. Any ground impact would therefore would be into a relatively soft surface. The replica spears' weights ranged between 700 grams and 800 grams with no additional weighting, while the sports javelins normally used by the throwers ranged between 600 and 800 grams. Three replica spear combinations were to be used for the experiment. An unglued spear tip with no binding was pushed onto the bevelled tip of a wooden shaft. Only the pinch of the basal split would hold it in place. The second type was glued using birch tar with no binding. The third was bound using lime bast fibres with no glue.

Table 5: Spear throwing results

Spear throwing recording sheet Date: 14/04/2019 Location: Marlborough College sport ground Weather conditions: Overcast, cold and windy					
Javelin throw	Distance of throw (metres)	Approx. Velocity (km/hr)	Footage number	Observations of spear throw during flight	Observations of spear after throw
1	22.5 m	29.5	001	Front lift causing slight tumble (high arc). Tip detached (no glue or binding)	No damage
2	19 m	42.2	002	Clean arc, spear landed, tip detached (glued)	Wing damage (detached)
3	13.5 m	29.8	003	Relatively clean arc, tip detached and truncated (bound)	Truncated tip and haft tip damage
4	20 m	30.6	004	Tip detached in flight due to flex (glued)	No Damage
5	38.5 m	43.4	005	Flat trajectory, light impact into ground (bound)	Tip detached but no damage
6	16 m	23.7	006	Front lift, tip detached on impact (no binding or glue)	No damage
7	13.5m	35.4	007	Clean arc, ground impact, (no glue or binding)	No damage to shaft. Split tip from base
8	13m	31.6	008	Low arc, tip detached, (bound)	No damage
9	18m	49	009	Low arc, tip remained attached (glued)	No damage
10	13.5m	36.5	010	Low arc, tip detached (no glue or binding)	No damage
11	15m	XX	XX	Clean arc, shallow impact (glued)	Wing damage (detached)
12	12m	XX	XX	Low arc, slight tumble of spear (bound tip)	No damage

The first throw used the spear tip with no glue or binding. Though the launch seemed successful (Fig. 57), the tip of the spear soon began lifting, to the point where the spear began to tumble and lose its direction in the air, resulting in the spear landing perpendicular to the direction of throw. This could be counted as a failed throw in a hunting scenario, as it would have failed to cause damage. The thrower commented that the wind could have caused the spear to lift in such a way, or that the balance could be off. Upon impact, the tip detached, though no damage was visible to either the tip or the spear shaft. The same tip was reattached to the first spear shaft for reuse.

Fig. 57: Throw 1: Silver Birch shaft A

Throw 2: Larch shaft A

The second throw used the spear with birch tar glue. The launch was good, and resulted in a clean, high arc that allowed the tip to impact the ground at a distance of 19m. Upon inspection, the tip had detached from the shaft (Fig. 58), but had also been damaged (one of the wings had split off). The tip was deeply buried in the ground (to around 15cm), while the shaft had only slightly embedded itself in the ground. The full impact appears to have occurred as follows: Flight > impact with ground > tip buries into the ground > as spear shaft decelerates, stress through tip increases > wing splits off > shaft continues into the ground with greatly reduced energy. The tip would no longer be useful as a split base point, though it could be repurposed as a simple-based point in a notched shaft.

Fig. 58: Throw 2, Larch shaft

Throw 3: Scots Pine shaft A

Throw three used the spear tip which was bound in place. The throw was good and also resulted in a clean arc. The spear tip impacted with the ground, causing the tip of the spear head to truncate (Fig. 59). Unfortunately, the tip of the spear head was lost, as it had buried into the ground and could not be located. The spear tip had detached from the spear shaft, with a small amount of wood between the wings. This was the only spear shaft damage observed during the experiment, though it was very minor and would not prevent the shaft from being used again. The break at the spear tip suggested that too much stress passed through the tip, before reaching the shaft and lower end of the spear tip.

Fig. 59: Throw 3, Scots Pine shaft

Throw 4: Silver Birch shaft B

The fourth throw used the glued spear tip. The throw was clean (Fig. 60), though it was clear that the tip detached during flight. This could also be counted as a failed throw in a hunting scenario. The thrower commented that the flex of the spear in flight seemed to cause the tip to fall out of position. No damage was suffered by either the tip or spear shaft.

Fig. 60: Throw 4: Silver Birch shaft B

Throw 5: Larch Shaft B

The fifth throw used the bound spear (with a fresh tip), but this time with a flat trajectory, unlike the previous four throws, which would be considered a normal sports javelin throw (Fig. 61). This throw achieved an impressive distance of 38.5m, and was probably the best throw on the day. The tip detached from the shaft upon impact with the ground, though no damage was observed. The lower arc of flight prevented the spear tip from embedding into the ground.

Fig.61: Throw 5: Larch Shaft B

Throw 6: Scots Pine shaft B

The sixth throw used the spear with no glue or binding. The throw had a clean launch, but the tip lifted, causing the whole spear to drop as it lost velocity. It could be argued this would be a failed throw in a hunting scenario. It is also likely that the wind played a part in causing the spear to lift in an undesirable fashion. Upon landing, the tip detached from the shaft, but no damage was observed.

Throw 7: Silver Birch shaft A

Throw seven used the spear with no glue or binding again. The throw was relatively short (only 13.5m), but flew in a clean arc and impact with the tip downwards. The tip of the spear buried into the ground and detached from the shaft. The shaft was undamaged, though the tip suffered significant damage: one of the wings split off (Fig. 62). Upon observation, the damage was very similar to that seen after throw two, which used the glued spear tip. Like the second throw, a certain level of force seems to be reached when the tip impacts cleanly with the ground, causing a part of the tip to fail.

Fig. 62: Throw 7, silver birch shaft.

Throw 8: Larch Shaft A

Throw 8 used the bound spear. It is worth noting that commentary in the footage stated, "throw 7"; this was an error. This throw employed a flat throw style, which travelled 13m. The thrower had practised with a number of sports (modern) javelins before the actual throw with the replica spear. This was to help the thrower adjust to throwing at a lower angle and to assist in positioning the camera. The throw itself had a clean launch, though the distal end of the spear shaft appeared to make contact with one of the grounded sport javelins as it was launched in the footage. The tip detached from the shaft but no damage was observed.

Throw 9: Scots pine shaft A

The ninth throw used the glued spear. Like the previous throw, the ninth throw was of the flat style. The launch and flight arc were clean (Fig. 63), causing the tip to impact with the ground. Surprisingly, the tip remained attached to the shaft and no damage was observed.

Fig. 63: Throw 9: Scots pine shaft A

Throw 10: Silver Birch shaft B

The tenth throw used the spear with no glue or binding. The throw was performed by the researcher after some training and a warm up. The style of throw was a flat trajectory. The flight arc was clean, and the tip impacted into the ground. No damage was observed.

Throw 11: Larch shaft B

Throw 11 was also performed by the researcher using the glued spear. The throw style was 'normal', though the flight arc could be considered relatively low (a flat throw). As such, the spear tip made contact with the ground at a low angle and buried itself (Fig. 64). Upon observation, the tip was damaged at the base where a wing had split off, much like throws 2 and 7. The shaft remained undamaged. Sadly, the footage for throws 11 and 12 was not available, as the camera operator had not pressed the record button properly.

Fig. 64: Throw 11, larch shaft

Throw 12: Scots pine shaft B

The final throw of the day was performed by the researcher using the bound spear. The flight was not clean, and the spear tumbled in the air, causing a failed throw. It was commented that the failed throw was probably caused by the wind conditions and lack of experience. No damage was observed.

Discussion

Out of the twelve throws, four spear points (of twelve) were damaged. Only one throw caused any damage to a spear shaft (Scots pine, throw 3), which can be regarded as almost superficial. Based on this evidence, it appears likely that in the scenario of a spear missing the target, the spearhead will suffer the greatest damage. Spearhead detachment was a relatively common occurrence (10 out 12 throws), with 4 out of those 10 detachments also showing damage to the spearhead. This is not to suggest that when a spearhead detaches it has an increased chance of damage. It is likely that weather conditions played a part in some of the throw trajectories, though it was also commented by one of the throwers that the unusual weight balance (which was consistent with all the replicas) could also cause unexpected flight patterns. Out of the spear shafts used, the Scots pine shaft was preferred. This may have been due to the shaft being slightly smoother and less knotted, but offered the chance to compare between a timber considered favourable for spear shafts and another (in this case silver birch) that would not normally be considered. The highly elastic silver birch shafts were chosen from woodland in southern England which was dominated by the species. Many of the trees grew straight, so were unlike those seen in northern Scotland. To find an area of straight-growing examples could therefore be considered a best-case scenario during MIS 3. As observed by one of the throwers, the twisting and winding of the spear shaft during flight could loosen the spear head. This came to fruition during throw 4, with a glued spear tip. These problems were not discussed in previous literature, though this is almost certainly down to the relatively short throwing range and target. In the cases of Knecht (1991), Nuzhnyi (1998), Guthrie (1983) and Rees (2003), the launch point to target distance was relatively short or not specified. In the case of the latter three authors, they used bows, calibrated crossbows or homebuilt launching systems to drive short versions of the spears into either animal carcasses or putty. This type of experiment would not have the potential to cause the types of potential problems seen during the experiment here. It therefore shows the importance of simulating flight patterns with known or suspected prehistoric projectiles to better understand the many facets of their use and maintenance.

From this experiment, it is conclusive that the spear head is the weakest hard component. It has already been demonstrated by previous researchers that bone- and antler-tipped projectiles have the potential to cause mortal wounds (including the work of Wood and Fitzhugh 2018). The spear tips that were damaged during the experiment could be re-worked to an acceptable working state. The damage experienced fell into two types: truncation and splitting. Out of the four damaged spear tips, three experienced splitting. The splitting damage resulted in loss of one wing that either split cleanly or showed a more angled shoulder break. The latter was almost certainly caused by excessive force on one wing side, rather than driving wedge-like stress through the spear tip. A similar type of break can be seen in Fig. 38 (spear tips from Hohle Fels IV). The image of a split-based point tip labelled "1" shows a harder shoulder wing break, like that seen after throw 2. The other split wing damage could be compared to damage seen on points from La Ferrassie (Figs. 22b and 23).

On evaluation of the experiment, there were a few aspects that could have been developed or improved upon. The first was the weather. In true British style, the weather played a part in carefully prepared plans to a detrimental extent. For a couple of the throws, it would be reasonable to suggest that the flight path was hindered by strong wind. This problem, however, would have been faced by prehistoric hunters. It is a near-certainty that they would have had to draw upon years of localised landscape experience to minimise the effect of weather conditions. This would have included stalking to launch spears, as wind direction could give away hunter presence through scent. Thus there may have been a preference to throwing into the wind despite the increased air resistance and distraction to the hunter.

Drop tower experiments

The drop tower used in this series of experiments is an Instron Drop Tower 9400 series (Fig. 42). They are designed and used for the testing of products under stresses and strains. This means they can be used to create controlled levels of energy and measure the forces applied to objects inside the drop tower. This equipment is fairly versatile, as it can be used to measure products being impacted, products on the tip of the "hammer", or both. For these experiments, the "hammer" had an aluminium socket which held a shortened spear shaft (made from one of the wood samples discussed in Chapter 6). A replica split-based point was attached to the bevelled tip of the spear shaft. At the bottom of the drop tower was a height-adjustable metal plate, which would support ballistics gelatine blocks.

It was quickly identified that there were several problems with the equipment for this experiment. It has been previously discussed that fully 'real world' testing scenarios are impossible to recreate, or are unethical. Therefore, experiments that focus on certain stages of tool use are the best substitute. One of the major areas of investigation of this thesis is the role of the spear shaft in Aurignacian hunting strategies. In the drop tower, it was only possible to use a shortened section of a spear shaft. This clearly meant it would not be possible to see what happened to a full-sized spear in this experiment. The drop tower was not designed to have such a long extension added to the hammer in any case, which caused further problems. The drop tower itself sat above an enclosed box, which contained the impact securely. The drop tower shaft and impact box were separated by a trap door, which opened seconds before the tip of the hammer or hammer attachment reached it. Typically, the drop tower can accommodate for an extension by simply adding the length of the attachment into the test parameters. This informs the drop tower computer that is should open sooner as the hammer is now longer. However, it was found during slow pre-tests that the trap door would not open. This problem was attributed to the unusual length of the hammer extension. A solution to this problem was to remove the impact box, to which the trap door formed part of the roof. The drop tower now was open to the floor below. This did not create a problem with regard to the experiment, but did create problems of a safety nature as the impact space was now open. This was rectified by covering the front of the space with a thick sheet of clear Perspex.

Another problem was identified in the form of the drop shaft height and ability to propel the hammer. During the development of this thesis, it was discussed with the team that manage the engineering space in which the drop tower is housed that it could propel the hammer at a very high speed if required. This was managed with the help of high pressure air guns at the top of the tower. However, at the point the experiments were set to take place, these air guns were not working. This left two options; the first was to delay the experiment and hope the air guns could be repaired or replaced, the second was to persist with the experiment and find alternative means to generate enough speed. The problem with the first option was the potential waiting time for a repair was likely to be very long. Another problem was that a large amount of ballistics gelatine had already been made, it would not keep for longer than a week as it is animal product derived. The problem with the second option is that the short spears would not travel at the required speed, so an alternative approach was required. A solution was to increase the weight above the hammer. This could be achieved by adding 5kg weights. Within the short space of the 2m drop tower it could therefore be possible to generate the required energy to match that generated by someone throwing a spear at between 25-30 metres/second, as seen in the spear throwing experiments.

To try and determine the required weight, it was necessary to try to match the result of a sum by increasing mass instead of velocity. The equation used was $\frac{1}{2}mv^2$ which gave 315 Joules. Using the drop tower's software, it suggested using 30kg worth of weights to reach that level of energy. It was suggested by the laboratory technician that this increase of weight would improve the chances of recording energy change over time as the spear struck the ballistics block. This was thwarted by the realisation that the markers which start recording the change in energy did not cross before the tip of the spear hit the gelatine (so it would not record anything). It was decided that this was not a serious issue for the experiment, as the variability of the spear tips and shafts would effect a change in energy anyway, and therefore might not generate any useful data. It was pointed out that the drop tower and software was designed to test machine-produced products that tend not to have as many variables.

It was hypothesised that the spear tips would be effective at creating deep wound channels, and not suffer notable damage until they started impacting with tougher materials than ballistics gelatine. Based on previous experimental work, it is clear that osseous points can create mortal wounds to large prey (based on Wood and Fitzhugh's (2018) criterion that wounds penetrating deeper than 20cm can be considered mortally wounding). Based on the results from the spear throwing tests at the sports fields, it was decided that the first series of drop shaft tests would not include any binding or adhesive. Neither proved effective during the spear throwing tests, and Knecht (1991, 1995) has previously argued that no particular adhesive has ever been found on Aurignacian osseous points. If it was clear that a lack of binding or adhesive was having a detrimental effect during the drop tower tests, it would be added for the later series of tests. If the shortened spears performed well without either, it would open the argument to suggestions that split-based points were most effective in corral scenarios, when fresh tips could be quickly attached to dispatch trapped prey quickly. This would imply more than one or two hunters would have been needed to execute a successful corral (Burch 1972).

Once a hard material was added (in the form of sheets of paper under a shorter block of gelatine), it was likely that more noticeable damage to the spears would occur. The sudden deceleration and twisting/bending strain on the spears would likely cause damage similar to what may have occurred when a spear point made contact with thick bone. The final series would to drop the spears directly on a block of paper. This would simulate the type of impact seen on bone close to the skin (skull or joints), or a missed shot. It was this final series that would have the highest chance of causing damage to the spears. The question was which part of the spear would break most frequently, if at all. This thesis set out to explore whether the split-based points were over-engineered (question 2); this part of the experiments would demonstrate whether they had been made to preserve the spear shafts. If so, the spear tips should break instead of the spear shafts.

Table 6: Drop tower results.

Series	Spear Shaft	Spear tip	Impact medium	Penetration depth (cm)	Observations
1	A	A	Gelatine	18	Spear tip break
1	A	B	Gelatine	19	No damage
1	A	C	Gelatine	23	No damage
1	A	D	Gelatine	17	No damage
1	A	E	Gelatine	18	No damage
1	A	F	Gelatine	20	No damage
2	B	A (Modified)	Gelatine	16	No damage
2	B	B	Gelatine	18	No damage
2	B	C	Gelatine	25	No damage
2	B	D	Gelatine	16	No damage
2	B	E	Gelatine	21	No damage
2	B	F	Gelatine	22	No damage

3	C	A (Modified)	Gelatine	15	No damage
3	C	B	Gelatine	17	No damage
3	C	C	Gelatine	21	No damage
3	C	D	Gelatine	14	No damage
3	C	E	Gelatine	19	No damage
3	C	F	Gelatine	22	No damage
4	D	A (Modified)	Gelatine/paper	20	No damage
4	D	B	Gelatine/paper	21	Tip damage
4	D	C	Gelatine/paper	21	Wing break
4	D	D	Gelatine/paper	13	No damage
4	D	E	Gelatine/paper	21	No damage
4	D	F	Gelatine/paper	20	No damage
5	E	A (Modified)	Paper	1	No damage
5	E	B (Modified)	Paper	1	Tip split
5	E	C (Modified)	Paper	2	No damage
5	E	D	Paper	1	No damage
5	E	E	Paper	2	Wing split
5	E	F	Paper	1	Tip damage

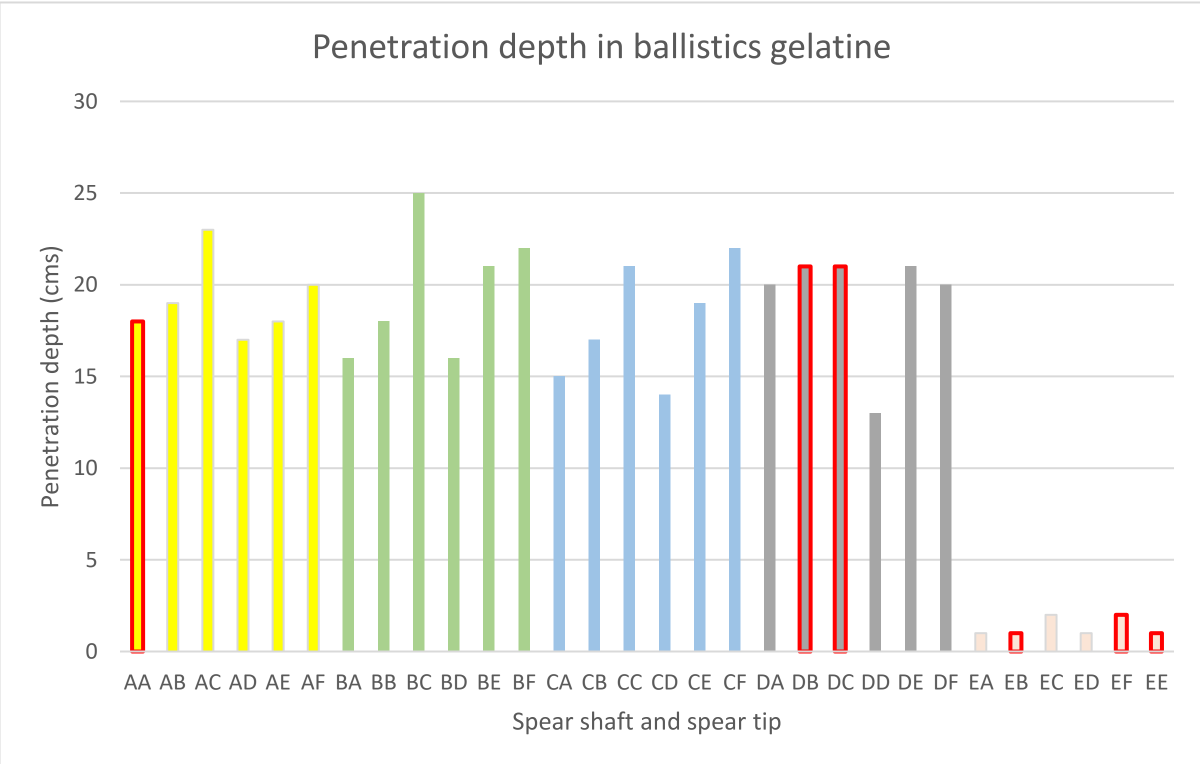

Fig. 65: Penetration depths into ballistics gel. Each series is represented by a different colour (series 1: yellow, series 2: green, series 3: blue, series 4: grey, series 5: orange). Tip damage shown with red outline.

The first series of drop tests used shaft A (see Table 6 for each drop series), which was selected from wood collection sample 2 (silver birch, see Chapter 6). It would be dropped into ballistics gelatine at

315 Joules of energy. This series simulated impact with purely soft tissue. The first drop punched through the gelatine to a depth of 18cm. A wound channel so close to the fatality threshold of 20cm would almost certainly have a severe effect on the prey animal. The proximal part did split on this first test to a state that left it unusable without modification by trimming off the base and creating a fresh split (Fig. 66). Notably, when the drop tower came down to pull up the hammer (and spear), the shaft came free easily while the tip remained buried in the gelatine. The following drops for the rest of the series resulted in no breaks to either the spear tip or shaft with varying wound depths of 17cm – 23cm. The damaged spear tip was modified by removing the broken wing, cutting off the attached wing, and creating a new split. The result was a small split-based point, much like those from La Ferrassie. This supports the argument that smaller SBPs were shortened examples that had seen several stages of reduction and use.

Fig. 66: Damaged spear tip A from drop series 1.

The second series of drop tests used a shaft from sample site 3; the shaft was made from Scots Pine. It would be dropped into ballistics gelatine with the same amount of force as the first series (315J). No significant difference was noticed throughout series 2 to series 1. A similar penetration depth was achieved (16-25cm), and several of the points remained embedded, while a few came out as the spear shaft was withdrawn. In series 2, out of the six drops there was no visible damage to either the spear tips or the shafts.

The third series of drop tests used a shaft from sample site 4, which was made from silver birch. This series of drops proved very much like series 2. There was a similar variation of penetration depths (15-21cm), and no damage to either the tips or shafts.

For the fourth series of experiments (shaft of silver birch from site 5), it was decided that as well as gelatine, a 10 cm thick bed of 80 gsm paper would be added. This would offer a more resistant surface that would simulate contact with bone, hard cartilage or where a tip had passed through a prey and into a hard surface behind the prey. This series was expected to highlight spear damage quickly. The penetration depths were slightly more consistent with one outlier at only 13cm, while the rest reached 20-21cm and made contact with the paper. The second and third drops caused visible damage, but only to the tips (Figs. 67 & 69). Drop two caused tip damage similar to Tejero's (2016) bevelled tip damage. The tip could be reused immediately, or sharpened with little effort near to its original shape (though shorter). Luc Doyon and Heidi Knecht's (2014) morphometric analysis of points indicates that several stages of shortening are expected, before the tip becomes as long as it was originally wide. Drop three resulted in a tip wing break after contact with the layers of paper. The break partially split towards the proximal end (closer to the joint between spear tip and shaft), beyond the point the split ended. This meant that modification that conducted on tip A from series 1 would be possible, but with less tip width to work with. This could result in a much weaker spear tip that was liable to break again.

Fig. 67: Damaged tip B from series 4.

Fig. 68: Damaged tip C from series 4.

The final series (5) was an attempt to determine which component of the spear would break if it made contact with a hard target. Rather than ballistics gelatine, the tip would make contact with the bed of paper. This would offer firm resistance, but it was not as resistant as metal or stone. This final series of drops produced the highest number of damages, but only to the tips B, E and F (Fig. 69-72). No damage to the shortened spear shafts was observed. Tip B had been previously modified slightly to re-sharpen the bevelled break. In the final drop series, tip B suffered a serious basal split that had clearly been caused by the point embedding into the paper and the wooden shaft acting like a wedge. Like the two previous points that suffered basal splits, it would be possible to re-work the point back to a usable SBP state with significant loss of length. Tip E suffered damage at the distal end (Fig. 71), similar to the bevelled break in the previous test series (tip B), though the broken section remained partially attached (Figs. 69 & 70). The break face was also slightly longer, so could potentially provide a sharp tip immediately if required, or if limited re-tooling time constrained the user (in a hunting scenario). Tip F also suffered a basal split (Fig. 72), which could be managed by wing removal and addition of a fresh split.

Fig. 69: Damaged tip B from series 5.

Fig. 70: Damaged tip B from series 5.

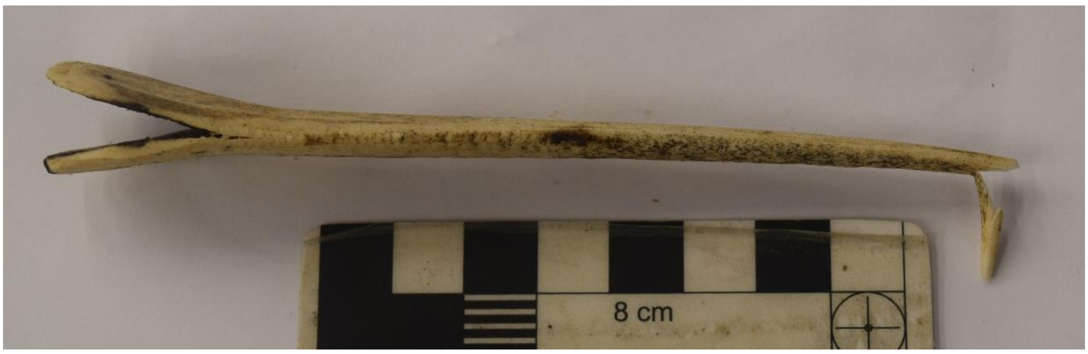

Fig. 71: Damaged tip E from series 5.

Fig. 72: Damaged tip F from series 5.

Consistently deep wound channels for these series in the drop tower experiment confirm split-based points were capable of dealing mortal wounds to large prey. As mentioned several times previously, an obvious limitation is in the replication of a very variable and fluid action. The ballistics gelatine shows split-based points can cause severe wounds that are often to a mortal level. A surprise came in the form of the effect the basal wings have in creating a wound channel. As well as facilitating the hypothetical hafting method favoured by Tartar & White (2013), among other researchers, the wings actually acted like a splint to keep the wound channel open once the shaft had been withdrawn (Figs. 73 & 74). This would clearly increase the rate of bleeding and eventual incapacitation of the prey. This observation has not been made previously in experimental research, though this would only be clear while using ballistics gelatine.

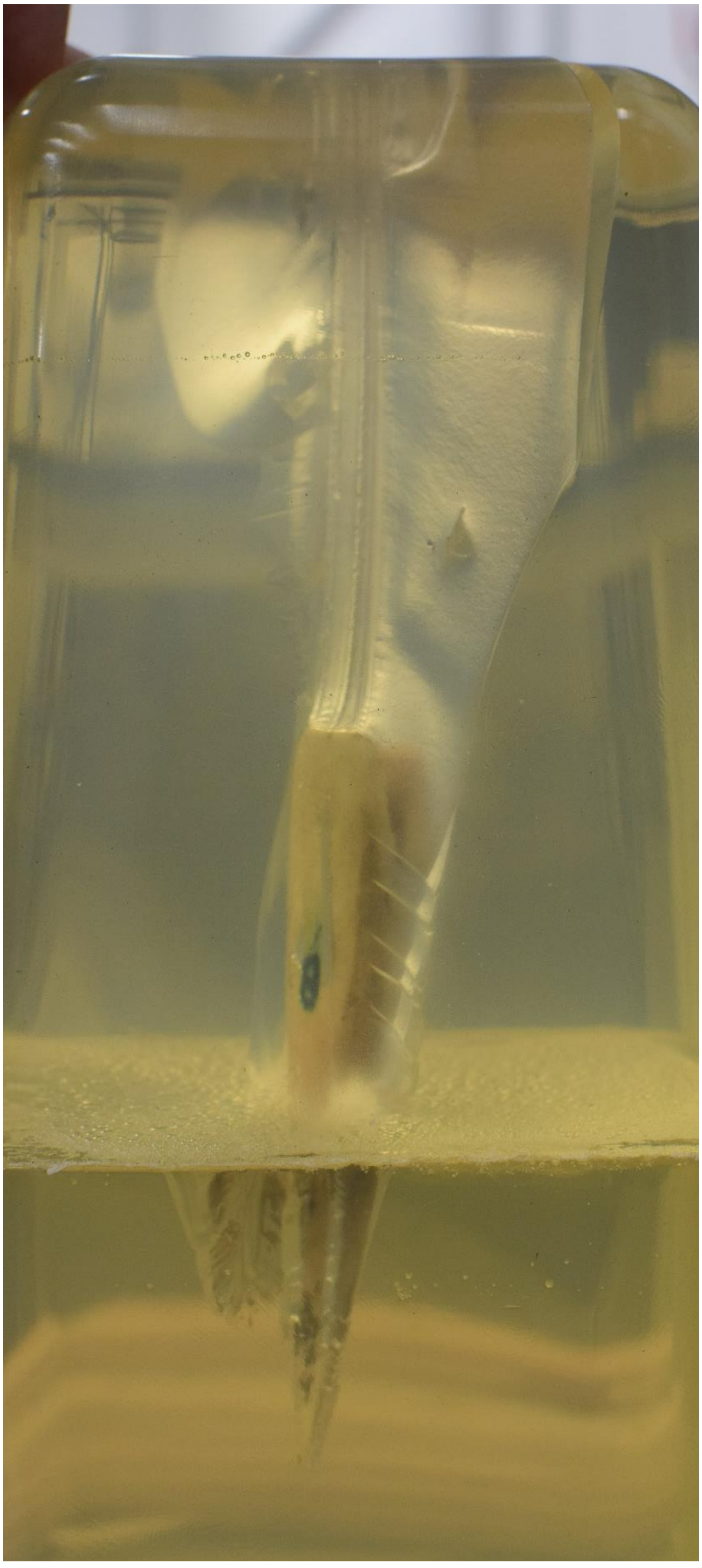

Fig. 73: Tip B (series 2) has created a large wound channel. It is clear that the proximal end of the spear tip kept the wound channel open behind it.

Fig. 74: Tip C series 3: before the shaft was withdrawn by the hammer, it was noticeable that although the shaft kept the wood open (though plugged), the wings of the SBP actually opened the wound wider than the shaft to a width of approximately 45mm.

Discussion

Hunting can be affected by a wide variety of factors that make the job of a hunter a difficult one, as it has been in the past and in the modern day with very different equipment. To replicate part of that action in a very controlled environment using equipment that is different to the propulsion used by prehistoric hunters does not give an exact view of equipment in action, but does show a stage or aspect. In the case of the drop tower, that stage is the point of impact and the result of that impact. A drop tower experiment does not take into account (or simulate) the additional stresses and strains caused by a projectile striking a target at an angle other than nearly 90° (partly due to safety reasons). It also cannot simulate stresses on a projectile once it has struck the target. For example, it is very likely that a spear could be damaged by the prey (via trampling). or by brushing against a hard surface as the prey flees (Bokelmann 1991). We can only speculate how these stresses could have affected the experiment, and refer these potential issues to the durability and reliability of the hunting equipment (Bleed 1986; Hutchings 2016).

This experiment follows on from the previous experiment observing the flight of these spears. This fed information to the drop tower experiment (particularly the required energy). It was hypothesised that the spear tips would prove effective and durable killing tools (research question 4). It was also hypothesised that they would break before the spear shafts, if the stress and strain from impact became too great. What was observed in the drop tower experiments confirmed these hypotheses. The reindeer antler tips proved exceedingly durable when dropped into the gelatine, except that used in the very first drop (which could be considered an outlier). The short spears also created a wound channel that typically ranged between 18 and 22cm, a depth which could be considered a mortal wound according to Wood & Fitzhugh (2018). It was only when a hard surface was added to the impact zone that some damage occurred more consistently. Throughout the experiment, the only damage that occurred was to the antler tips, not the wooden shaft. After 30 drops with different points and shafts into both soft and hard surfaces it was assumed there might be a little damage. A small amount of damage to one spear shaft was observed during the spear throwing experiment, though it was almost superficial. Both experiments clearly demonstrate that in a scenario when high levels of force pass through an Aurignacian spear with a split-based point, the antler point rather than the shaft will consistently break. The tips almost always broke in a way that allowed for reuse after varying levels of retooling. If a bevelled break was caused, it generally only required light retooling (if at all). These types of breaks, as identified by Tejero (2016), would only result in a small amount of tip length loss. If a hunter started with a large SBP, such as some of the larger examples discussed by Knecht in her thesis (1991), it is likely it would be used and retooled over many episodes. Basal splitting is clearly more significant damage, but only requires that the damaged wings are removed and a new split added (or existing split lengthened). This greater loss of length would clearly reduce the lifespan of a SBP, but not make it unusable unless the point was too short or the split very devastating (Knecht 1991; Doyon & Knecht 2014). Damage and subsequent retooling at both the distal and proximal ends of a projectile tip are quite unusual, and essentially reduce the chance of a tip becoming unusable before it is too small. The phrase "to burn the candle at both ends" implies working in an unsustainable manner because reserves of energy will be depleted at a faster rate (though the potential light and heat energy in a wax candle when burned will deplete all the same). If a SBP only broke at the distal end, it would clearly last longer (like a candle burning at one end). However, as demonstrated during the experiments, breakage can occur at either end, so our hypothetical candle burns at both ends. This is not necessarily a disadvantage. Lithic points often are left in an unusable state after breakage, with only unusual cases in which retooling can make them effective once more (Shea *et al.* 2011).

In reference to research question 4, the osseous-tipped spears performed very well; certainly well enough to be used on large fauna such as reindeer or horses. The spear throwing experiments demonstrated they did not require fletching (question 4a), and could be thrown with enough force (around 300 Joules) to create a wound channel deep enough to kill large prey. Perhaps the most interesting question is why split base points were made in the way they were (question 2). Were they over-engineered? Based on these experiments: probably not. They assist in improving the longevity of the spear shafts by reducing their chance of breaking; by absorbing much of the impact force and breaking first. Further efficiency testing against other osseous points such as simple-based points could determine whether the time invested in creating the basal split was worthwhile (see Chapter 7). That side of the design focusses on the re-use and maintenance of the spear, which could fall into Bleed's (1986) maintainable system: a modular design with easily repairable (or replaceable) components. As well as maintenance, the split base points appears to offer something extra that many prehistoric projectiles do not. The wings on the split base facilitate hafting. Tartar & White (2013) concluded that a bevelled wooden shaft tip occupied the space at the basal split. Knecht (1991) favoured a hafting style in which an extra piece of osseous material (the "shim") fitted into the basal split, and the spear tip with shim fitted into a notched or split spear shaft's proximal end. This thesis' research favoured the former style of the basal split accommodating the spear shaft rather than an extra armature. During the drop tests into ballistics gel it was found that the wings could act like a splint to keep wound channels open. If it is assumed that the tips were not glued (as no evidence has yet been found (Knecht 1993), it is likely that they would remain in the wound when the shaft was pulled or fell out. This was demonstrated consistently when the drop tower reset and pulled the hammer up from the impact zone. This feature would be a useful addition in almost all hunting styles, as it is imperative the hunted prey falls quickly to reduce tracking efforts. The osseous tips do not have the cutting edges of lithic points as demonstrated by Wood & Fitzhugh (2018), but they do have the durability and penetrative power to cause sufficient damage. They also offer an extra bleed-out trait, by widening a wound channel that lithic points (even with armatures) do not. Therefore, in regards to research question 2, they are carefully engineered to offer both improved longevity of valuable components and improved wound fatality through bleed-out if a vital organ is not punctured.

Chapter 6: Collection of wood samples

Wood samples were collected from high-latitude and high-altitude areas to determine structural characteristics of timber growing there. The aim was to identify species that could provide sections of wood suitable for producing spear shafts. It was assumed prior to collection that trees present would be restricted to boreal woodland species, with some outliers that would probably be dwarf or cold-resistant varieties. Several locations were identified to collect wood samples in northern Scotland, as transects could be applied to the landscape. Permission was kindly given to obtain samples by Dounby Farm and the Cairngorms National Park Authority. Dominant species in the area matched those of charcoal and reliable pollen records for parts of Europe during MIS 3, so would make ideal locations to collect samples. Common taxa in the area included *Pinus, Picea, Betula, Larix* and some *Salix*: all species identified in parts of Western Europe during MIS 3.

It was assumed prior to collection that suitable branches, shoots or sections from trees for light spear shafts would not be easy to find. This was down to a number of reasons, but mainly the form of the trees/branches. Some curves or light kinks could be straightened using heat and tools based on those from Aurignacian assemblages. However, heavily-twisted and bent branches/shoots would be totally unsuitable for spear shafts. Therefore it was necessary to gather images of the trees that were sampled. This would allow sampled trees to be scored visually before the sample was tested. While the branches/shoots might be of an ideal form, they might prove to be too dense (resulting in excess weight and lack of flex) in later testing. This could cause issues when launching spears, or at the point of impact, as a lack of flexion or "spine" could cause the shaft to break under the strain (Baugh 2003, Hughes 1998, Ellis 1997, Wilkins *et al.* 2014). Alternatively, a spear shaft with no flexion or ability to absorb shock on impact could result in a split or damaged spear point, as the latter would have to absorb most of the shock from the shaft.

Samples were collected from Caithness through into the Cairngorms. A sample was originally planned from Orkney (sample 1); however, this was abandoned due to problems finding woodland that had not been planted in the last 10 years outside gardens or intensely-managed properties. A portable GPS gave readings that could be plotted later; on some occasions an elevation above sea level was given. However, the accuracy of elevation readings needed checking, and so would be confirmed subsequently using OS maps on online topographic maps. In the Cairngorms it was possible to collect samples from valley bottoms and further up slopes. This would provide a set of wood samples that had been growing under different stresses, as tress at a higher elevation would be subject to harsher weather and very limited soils. All samples were detached from trees using a small folding saw. Samples were taken from branches that would not cause too much damage to the tree by their removal. The thickness of potential branches had to exceed 2.5cm, but was not thicker than 10cm. The form of the branches had to be relatively straight (not severely twisting) and at least 30cm in length. This would give plenty of timber to use for testing later.

Fig. 75 shows the location from which samples were taken in northern Scotland. The transect across Scotland is over 250km in a straight line, so will provide carefully-selected range of samples from different latitudes and altitudes. The supporting table shows sample coordinates, elevations, regional locations, number of samples taken and the genus of samples. As stated, the common species available in the sample areas were similar to those identified in Western Europe during the Aurignacian.

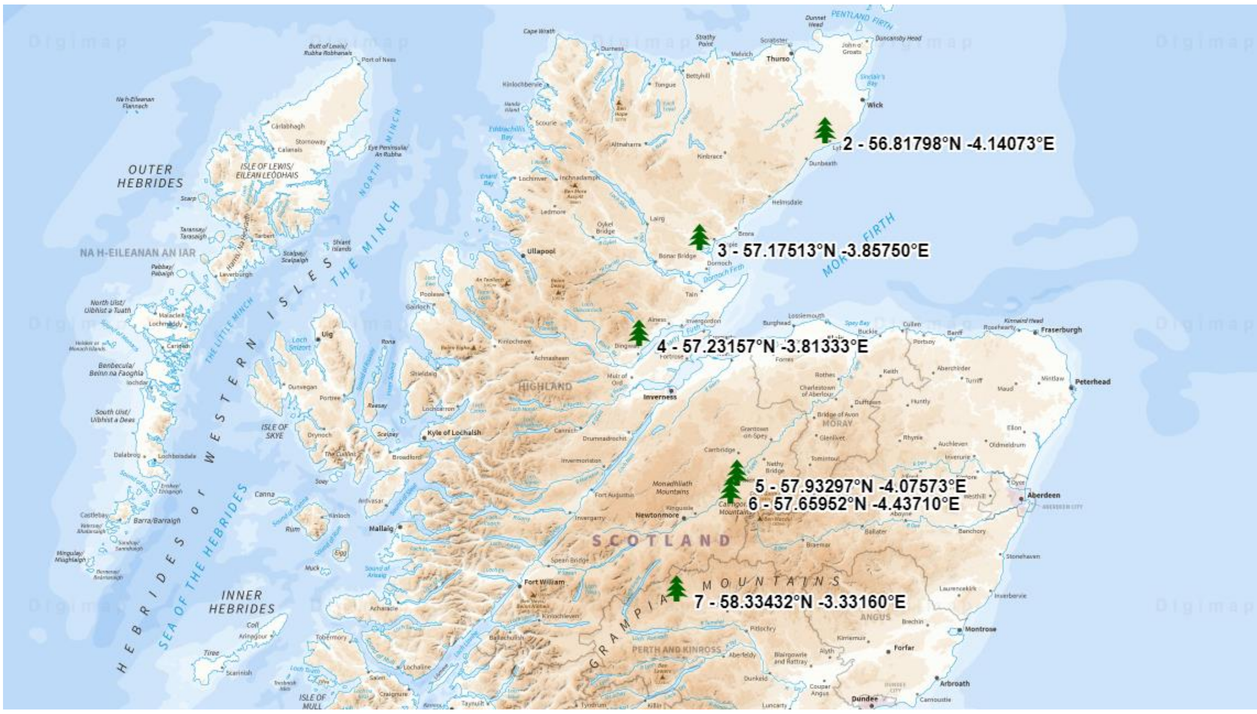

Fig. 75: Wood sampling transect through Scotland. Site number next to tree symbol with grid reference (see also Table 6 in appendix)

This chapter, in combination with chapter 3, will answer research question 3 about the potential resource management of Aurignacian people. It will feed into answering the final thesis chapter (7) regarding Tartar and White's (2013) suggestion that osseous spear points suit small groups or solitary hunting strategies. The following table (5) provides location, elevation and visual descriptions of trees selected in sample areas. It must be noted that time was spent at each location trying to find the most suitable trees that could offer something close to a spear shaft. It is also worth noting at this stage that the task was a challenging one. Many of the environments visited to collected samples showed some similarities to organic samples and plant proxy data from MIS 3 in NW Europe. These are discussed in Chapter 3.

Table 7: Wood sample collection. See Fig. 71 for location grid references.

Sample site: 2
Location: Lybster (Caithness)
Elevation: 377.3m

Tree specimen could feasibly offer straight length for spear shaft. However, a large amount of time would be required to thin down the timber into a suitable thickness. Without woodworking tools, this would pose a significant challenge. Site 2 was located on very high ground with plenty of soil, though it was very dry.

Sample site: 2
Location: Lybster (Caithness)
Elevation: 377.3m

Similarly to the first tree sampled at site two, a large amount of work would need to be invested before a viable spear shaft could be produced. It is also highly likely that the finished spear shaft would not be entirely straight.

Sample site: 2
Location: Lybster (Caithness)
Elevation: 377.3m

The third tree from site 2 was a fairly young birch. It offered the best opportunity for a spear shaft, as less time would be needed to thin the shaft. The young growths were also relatively straight. In the area of site two, younger tree specimens seemed to be the best chance of a reasonable spear shaft.

Sample site: 3
Location: Shelbo (Sutherland)
Elevation: 254.8m

At site 2, young birches offered reasonable lengths for spear shafts. Some young specimens have shoots/young trunks that were a good width, but were not straight. In several examples it was clear that attempting to straighten the wood by flexing and heating would not be viable.

Sample site: 3
Location: Shelbo (Sutherland)
Elevation: 254.8m

Pine species in site 3 contained only a few younger specimens that could have offered possible spear shafts. A second option would be branches from older trees. Due to the highly flexible and resinous nature of pine branches, it is likely they would need to be dried, seasoned or fire hardened.

Sample site: 3
Location: Shelbo (Sutherland)
Elevation: 254.8m

An older birch stand at site 3 offered fewer opportunities for spear shafts. Some branches were a possible option, but would require a large time investment to straighten or thin down. Site 3 was located in a fairly high-altitude area with a reasonable quantity of soil.

Sample site: 4
Location: Swordale (Ross-shire)
Elevation: 256.1m

Site 4 was located in an area of almost exclusively silver birch. Though the area was fairly high-lying, the ground was quite damp through to boggy in places. The first tree specimen (silver birch) would require a large amount of thinning work to produce a serviceable shaft.

Sample site: 4
Location: Swordale (Ross-shire)
Elevation: 256.1m

Specimen 2 (silver birch) from site 4 offered very poor options for a spear shaft, and represented a number of trees in this area that would have probably been avoided altogether.

Sample site: 4
Location: Swordale (Ross-shire)
Elevation: 256.1m

Specimen 3 (silver birch) from site 4 was an older tree, whose branches offered opportunities. These could be broken near the trunk and thinned down.

Sample site: 4
Location: Swordale (Ross-shire)
Elevation: 256.1m

Specimen 4 from site 4 came from a space filled with young birch trees. These were the best option in the area for spear shafts. There were many to choose from and many would require only limited work. The ground around specimen 4 was better drained.

Sample site: 5
Location: Aveilochan (Cairngorms)
Elevation: 71.3m

Both samples at site 5 were reasonable options for spear shafts. Both were young silver birch trees that were fairly straight and of a consistent thickness for at least 1.5m. The ground here was not very high-lying, had good soil, and was well-drained. An area like this would have been a good place to look for spear shafts.

Sample site: 5
Location: Aveilochan (Cairngorms)
Elevation: 71.3m

Specimen 2 from site 5 was located about 200m away. More mature trees grew in this area, though young, viable trees still grew here.

Sample site: 6
Location: Aviemore (Cairngorms)
Elevation: 246.6m

The first sample from site 6 was from a young birch. It was relatively straight, though would require significant time to thin down. There was only a limited number of young specimens in this area.

Sample site: 6
Location: Aviemore (Cairngorms)
Elevation: 246.6m

Specimen 2 at site 6 came from one of the more frequent mature silver birches in the area (which was otherwise dominated by younger specimens). A branch was chosen, as the trunks of these mature trees were far too thick. There was a very limited number of branches that were even slightly viable. The ground was very steep at site 6, with very limited soil in places.

Sample site: 6
Location: Aviemore (Cairngorms)
Elevation: 246.6m

Specimen 3 from site 6 was unusual in that it was a rowan tree (*Sorbus*). Several branches from this tree were possible options, though they would require a large amount of time and effort to thin down.

Sample site: 6
Location: Aviemore (Cairngorms)
Elevation: 246.6m

Specimen 4 from site 6 came from a very mature silver birch growing on rocks. The sample came from a branch. There were few opportunities for spear shafts, and it would probably have been the sort of tree to avoid due to distorted, twisted limbs.

Sample site: 6
Location: Aviemore (Cairngorms)
Elevation: 246.6m

Specimen 5 from site 6 came from a tree in a similar setting to specimen 4; the difference was in the age of the tree. Sample 5 came from a much younger tree, though it also offered very poor options due to heavily twisted limbs that changed thickness rapidly along its length (meaning it would require significant time investment to shave down to a relatively equal thickness for a shaft.

Sample site: 7
Location: Blair Atholl (Perthshire)
Elevation: 128m

Sample 1 from site 7 offered a few opportunities for spear shafts, though a significant amount of time would be required to thin and straighten shafts. The area of site 7 had patches of decent soil coverage, mixed with bare scree.

Sample site: 7
Location: Blair Atholl (Perthshire)
Elevation: 128m

Specimen 2 from site 7 came from a tree growing on scree with extremely limited soil. Surprisingly, several of the branches offered possible options for spear shafts, though some time would be required to thin and straighten these branches before they were viable. As well as the scree, the tree was on very steep ground in a fairly exposed position.

Discussion

Clearly the samples and sample sites are not exhaustive, but they do give a picture of the most favourable conditions in NW Europe during MIS 3; every main type of tree species and environmental condition for MIS 3 was targeted. Limited soil and shorter growing seasons have taken their toll on many of the trees seen at sample sites. It has previously been argued that dense timbers do offer some advantages in spear fore shafts, though this relies on the shafts used being fairly straight to begin with. The issue of tree limb straightness is perhaps the key problem, and would have made the job of sourcing spear shafts in NW Europe during the Upper Palaeolithic a challenge. The spear throwing and drop shafts tests demonstrated that once a relatively straight length of wood is obtained, the species variation makes little difference to performance. This adds weight to the argument that Aurignacian hunters made do with what was available, rather than establishing or maintaining long-distance exchange or travel routes to obtain spear shafts of tree species classically associated with that hunting tool. There is no environment that will be the perfect proxy for an Aurignacian landscape for a variety of reasons, such as differences in CO_2 levels, as discussed in Chapter 3 (Huntley *et al.* 2013).

To answer research question 3, it is certainly possible to see what appears to be quite focussed resource management in the form of the split-based points. To spend extra time producing an osseous tip that includes an awkward split, instead of a lithic tip, implies reasoning and forethought. It has been thoroughly discussed that lithic tips suffered from hard impact, especially in cold weather, in Chapter 2, though lithic tips do reappear through the Upper Palaeolithic. It is quite possible that the exact killing power of a spear tip is less important than the hunting strategy, which determined the material used for spears. It will of course be very difficult and unrealistic to be able to plot out exactly what prehistoric hunting strategies were used, or to suggest everyone used the same tactics. In previous discussions, possible hunting strategies have been compared to prey ecology and the landscape of NW Europe during the Aurignacian. The widespread occurrence of osseous tips both implies a reliance on the technology by hunters and a reliability of the technology in use and sourcing of materials (and the curation of certain spear elements). Over a widespread area (in which the Aurignacian occurs), different terrain, microclimates and species will have been encountered by human groups. The fact that osseous, and specifically split base points occur from the Levant to Britain demonstrates they can be used in a variety of hunting scenarios that use different tactics on different prey. Therefore the flexibility in osseous points is not simply down to their advantageous material characteristics over lithic tips, but their broader flexibility in different strategies, be they hunting or resource management.

To return briefly to lithics, it would appear likely that tool makers and users curated tools and used them sparingly. The heavily backed nature of classic Aurignacian blade tools implies curation. As was found and discussed in chapter 4 (The production of stone tools), it is reasonable to assume that sharp lithics represented the earliest stages of use-life in stone tools, while heavily-backed tools represented examples that had been carried and retooled over several occasions. Lithic tips and osseous tips that are held in place by a notch have been demonstrated to cause damage to spear shafts (Wood & Fitzhugh 2018). It was observed that they created a significant weakness (to the spear shaft), which is avoided when applying that notch or split to the tip rather than the spear shaft.

To conclude on question 3a: Yes, there were potentially sources of usable timbers for spear shafts, though they would have been difficult to find, and carefully curated when located. Such slow growth as indicated by low ANPP (see Chapter 3), demonstrates careful curation of usable spear shafts must have been key to maintaining reliable hunting equipment (Bleed 1986). Can this help in answering question 3b? Yes, but neither it confirms nor disproves that people prepared spear shafts before moving into tree-less areas. Assuming the hunting strategy in these new environments remained the same or similar as in the known habitats, it is very likely that they did.

Chapter 7: Conclusion

To conclude this thesis, it would be most effective to address each question in turn before summarising on future research priorities. As discussed at length previously, to best understand a complex issue like hunting strategies, it is necessary to focus on specific questions that can then be viewed collectively. It would not be possible to evaluate the capacity for Aurignacian hunting tools and techniques by attempting to recreate scenarios in a 'real-world' style. As well as being very challenging to set up, there are numerous ethical and logistical issues which would critically inhibit such an effort. The results and discussion to each question is compared to Bleed's (1986) lists of maintainable and reliable systems, see Chapter 2: A view to a kill. Many parts of Bleed's dichotomy are applicable to Aurignacian osseous spear technology, though some parts are too vague or too rigid for use regarding this type of technology such as A3 (parallel subsystems), B2 (arranged subsystems) or B5 (design for partial function). The two lists do, however, help us to better understand split-based point technology and the way it fitted into a hunting group's strategy at the moment a spear was thrown, and in the aftermath when the spear was serviced and maintained.

Before putting any spears through their paces, a good place to start the journey to understand their role in Aurignacian groups was to look at their manufacture and raw materials. This aspect has been explored by several researchers (from the 1930s to the present day) pursuing slightly different aims, though all hoping to better understand split-based points (see chapter 2). Between previous researchers, there appeared to be a divide over the exact production method. One side of the argument favoured creating the basal split via cleavage with a wedge (Henri-Martin in 1931, and followed by Knecht from 1991 onwards, then Rees in 2003), while the other side favoured removal of material by flexion (Peyrony in 1933, then Tartar and White in 2013). There were some researchers who appreciated that there may have been aspects from both production theories, and either demonstrated experimentally that they could be used in combination (Nuzhyni 1998), or by simply looking at existing examples (Tejero 2016). In the past, publications that have included an experimental element, replica stone tools were used to create osseous points (Knecht 1991, 1995; Nuzhyni 1998; Rees 2003; Tartar & White 2013). Limited discussion was offered as to the role and value of stone tools in these production processes. Therefore question 1 of this thesis was designed to fill the gap. During the production of replica split-based points, it was noticed that limited damage was caused to the stone tools, apart from the basal splitting process in which a thick blade was used as a wedge. It was observed that a fresh blade could be used extensively for scraping sequences to create or re-sharpen a point. This both matches the proposed theory that an Aurignacian toolkit was carefully curated, and not damaged or 'spent' cheaply, and matches split base points from the archaeological record (Knecht 1991; Tartar & White 2013; Tejero 2016). It is therefore highly likely that Aurignacian hunters carried toolkits of blades to maintain osseous points when needed, or at the very least knew where there were caches of tools (maintainable systems B3). An interesting observation from the use of replica lithics was the role played by blades at different stages of use. Tejero's (2016) manufacturing approach that broke antlers down into split blanks or "baguettes" was most effective with blades that had been retouched. Fresh blades were almost useless that this stage. Blades that were heavily backed, or had stepped edges, were effective at creating the basal split. The flow chart at the end of Chapter 4 outlined the sequence in which blades were probably used, and how they changed over time. This of course assumes they were only used for this activity, and that the user only used each blade for its most suitable task (there were no doubt exceptions). This addresses research questions 1 and 1b specifically. Replica tool types were very effective at certain parts of the production sequence of split base points (maintainable systems B3). Almost all stone tools were either a blank or flake, before becoming a recognised tool type; that, however, does not mean they were used extensively before being retouched into an Aurignacian backed or strangulated blade. Sub-question 1a asked whether mastics were required to secure split base points. Knecht (1991, 1993, 1995) previously ruled out the use of mastics during her thesis and following research. It was also demonstrated in the spear throwing and drop tower experiments that glue, mastics, or even bindings, offered little and could arguably hinder SBPs' effectiveness if they were intended to remain in a wound.

Research question 2 is a key question in this thesis, as it has critical effect on the following questions. It has previously been asked whether split base points were over-engineered, but not explored beyond production (Tartar & White 2013). It was hypothesised that split-based points were carefully made to improve a spear shaft's longevity (Bleed's 1986 reliable systems: A1) by shifting the joint weakness to the spear tip rather than the spear shaft (main hypothesis 2). This was put to the test during the spear throwing and drop tower experiments. It was also expected that the spears would work effectively at reaching wound depths capable of causing mortal wounds (20-28cm), as outlined by Wood and Fitzhugh (2018). In both experiments, the spear tips showed damage after repeated use or exposure to high levels of force designed to cause a break. The break consistently occurred to the tip rather than the shaft, which confirms the theory that they were at least in part engineered to break before the more valuable spear shaft (reliable systems A1 and A2). What was not expected was the direct killing potential these osseous points offered (even before strategies such as corralling are considered). Previous experimental research, as outlined in Chapter 2, included accounts of replica spears piercing animal carcasses and putty to an effective depth. In this research it was noted that once the spear tips were embedded, they were not easy to remove with the shaft. They also kept the wound channel open like splint due to the flared base of the points. This observation in particular is interesting and new to the field of split base point research. The addition of armatures has previously been discussed by Knecht (first in 1991), and subsequent researchers who referred to Knecht (Nuzhyni 1998; Rees 2003; Tartar & White 2013), but with no discussion on what the points themselves could offer aside from a projectile point.

Research question 3 asked to what extent can resource management be identified when comparing palaeo-environments to the spread and presence of Aurignacian people. As discussed in chapter 1, the Aurignacian was identified by the presence of osseous tools, particularly osseous points. Early researchers, such as Peyrony (1933) used them as markers in deposits to distinguish stages in the Aurignacian. Osseous points have been identified from earlier deposits at sites such as Torralba and Ambrona, but they do not occur consistently over a wide area as split-based points do (Villa & d'Errioc 2001; Tejero 2016). Therefore we can say that Aurignacian people brought a consistent osseous point style to Western Europe for the first time. The question for this thesis is what that presence of osseous points represents. Is it purely a spread of cultural expression? Or a response to environmental challenges? A reasonable response would be to suggest a mix of the two (and probably other factors). A consistent style implies some cultural pressure, even if that style is carefully engineered to offer both valuable component longevity and lethality (maintainable systems B4). As demonstrated by the Stage Three Project and supporting data outlined in Chapter 3, the growing season would have been very short in NW Europe. This, combined with limited soil generation, would have resulted in a small selection of tree species in sheltered areas. In NW Europe, those species would have been limited to birch, pine, larch and some dwarf willows. Addressing question 4 regarding performance, it was clear that some of these species could produce spear shafts that performed well enough as thrown spears and in the drop tower (for thrusting or the impact of a throw). This, in answer to Q3a, shows that there may have been sources of timber in NW Europe, but still suggests they were carefully curated (due to their scarcity, based on the Stage 3 simulated biomes). The results from the spear use experiments also suggest the tips were made to preserve the shaft rather than the tips. As discussed in Chapter 2, deer antler would have been a readily available resource. So did Aurignacian hunters have to prepare shafts before moving into northern hunting grounds? Possibly, but it is very difficult to say exactly what equipment or repair kit preparation was involved for every hunting group in every region (reliable systems A5 or maintainable systems B3). It is, however, a very reasonable statement to say that people obtained spear shafts in an opportunistic manner with what was available and simply improved or changed hunting strategies to make up for unreliable hunting equipment due to inconsistent raw materials (limited access to straight timber for spear shafts). This could be while on the move and a stand of suitable trees was spotted, or while people were living in a more favourable region for direct procurement or exchange for spear shafts. We certainly know that those more 'favourable' regions for tree species in to the south. But if people were not moving north and south for any other reason than obtaining spear shafts, is that enough to warrant such a journey? Probably not, but a higher resolution survey of isotopic data from tooth enamels could offer more evidence on this issue. So can a trading economy around spear shafts be ruled out? For the moment, yes. If the samples from Scotland (which were considered very favourable conditions for a MIS 3 landscape) performed poorly in experiments, a trade or exchange route could have been investigated. However, based on lithic and shell provenancing patterns presented by Schmidt & Zimmermann (2019), these networks existed for other resources. Aurignacian hunters may have had to increase their access to better spear shafts through or along these networks as seen in more modern hunting groups in Tasmania (Spencer 1914). For this research, the Scottish samples performed acceptably (both full size in spear throwing and shortened lengths in the drop tower), so the opportunistic gathering theory seems more likely.

Another important question to answer in this thesis was the flight performance of Aurignacian spears, and whether they required fletching of some kind. To answer the fletching question (4a) quickly and easily: No, after limited practice to get used to the weight difference, the javelin throwers could achieve a consistent flight path. This showed the spears could fly without the need of fletching to prevent the spears from tumbling in mid-flight. Chapter 5 outlined the results from both the spear throwing and drop tower experiments. The results showed (as hypothesised) that the spears would perform well when thrown by an experienced javelin thrower, without the need for stabilisation. The drop tower experiments also showed that the osseous tips could withstand huge levels of force as they were driven into ballistics gelatine, only breaking when a hard surface was added. This confirmed hypothesis 2 that they were carefully engineered (see above), and that they could create a deep enough wound penetration while remaining resistant to sudden impact (reliable systems A1). It is also worth pointing out that the spear tips only started to break once a hard surface was added to simulate a missed shot or contact with bone. Even then, the spear tips did not break on every impact, demonstrating their high resistance to impact on a hard surface. Wood and Fitzhugh (2018) had already observed the high resistance of osseous points, and commented on how they could be reused several times. This feeds into the final question of the thesis regarding the osseous point suiting small group/solitary hunting strategies, as indicated by Tartar & White (2013).

This question clearly comes down to the hunting strategy itself. Sadly, we do not have a perfect case-study site like Stellmoor that shows exactly how hunters utilised the landscape to effectively trap and dispatch their prey (Bratlund 1991). We can say, however, that many of these split base points are found in areas where the landscape could easily be used in a similar way, such as the Vézère Valley. We can also say that these osseous-tipped spears could be used effectively as both javelins and thrusting spears. Do they suit small-group hunting though? Complex hunting equipment requires skilled craftspeople to produce (reliable systems: A7), especially fine lithic points, which can be quick to produce in the right hands, but break easily. Osseous points also required skilled hands and well-made tools to make and maintain (Reliable systems A4, and Maintainable systems: B6), but they lasted much longer. It would be impossible to determine exactly whether skilled craftspeople manufactured and maintained the equipment for other hunters or whether hunters were skilled enough to make and maintain their own (reliable systems A7 vs. maintainable systems B7). It is likely with most crafts, there would have been a range of skills between people in a group and some would have been more experienced in certain crafts. Particularly skilled individuals may have prepared antler points before a hunting season by collecting and soaking antler then producing points months in advance. A container of pre-made tips would have been much easier to carry, and lighter, without risk of breaking in transit than several complete spears (Maintainable systems B1). If a small hunting group did not have an experienced tool or split-based point maker in the group (reliable systems: A7), so long as they carried a set of stone tools, a set of osseous tips and at least one spear shaft (as seen ethnographically, and again listed by Bleed 1986: A5), they could travel and hunt for an extended period of time (Moseley 1877). They would not need to make contact with a tool point maker until either their spear shafts had broken, or their points had all broken and been reshaped and retooled down to stubs. Based on the spear throwing and drop tower experiments, that occasion would only come about after many impacts and re-sharpening sequences (maintainable systems: B7).

As discussed previously, Aurignacian hunters may have employed several different hunting approaches. Either corral systems or intercept hunting in narrow gorges would have made sensible options for utilising an osseous tipped spear's ability to cause heavy impact and even spinal shock (Wood & Fitzhugh 2018). If small hunting groups had no means of trapping prey, they would have had to rely either on very accurate, damage hits, or fast blood loss to slow injured prey down. The wound splint effect of the flared basal split would almost certainly help disable an animal quicker to prevent it escaping from a small hunting group, who would otherwise struggle to contain or dispatch injured prey.

To conclude this conclusion, a view to future research priorities will give clear indication of where and how best to better understand the Aurignacian pioneers. This thesis has focussed on split base points ("*pointes d'Aurignac*"), characteristic of the early Aurignacian according to Peyrony's (1933) sequence based on La Ferrassie. An expanded study could include later point styles such as the lozangic point (Aurignacian II), lozangic with oval section (Aurignacian III), biconical point (Aurignacian IV) and cylindro-conical point with single-bevelled base from after the Aurignacian (Peyrony 1933). Such a study could investigate why the split base was replaced with a more traditional simple base projectile point that probably fitted into a notched spear shaft. As many simple base points were often made of ivory rather than antler, a polymer substitute could be used (Knecht 1997). Presence of barbs to improve cutting power may have an adverse effect on air resistance, but could be necessary to improve the “killing power” of the spears. A second phase of spear testing under possible use conditions will be in a wind tunnel. Such a test has not been made with Upper Palaeolithic projectiles, so will provide some interesting new data. The focus would of course be placed upon the tip of the spear, which will undoubtedly create the most noticeable effect when in the tunnel. Different styles of spear point should provide marginally different results. It will be important to use a full-size spear shaft rather than a shortened version in case there are any unexpected results. Hughes (1998) specifies the transition between the tip of a projectile and the shaft as one of the more important sections regarding air resistance. This is due to pressure build-up as the projectile cross section gets wider, causing wake drag (Hughes 1998).

Important questions could include:

- What advantages can be seen in later Aurignacian osseous projectiles?
- Are later Aurignacian projectiles as effective as split-based points at preserving spear shafts?
- Are later osseous points easier and quicker to make than split-base points?
- Can a change in hunting strategy be identified, as osseous points change style over time (Tartar & White 2013)?
- Can environmental or climatic changes give clues as to why osseous points changed through the Aurignacian? Can a clear diachronic sequence be identified , or are there outliers such as Hohle Fels IV (Dinnis *et al.* 2019)?

Further study could include spear or projectile points that were made prior to the Aurignacian, and points from the following periods that utilised lithic points and armatures. Wood & Fitzhugh’s (2018) study was an excellent insight into different projectile point styles and materials, though their study was focussed on remains from Alaska rather than Upper Palaeolithic Europe. It may also be possible to use synthesised spear shafts made of resin with a pre-determined weight and density to match the wood samples collected from different growing conditions. This would provide consistent variables, but may not accurately demonstrate the full characteristics of a length of timber, i.e. wood grain/fibre strength.

During the spear throwing experiments, the throws did not appear hindered by wind action which gave interesting observational data, alongside comments from the throwers about weight balance (as discussed). Improvements to the spears themselves would be limited, though further study using replicas that are weighted could offer interesting observations. A final hafting combination to explore would be to glue a spear tip and bind it tightly to the spear shaft. This would reduce the chance of the tip detaching during flight, though it is worth noting that the spear tips with no glue or binding did not detach during flight, only upon impact (which could have been an intentional feature). Further throws would of course provide a larger sample of possible damage and flight observations, though the data collected are certainly adequate to conclude that the weakest part of the spear is the tip based on damage. As discussed previously, this may be an intentional feature, so continuing the experiment with tips of different sizes or maintenance stages would be interesting. The addition of an upright target is an option that was considered when the experiment was in its planning stages. However, using a target would simulate experiments already conducted, and not evaluate the replica spears put through the "missed shot" scenario designed to put the spears through higher levels of stress and strain.

An updated palaeo-environmental study of MIS 3 would give a clearer view of the Aurignacian landscape, and probably give a better indication of resource availability. A study that included results from Greenland ice cores, pollen, charcoal samples and updated biomes would offer a better model for understanding group movements, hunting strategy and decisions regarding resource procurement. As a separate study that could then be combined for a larger investigation of clusters of sites would be a survey of isotope data collected from tooth enamel at Aurignacian sites as there is currently very little existing literature on the subject. Understanding how and where prey were moving seasonally will give a clear indication of how hunters are using the landscape and give a better idea of Aurignacian lifestyle. We currently have a collection of sites that are identified as hunting stations or workshop sites, such as Maisières-Canal, but cannot yet put them in a connected landscape of Aurignacian sites.

Chapter 8: Implications for the study of spear technology in prehistory

The approach and aim of this thesis was to gain a broader view of the manufacture, use and maintenance of early Aurignacian spear technology. Split base points were a suitable case study for investigation due to their unusual style in comparison to spear points from the rest of the Upper Palaeolithic in NW Europe. Differences within artefact types encourages discussion as to why variations exist, and what they could mean. A steady or subtle change in artefact form over time in one site or region might suggest gradual change of one or more factors that affected the artefact users. Some of those factors might be traceable, such as climate change. While others, such as social change, can be much harder to track. A sudden change in artefact style would imply a sudden change to at least one of the important factors that affected the users of the artefact. That change might be climate or social change as mentioned, but it might also be the result of the arrival of a new group of people. A new group on the scene with new ideas or experiences would undoubtably leave remains of their different approaches to problem solving. Over time, the remains they leave may start to look similar to previous groups, as they face similar problems and landscape characteristics or assimilate with existing people. However, a different approach to making and using objects existed at the start or 'arrival', and would potentially be clear archaeologically.

As discussed at the start of chapter 2, using osseous materials for spear points was not a new concept, though it was not used with much uniformity beyond isolated sites. The appearance of osseous spear points in the Aurignacian, and their spread into Western Europe are plainly very different to past examples of osseous technology. Instead of group(s) at one site or local region trying a new material, we see the spread of new people with a new techno-complex. The Aurignacian spear type that typically gains the most attention is the split base point, despite other types of osseous point appearing later and composite, lithic-based projectiles in use prior to SBPs. Much like later Solutrean laurel leaf points, the Aurignacian SBPs stand out because they are different to what has been and what follows. They were used as type artefacts to identify the Aurignacian, and in more recent times have been the 'point' of debate as to their manufacture.

Possible methods of manufacture have been proposed and tested experimentally (as discussed in chapter 2). It seems likely that Aurignacian groups in different areas used slightly different methods where opportunities or restrictions existed (such as raw material scarcity or an opportune truncation in a piece of antler). Tartar and White (2013) suggested that the SBP might have been created to suit highly mobile hunting in small groups. This would be a challenging theory to explore without using replica Aurignacian hunting equipment in a MIS 3 proxy environment for an extended period. Testing ancient hunting equipment is exceedingly difficult if the reconstruction and testing in 'real-world' scenarios are not viable. Laboratory tests or semi-controlled experiments can give indications of the benefits or problems with certain equipment, but could never highlight everything to a researcher that would have been seen or known by an Aurignacian hunter. It is for this reason that we must invest careful consideration and investigation into the other traceable aspects that affected a hunter's world. That broader view meant contextualising the world of the Aurignacian hunter, rather than focussing on the SBPs themselves. Thankfully, the diligent work of previous researchers has meant the object-focussed research has been thorough (see Chapter 2: Missing the mark in past literature).

A key issue I have highlighted in this thesis is that climate and environment were arguably the most important factors to human groups. It would have been especially important to hunter-gatherer groups as they moved through different regions during changing seasons. Some climates and environments have a limited supply of certain resources, and this would have been an aspect of life for these human groups that could not be ignored. The only way of negotiating these resource-poor landscapes would have either been to make do or plan and prepare. It is likely an element of make do with a sprinkling of luck helped these groups, but without a prepared approach, these Aurignacian groups would have likely failed. This can be said for groups before and after the Aurignacian in NW Europe, so how were Aurignacian groups different? Or more specifically, how can we demonstrate Aurignacian methods of preparation? This is where the SBPs come into the picture. Their unusual design might be evidence of preparing for a difficult landscape. As outlined through the thesis, SBPs take more time and energy to produce than lithic spear tips. They are different to most other osseous points in that they have an intentional split at the proximal end. As hypothesised and subsequently demonstrated, it seems that the investment to create this unusual spear tip design was intended to transfer the weak part of a composite spear to a different component.

Prior to socketed spears of the Bronze Age, it was the spear shaft that typically facilitated the spear head in a notch cut into the wood. Some spear tips were possibly bound onto the side of a bevelled spear shaft end, though how common this was is not clear. With the notch in the spear shaft, any impact force would cause strain on that joint. With the weakest part of the joint on the notched spear shaft being the notch itself, it is likely to break first. The severity of spear shaft breakage will depend on the exact circumstances of the break. An almost endless list of scenarios could be compiled in which differing breaks, or likelihoods of damage could be outlined. However, the underlying theme is that the spear shaft will suffer damage. This is not to suggest it will break more often that a lithic spear tip. As demonstrated by Wood & Fitzhugh 2018, damage to the replica spear shafts caused data collection problems to their experiments because they appeared to have run out of shafts. They had anticipated lithic tip breakage and had a large collection of backup tips. To take this problem in testing and transfer it into a prehistoric hunter's world, this problem would not mean a loss of data collection, but a loss of opportunities to hunt prey. Essentially, the decision to transfer the 'facilitator' of the spear joint from the shaft to the spear tip demonstrates the tip is expendable, and thus made in a more easily accessible material.

To replace a spear shaft in NW Europe during MIS 3 has been addressed as potentially a tricky issue in chapter 3. The simulated biomes and fauna analysis through pollen and charcoal have indicated a very limited variety of tree species, which may have only grown in sheltered pockets. Without surviving examples, we cannot know the exact construction method or style of Aurignacian spear shafts. They may have been composite, with a fore shaft, or a single piece of timber. Due to the resource limitations, they may have simply had to 'make do' with what was available. But what we can see from more recent accounts of hunter gatherer groups around the world, is that hunters can be very fussy when selecting spear shaft timber: in the case of some groups, to the extent that trading networks were established so spear shafts of certain characteristics could be obtained by groups who lived in areas where such timber did not grow (Spencer 1914). Sadly, we cannot suggest Aurignacian groups established such trading networks without more solid evidence, but it does demonstrate the preference in some hunter gatherer groups for better quality spear shafts, instead of simply 'making do'. Based on the faunal remains from many Aurignacian sites, we can without doubt state that antler would have been a readily available resource (Mellars 2004). Between the two main components of a likely Aurignacian spear construction, an antler tip and wooden shaft, material for the tip would have been far more plentiful. As discussed by Tartar & White (2013) and Tejero (2016), several SBPs could be produced from one antler. This observation was made apparent during the replication of points for this thesis too. Therefore, as previously argued, the shaft of an Aurignacian spear is the most valuable component.

Intentionally designing a component to fail to mitigate damage to more valuable components is a concept we understand in the modern world. Such a component is common in our lives as we use electrical appliances, though we do not often see it unless there is a power surge. This component is of course the humble fuse. This sacrificial device prevents damage to expensive electrical components by breaking a current when there is a surge. A SBP is slightly different to a fuse in function and material, in that a fuse has the sole purpose of protecting appliances. A SBP still has to function effectively enough to provide killing power. The ability to think about protecting more valuable components by intentionally weakening others demonstrates a very capable maker with incredible foresight. Credit has been given to Aurignacian groups for being highly adaptable pioneers of Europe (Davies 2001; Mellars 2004, 2006). However, it is not unreasonable to improve on that credit and suggest that early Aurignacian groups who recognised a resource problem and attempted to solve it with the creation of SBPs were technological pioneers. Evidence of decisions to manage resources has proven difficult to find in the prehistoric archaeological record prior to the Neolithic. Yet with this Aurignacian case study we may have a rare example of how people recognised a problem that was outside of their control (timber resources in NW Europe), and managed it by finding a solution with the resources they had more control over. Using a broader view of the world around the Aurignacian people of NW Europe, it has been possible to identify decisions made over the creation of important objects within a techno-complex. The impact this may have had on the social organisation of Aurignacian people is hard to measure, but we can say that a greater focus on antler resources impacted on the curation of? limited timber resources. To that end, when analysing artefacts it might be advisable to ask ourselves, “What factors can be identified that affected this artefact’s form?” rather than simply “Why does this artefact have this shape or style?”

Technology has generally developed to solve problems. The lance spear appeared to offer extended reach and eventually to ability to engage prey from a distance using a javelin spear. Stone tips were attached when spears needed more cutting power, and binding or glue when the stone tip fell off the shaft. Antler tips may have solved several problems as previously identified, including stone tip fragility, access to quality lithic material and, importantly for this thesis, access to timber resources. Problems outside the immediate sphere of prehistoric technology are often not considered (as discussed in chapter 2). It may be due to unconscious bias towards the physical object in a researcher’s view. The object sits in front of you, and you can assume there were methods of material procurement and manufacture to make what is in front of you. But if those assumptions are simply overlooked, without consideration of what might have affected those processes, we cannot fully understand the object in front of us. As Sir Arthur Conan Doyle wrote for a quote from Sherlock Holmes: “Data! Data! Data! - I cannot make bricks without clay”. In the case of our Aurignacian hunters, they could not make spears without timber for shafts.

Appendices

Table 6 – Wood sample data from northern Scotland

Sample site number	coordinates	elevation	Regional location	Number of samples	Sample Genus
1	58.33432°N -3.33160°E	377.3m	Lybster, Caithness	3	Betula
2	57.93297°N -4.07573°E	254.8m	Skelbo, Sutherland	3	Betula, Pinus
3	57.65952°N -4.43710°E	256.1m	Swordale, Ross-shire	4	Betula, Sorbus
4	57.23157°N -3.81333°E	71.3m	Aveilochan, Cairngorms	2	Betula
5	57.17513°N -3.85750°E	246.6m	Aviemore, Cairngorms	5	Betula,
6	56.81798°N -4.14073°E	128.0m	Blair Atholl, Perthshire	2	Betula, Sorbus

References

Albrecht, G., 1977. Testing of materials as used for bone points of the Upper Palaeolithic. In H. Camps-Fabrer (ed.), *Méthodologie appliquée à l'industrie de l'os préhistorique: Deuxième colloque international sur l'industrie de l'os dans la Préhistoire (actes du colloque international, Abbaye de Sénanque (Vaucluse), 9-12 juin 1976)*, pp.124-199. C.N.R.S., Paris.

Allen, H. and Akerman, K., 2015. Innovation and change in northern Australian Aboriginal spear technologies: the case for reed spears. *Archaeology in Oceania*, *50*, pp.83-93.

Alfano, M.J., Barron, E.J., Pollard, D., Huntley, B. and Allen, J.R., 2003. Comparison of climate model results with European vegetation and permafrost during oxygen isotope stage three. *Quaternary Research*, 59(1), pp.97-107.

Álvarez-Lao, D.J. and García, N., 2011. Geographical distribution of Pleistocene cold-adapted large mammal faunas in the Iberian Peninsula. *Quaternary International*, *233*(2), pp.159-170.

Andersen, K.K., Svensson, A., Johnsen, S.J., Rasmussen, S.O., Bigler, M., Röthlisberger, R., Ruth, U., Siggaard-Andersen, M.L., Steffensen, J.P., Dahl-Jensen, D. and Vinther, B.M., 2006. The Greenland ice core chronology 2005, 15–42 ka. Part 1: constructing the time scale. *Quaternary Science Reviews*, *25*(23-24), pp.3246-3257.

Anderson, K., 2011. Slashing and thrusting with Late Bronze Age spears: analysis and experiment. *Antiquity*, *85*(328), pp.599-612.

Anderson, L., Lejay, M., Brugal, J.P., Costamagno, S., Heckel, C., de Araujo Igreja, M., Pradeau, J.V., Salomon, H., Sellami, F., Théry-Parisot, I. and Barshay-Szmidt, C., 2018. Insights into Aurignacian daily life and camp organization: The open-air site of Régismont-le-Haut. *Quaternary International*, *498*, pp.69-98.

Aranguren, B., Revedin, A., Amico, N., Cavulli, F., Giachi, G., Grimaldi, S., Macchioni, N. and Santaniello, F., 2018. Wooden tools and fire technology in the early Neanderthal site of Poggetti Vecchi (Italy). *Proceedings of the National Academy of Sciences*, *115*(9), pp.2054-2059.

Arndt, S. and Newcomer, M., 1986. Breakage Patterns on Prehistoric Bone Points: An Experimental Study. In D. A. Roe (ed.), *Studies in the Upper Palaeolithic of Britain and Northwest Europe*. *BAR. International Series*, (296), pp.165-173, Oxford.

Baales, M., Birker, S. and Mucha, F., 2017. Hafting with beeswax in the Final Palaeolithic: a barbed point from Bergkamen. *Antiquity*, *91*(359), pp.1155-1170.

Back, E.L., 2002. Pattern of parenchyma and canal resin composition in softwoods and hardwoods. *Journal of Wood Science*, *48*(3), pp.167-170.

Bahn, P.G., 1977. Seasonal migration in South-west France during the late glacial period. *Journal of Archaeological Science*, *4*(3), pp.245-257.

Banks, W.E., d'Errico, F. and Zilhão, J., 2013. Human–climate interaction during the Early Upper Paleolithic: testing the hypothesis of an adaptive shift between the Proto-Aurignacian and the Early Aurignacian. *Journal of Human Evolution*, *64*(1), pp.39-55.

Barron, E. and Pollard, D., 2002. High-resolution climate simulations of Oxygen Isotope Stage 3 in Europe. *Quaternary Research*, *58*(3), pp.296-309.

Bar-Yosef, O. and Belfer-Cohen, A., 1996. *Another look at the Levantine Aurignacian*. In A. Palma di Cesnola & A. Montet-White (eds.), *The Late Aurignacian (Colloquium XI; Section 6, The Upper Palaeolithic; XIII UISPP Congress)*, pp. 139-150. ABACO Edizioni, Forlí.

Bar-Yosef, O., 2000. The Middle and early Upper Paleolithic in Southwest Asia and neighbouring regions. In O. Bar-Yosef & D. Pilbeam (eds.), *The geography of Neandertals and modern humans in Europe and the Greater Mediterranean*. *Peabody Museum Bulletin*, *8*, pp.107-156.

Bar-Yosef, O. and Bordes, J.G., 2010. Who were the makers of the Châtelperronian culture?. *Journal of human evolution*, *59*(5), p.586.

Baugh, R.A., 2003. Dynamics of spear throwing. *American Journal of Physics*, *71*(4), pp.345-350.

Behre, K.E., 1989. Biostratigraphy of the last glacial period in Europe. *Quaternary Science Reviews*, *8*(1), pp.25-44.

Belfer-Cohen, A. and Bar-Yosef, O., 1981. The Aurignacian at Hayonim Cave. *Paléorient*, pp.19-42.

Belfer-Cohen, A. and Bar-Yosef, O., 1999. The Levantine Aurignacian: 60 years of research. In W. Davies & R. Charles (eds.), *Dorothy Garrod and the Progress of the Palaeolithic*, pp.118-134. Oxbow Monographs, Oxford.

Bémilli, C. and Bayle G., 2009. Aurignacian animal exploitation at Solutré (Saône-et-Loire, France). In: *L. Fontana/F. X. Chauvière/A. Bridault (eds.) In search of total animal exploitation: case studies from the Upper Palaeolithic and Mesolithic*. Proceedings of the XVth UISPP Congress, Session C61, vol. 42, Lisbon, 4–9 September 2006. BAR International Series 2040, 21–31. Oxford.

Bennett, K.D., 1988. Post-glacial vegetation history: ecological considerations. In *Vegetation history* (pp. 699-724). Springer Netherlands.

Berger, J., 1985. Interspecific interactions and dominance among wild Great Basin ungulates. *Journal of Mammalogy*, *66*(3), pp.571-573.

Bergman, C.A., 1981. Point types in the Upper Palaeolithic sequence at Ksar Akil, Lebanon. In J. Cauvin & P. Sanlaville (eds.), *Préhistoire du Levant (Maison de l'Orient, Lyon, 10-14 juin 1980), CNRS, Paris*, pp.319-330.

Bergman, C.A., 1987. Hafting and use of bone and antler points from Ksar Akil, Lebanon. *Travaux de la Maison de l'Orient*, *15*(1), pp.117-126.

Bergman, C.A., McEwen, E. and Miller, R., 1988. Experimental archery: projectile velocities and comparison of bow performances. *Antiquity*, *62*(237), pp.658-670.

Beyer, J. C., 1962. *Wound Ballistics*. Medical Department, U.S. Army, United States Army Medical Service, Washington, DC.

Bignon-Lau, O., 2014. Hunting practices targeting large mammal communities in the Paris Basin in the Upper Palaeolithic. *Quaternary International*, *337*, pp.114-128.

Binford, L.R., 1980. Willow smoke and dogs' tails: hunter-gatherer settlement systems and archaeological site formation. *American antiquity*, pp.4-20.

Blades, B.S., 2001. *Aurignacian Lithic Economy: Ecological Perspectives from Southwestern France*. Springer Science & Business Media.

Bleed, P., 1986. The optimal design of hunting weapons: maintainability or reliability. *American antiquity*, *51*(4), pp.737-747.

Bocherens, H., Bonilla, M.D.Z., Daujeard, C., Fernandes, P., Raynal, J.P. and Moncel, M.H., 2016. Direct isotopic evidence for subsistence variability in Middle Pleistocene Neanderthals (Payre, southeastern France). *Quaternary Science Reviews*, *154*, pp.226-236.

Boddington, C. and O'Keefe, L., 2002. *The perfect shot, North America: Shot placement for North American big game*. Safari Press.

Boëda, E., Connan, J., Dessort, D. and Muhesen, S., 1996. Bitumen as a hafting material on Middle Palaeolithic artefacts. *Nature*, *380*(6572), p.336.

Bokelmann, K., 1991. Some new thoughts on old data on humans and reindeer in the Ahrensburgian tunnel valley in Schleswig-Holstein, Germany. In D.A. Roe, A. Roberts & N. Barton (eds.), *The Late Glacial in north-west Europe: human adaptation and environmental change at the end of the Pleistocene. CBA Research Report*, (77), pp.72-81.

Bordes, J.G., 2006. News from the West: a reevaluation of the classical Aurignacian sequence of the Périgord. In O. Bar-Yosef & J. Zilhão (eds.), *Towards a Definition of the Aurignacian (Proceedings of the symposium held in Lisbon, Portugal, June 25-30, 2002)*, pp. 147-171. Trabalhos de Arqueologia 45, Instituto Português de Arqueologia, Lisbon.

Borgia, V., Carlin, M.G. and Crezzini, J., 2017. Poison, plants and Palaeolithic hunters. An analytical method to investigate the presence of plant poison on archaeological artefacts. *Quaternary International*, *427*, pp.94-103.

Borodovsky, A.P. and Tabarev, A.V., 2016. Modeling the Deformation of Bone Points: Archaeological and Experimental Data. *Archaeology, Ethnology and Anthropology of Eurasia*, *44(3),* pp.87-92.

Bratlund, B., 1991. A study of hunting lesions containing flint fragments on reindeer bones at Stellmoor, Schleswig-Holstein, Germany. In D.A. Roe, A. Roberts & N. Barton (eds.), *The Late Glacial in north-west Europe: human adaptation and environmental change at the end of the Pleistocene. CBA Research Report*, (77), pp.193-207.

Britton, K., Grimes, V., Niven, L., Steele, T.E., McPherron, S., Soressi, M., Kelly, T.E., Jaubert, J., Hublin, J.J. and Richards, M.P., 2011. Strontium isotope evidence for migration in late Pleistocene Rangifer: implications for Neanderthal hunting strategies at the Middle Palaeolithic site of Jonzac, France. *Journal of human evolution*, *61*(2), pp.176-185.

Brown, E.J., Rose, J., Coope, R.G. and Lowe, J.J., 2007. An MIS 3 age organic deposit from Balglass Burn, central Scotland: palaeoenvironmental significance and implications for the timing of the onset of the LGM ice sheet in the vicinity of the British Isles. *Journal of Quaternary Science*, *22*(3), pp.295-308.

Burch, E.S., 1972. The caribou/wild reindeer as a human resource. *American Antiquity*, *37*(3), pp.339-368.

Carbonell, E., Vaquero, M., Maroto, J., Rando, J.M. and Mallol, C., 2000. A geographic perspective on the Middle to Upper Paleolithic transition in the Iberian Peninsula. In O. Bar-Yosef & D. Pilbeam (eds.), *The Geography of Neandertals and Modern Humans in Europe and the Greater Mediterranean. Peabody Museum Bulletin*, *8*, pp.5-34.

Chapin III, F.S., Hollingsworth, T., Murray, D.F., Viereck, L.A. and Walker, M.D., 2006. *Floristic diversity and vegetation distribution in the Alaskan boreal forest* (pp. 81-99). Oxford University Press, New York.

Chilardi, S., Frayer, D.W., Gioia, P., Macchiarelli, R. and Mussi, M., 1996. Fontana Nuova di Ragusa (Sicily, Italy): southernmost Aurignacian site in Europe. *Antiquity*, *70*(269), pp.553-563.

Churchill, S.E., 1993. Weapon technology, prey size selection, and hunting methods in modern hunter-gatherers: implications for hunting in the Palaeolithic and Mesolithic. In G.L. Peterkin, H.M. Bricker & P. Mellars (eds.), *Hunting and Animal Exploitation in the Later Palaeolithic and Mesolithic of Europe.* Archeological Papers of the American Anthropological Association, 4, pp.11-24.

Churchill, S.E., 2002. Of assegais and bayonets: reconstructing prehistoric spear use. *Evolutionary Anthropology*, *11*(5), pp.185-186.

Clark, G., 1967. The Stone Age Hunters (Library of the Early Civilizations).

Coles, J., 1968. Experimental archaeology. *Proceedings of the Society of Antiquaries of Scotland*, 99, pp. 1-20.

Conard, N.J. and Bolus, M., 2008. Radiocarbon dating the late Middle Paleolithic and the Aurignacian of the Swabian Jura. *Journal of Human Evolution*, *55*(5), pp.886-897.

Cundy, B.J., 1989. *Formal variation in Australian spear and spearthrower technology*, 546. British Archaeological Reports Ltd.

Currant, A. and Jacobi, R., 2001. A formal mammalian biostratigraphy for the Late Pleistocene of Britain. *Quaternary Science Reviews*, *20*(16-17), pp.1707-1716.

Davies, W., 2001. A very model of a modern human industry: new perspectives on the origins and spread of the Aurignacian in Europe. *Proceedings of the Prehistoric Society*, 67, pp. 195-217.

Davies, W., White, D., Lewis, M. and Stringer, C., 2015. Evaluating the transitional mosaic: frameworks of change from Neanderthals to Homo sapiens in Eastern Europe. *Quaternary Science Reviews*, 118, pp.211-242.

d'Errico, F., Zilhão, J., Julien, M., Baffier, D. and Pelegrin, J., 1998. Neanderthal Acculturation in Western Europe? A Critical Review of the Evidence and Its Interpretation 1. *Current Anthropology, 39*(S1), pp.S1-S44.

d'Errico, F., Backwell, L., Villa, P., Degano, I., Lucejko, J.J., Bamford, M.K., Higham, T.F., Colombini, M.P. and Beaumont, P.B., 2012. Early evidence of San material culture represented by organic artifacts from Border Cave, South Africa. *Proceedings of the National Academy of Sciences, 109*(33), pp.13214-13219.

Delporte, H., Djindjian, F. and Mazière, G., 1983. Etudes sur l'Aurignacien de la Ferrassie. In M. Otte (ed.), Aurignacien et Gravettien en Europe. Actes des réunions de la 10 Commission de l'UISPP, Aurignacien-Périgordien-Gravettien et cultures dérivées. Fasc. 1: Nice 1976. ERAUL (Etudes et Recherches Archéologiques de l'Université de Liège), Liège, *13*(1), pp.13-26.

Delporte, H., Hahn, J., Mons, G., Pinçon, G. and de Sonneville-Bordes, D., 1988. *Cahier I. Sagaies*. Fiches typologiques de l'industrie osseuse préhistorique. Commission de Nomenclature sur l'Industrie de l'Os Préhistorique (UISPP). Université de Provence, [Aix-en-Provence].

Dinnis, R., Pawlik, A. and Gaillard, C., 2009. Bladelet cores as weapon tips? Hafting residue identification and micro-wear analysis of three carinated burins from the late Aurignacian of Les Vachons, France. *Journal of Archaeological Science*, *36*(9), pp.1922-1934.

Dinnis, R., 2011. The Paviland burin, the burin busqué and Aurignacian occupation of Britain. *Anthropologica et Præhistorica*, *122*, pp.5-17.

Dinnis, R., 2012. The timing of Aurignacian occupation of the British Peninsula. *Quartär*, 59, pp.67-83.

Dinnis, R., 2015. Identification of Longhole (Gower) as an Aurignacian site. *Lithics–The Journal of the Lithic Studies Society*, (33), p.17.

Dinnis, R., 2015. On the technology of late Aurignacian burin and scraper production, and the importance of the Paviland lithic assemblage and the Paviland burin. *Lithics–The Journal of the Lithic Studies Society*, (29), p.18.

Dinnis, R. and Flas, D., 2016, December. Trou du Renard and the Belgian Aurignacian. *Proceedings of the Prehistoric Society*, 82, pp. 1-25.

Dinnis, R., Bessudnov, A., Chiotti, L., Flas, D. and Michel, A., 2019, December. Thoughts on the structure of the European Aurignacian, with particular focus on Hohle Fels IV. In *Proceedings of the Prehistoric Society*, 85, pp. 29-60.

Discamps, E., Jaubert, J. and Bachellerie, F., 2011. Human choices and environmental constraints: deciphering the variability of large game procurement from Mousterian to Aurignacian times (MIS 5-3) in southwestern France. *Quaternary Science Reviews*, *30*(19-20), pp.2755-2775.

Doyon, L. and Knecht, H.K., 2014. The effects of use and resharpening on morphometric variability of Aurignacian antler projectile points. *Mitteilungen der Gesellschaft für Urgeschichte*, *23*, p.83.

Driver, H.E., 1939. *Culture Element Distributions: Northwest California*. University of California.

Dyson-Hudson, R. and Smith, E.A., 1978. Human territoriality: an ecological reassessment. *American Anthropologist*, *80*(1), pp.21-41.

Ellis, C.J., 1997. Factors influencing the use of stone projectile tips. In H. Knecht (ed.), *Projectile technology* (pp. 37-74). Springer US.

Enloe, J.G. & F. David 1997. Rangifer herd behavior: seasonality of hunting in the Magdalenian of the Paris Basin. In L.J. Jackson & P. Thacker (eds.), *Caribou and Reindeer Hunters of the Northern Hemisphere*, pp. 47-63. Avebury Press, Aldershot.

Fa, J.E., Stewart, J.R., Lloveras, L. and Vargas, J.M., 2013. Rabbits and hominin survival in Iberia. *Journal of human evolution*, *64*(4), pp.233-241.

Fairbanks, R.G., Mortlock, R.A., Chiu, T-C., Cao, Li., Kaplan, A., Guilderson, T.P., Fairbanks, T.W., Bloom, A.L., Grootes, P.M., Nadeau, M-J., 2005. Radiocarbon calibration curve spanning 0 to 50,000 years B.P. on paired 230TH/234U/238U and 14C dates on pristine corals. *Quaternary Science Reviews 24*: 1781–1796.

Falcucci, A., Conard, N.J. and Peresani, M., 2017. A critical assessment of the Protoaurignacian lithic technology at Fumane Cave and its implications for the definition of the earliest Aurignacian. *PloS one*, *12*(12): e0189241. https://doi.org/10.1371/journal.pone.0189241.

Falguères, C., Bahain, J.J., Pérez-González, A., Mercier, N., Santonja, M. and Dolo, J.M., 2006. The Lower Acheulian site of Ambrona, Soria (Spain): ages derived from a combined ESR/U-series model. *Journal of Archaeological Science*, *33*(2), pp.149-157.

Féblot-Augustins, J., 2009. Revisiting European Upper Paleolithic raw material transfers: the demise of the cultural ecological paradigm? In B. Adams & B.S. Blades (eds.), *Lithic materials and Paleolithic societies*. Wiley-Blackwell, Oxford, pp. 25-46.

Figueiral, I., 1995. Charcoal analysis and the history of Pinus pinaster (cluster pine) in Portugal. *Review of Palaeobotany and Palynology*, *89*(3), pp.441-454.

Finsinger, W., Tinner, W., van der Knaap, W.O. and Ammann, B., 2006. The expansion of hazel (Corylus avellana L.) in the southern Alps: a key for understanding its early Holocene history in Europe? *Quaternary Science Reviews*, *25*(5), pp.612-631.

Fladerer, F.A., Salcher-Jedrasiak, T.A. and Händel, M., 2014. Hearth-side bone assemblages within the 27 ka BP Krems-Wachtberg settlement: fired ribs and the mammoth bone-grease hypothesis. *Quaternary International*, *351*, pp.115-133.

Flas, D., 2015. The chronocultural sequence of Belgian complexes in the European Aurignacian context. *Palethnologie,* (7) (http://journals.openedition.org/palethnologie/736).

Follieri, M., Magri, D. and Sadori, L., 1988. 250000-Year pollen record from Vallée di Castiglione (Roma). *Pollen et spores*, *30*(3-4), pp.329-356.

Fontana, L., 2017. The four seasons of reindeer: Non-migrating reindeer in the Dordogne region (France) between 30 and 18 k? Data from the Middle and Upper Magdalenian at La Madeleine and methods of seasonality determination. *Journal of Archaeological Science: Reports*, *12*, pp.346-362.

Foucher, P., 2015. Flint economy in the Pyrenees: A general view of siliceous raw material sources and their use in the Pyrenean Gravettian. *Journal of Lithic Studies*, *2*(1), pp.111-129.

Fredriksson, M. and Lindgren, O., 2013. End grain water absorption and redistribution in slow-grown and fast-grown Norway spruce (*Picea abies* (L.) Karst.) heartwood and sapwood. *Wood Material Science & Engineering*, *8*(4), pp.245-252.

Frison, G. C., 1991, *Prehistoric Hunters of the High Plains*, Second Edition. Academic Press, San Diego.

Friesen, T.M., 2013. The impact of weapon technology on caribou drive system variability in the prehistoric Canadian Arctic. *Quaternary International*, *297*, pp.13-23.

Garrod, D.A., 1953. The relations between south-west Asia and Europe in the later palaeolithic age. *Journal of World History*, *1*(1), pp. 13-37.

Gaudzinski, S., 1999. Middle Palaeolithic bone tools from the open-air site Salzgitter-Lebenstedt (Germany). *Journal of Archaeological Science*, *26*(2), pp.125-141.

Gaudzinski, S. and Roebroeks, W., 2000. Adults only. Reindeer hunting at the middle palaeolithic site salzgitter lebenstedt, northern Germany. *Journal of Human Evolution*, *38*(4), pp.497-521.

Gaudzinski, S., 2004. A matter of high resolution? The Eemian Interglacial (OIS 5e) in north-central Europe and Middle Palaeolithic subsistence. *International Journal of Osteoarchaeology*, *14*(3-4), pp.201-211.

Grayson, D.K. and Delpech, F., 2002. Specialized early Upper Palaeolithic hunters in southwestern France?. *Journal of archaeological science, 29*(12), pp.1439-1449.

Goring-Morris, A.N. and Belfer-Cohen, A.N.N.A., 2006. A hard look at the "Levantine Aurignacian": How real is the taxon. In O. Bar-Yosef & J. Zilhão (eds.), *Towards a Definition of the Aurignacian (Proceedings of the symposium held in Lisbon, Portugal, June 25-30, 2002)*, pp. 297-314. Trabalhos de Arqueologia 45, Instituto Português de Arqueologia, Lisbon.

Guthrie, R.D., 1983. Osseous projectile points: biological considerations affecting raw material selection and design among Paleolithic and Paleoindian peoples. *Animals and archaeology*, *1*, pp.273-294.

Guiot, J., De Beaulieu, J.L., Cheddadi, R., David, F., Ponel, P. and Reille, M., 1993. The climate in Western Europe during the last Glacial/Interglacial cycle derived from pollen and insect remains. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *103*(1-2), pp.73-93.

Gutiérrez-Zugasti, I., Cuenca-Solana, D., del Río, P.R., Muñoz, E., Santamaría, S. and Morlote, J.M., 2013. The role of shellfish in hunter–gatherer societies during the Early Upper Palaeolithic: A view from El Cuco rockshelter, northern Spain. *Journal of Anthropological Archaeology*, *32*(2), pp.242-256.

Hahn, J., 1988. 1. Fiche sagaie à base simple de tradition aurignacienne. *Sagaies. Fiches typologiques de lindustrie osseuse préhistorique, Cahier I. Union Internationale des Sciences préhistoriques et protohistoriques: Commission de Nomenclature sur l'Industrie de les préhistorique. p*, pp.1-17.

Angus Hanton. 2011. *Woodlands.co.uk*. [ONLINE] Available at: http://www.woodlands.co.uk/blog/woodland-activities/annual-rings-climate-and-history/. [Accessed 13 June 2017].

Harrold, F.B., 1989. Mousterian, Châtelperronian and early Aurignacian in Western Europe: continuity or discontinuity. In P. Mellars & C. Stringer (eds.), *The human revolution: behavioural and biological perspectives on the origins of modern humans*, pp.677-713. Edinburgh University Press, Edinburgh.

Haynes, G., 1988. Longitudinal studies of African elephant death and bone deposits. *Journal of Archaeological Science*, *15*(2), pp.131-157.

Hays, M.A. and Lucas, G., 2001. Experimental investigations of Aurignacian Dufour bladelets. In M.A. Hays & P.T. Thacker (eds.), *Questioning the Answers: Re-solving fundamental problems of the Early Upper Paleolithic*, *BAR International Series*, *1005*, Oxford, pp.109-116.

Henri-Martin, D., 1931. *La Station Aurignacienne de La Quina (Charente). Bulletin de la Société archéologique et historique de la Charente, 1930*, pp. 5-72.

Hoare, B., 2009. *Animal migration: remarkable journeys in the wild*. University of California Press.

Hopcraft, J.G.C., Olff, H. and Sinclair, A.R.E., 2010. Herbivores, resources and risks: alternating regulation along primary environmental gradients in savannas. *Trends in Ecology & Evolution*, *25*(2), pp.119-128.

Hublin, J.J., 2015. The modern human colonization of western Eurasia: when and where? *Quaternary Science Reviews*, *118*, pp.194-210.

Hughes, S.S., 1998. Getting to the point: evolutionary change in prehistoric weaponry. *Journal of Archaeological Method and Theory*, *5*(4), pp.345-408.

Huntley, B., Alfano, M.J., Allen, J.R., Pollard, D., Tzedakis, P.C., de Beaulieu, J.L., Grüger, E. and Watts, B., 2003. European vegetation during marine oxygen isotope stage-3. *Quaternary Research*, *59*(2), pp.195-212.

Huntley, B., Allen, J.R., Collingham, Y.C., Hickler, T., Lister, A.M., Singarayer, J., Stuart, A.J., Sykes, M.T. and Valdes, P.J., 2013. Millennial climatic fluctuations are key to the structure of last glacial ecosystems. *PLOS one, 8*(4), e61963. (https://doi.org/10.1371/journal.pone.0061963)

Hutchings, W.K., 2016. When is a point a projectile? Morphology, impact fractures, scientific rigor, and the limits of inference. In R. Iovita & K. Sano (eds.), *Multidisciplinary approaches to the study of Stone Age weaponry* (pp. 3-12). Springer, Dordrecht.

Iovita, R., Schönekeß, H., Gaudzinski-Windheuser, S. and Jäger, F., 2014. Projectile impact fractures and launching mechanisms: results of a controlled ballistic experiment using replica Levallois points. *Journal of Archaeological Science, 48*, pp.73-83.

Jacobi, R.M. and Pettitt, P.B., 2000. An Aurignacian point from Uphill Quarry (Somerset) and the earliest settlement of Britain by *Homo sapiens sapiens*. *Antiquity, 74*(285), pp.513-518.

Jacobi, R.M. and Higham, T.F.G., 2008. The “Red Lady” ages gracefully: new ultrafiltration AMS determinations from Paviland. *Journal of Human Evolution*, *55*(5), pp.898-907.

Jelinek, A.J., 1994. Hominids, energy, environment, and behavior in the late Pleistocene. In M.H. Nitecki & D.V. Nitecki (eds.), *Origins of Anatomically Modern Humans* (pp. 67-92). Interdisciplinary Contributions to Archaeology, Springer US.

Jéquier, C., 2016. The incised bone points from the Early Aurignacian of Potočka zijalka (Slovenia), hafting system or ornament? *Quaternary International*, *403*, pp.51-56.

Jöris, O., Street, M., Terberger, T. and Weninger, B., 2011. Radiocarbon dating the Middle to Upper Palaeolithic transition: the demise of the last Neanderthals and the first appearance of anatomically modern humans in Europe. In S. Condemi & G.-C. Weniger (eds.), *Continuity and discontinuity in the peopling of Europe: One hundred fifty years of Neanderthal Study* (pp. 239-298). Vertebrate Paleobiology and Paleoanthropology, Springer, Dordrecht.

Julien, M.A., 2011. Chasseurs de bisons: apports de l'archéozoologie et de la biogéochimie isotopique à l'étude palethnographique et paléoéthologique du gisement épigravettien d'Amvrosievka (Ukraine). PhD thesis? If so, where?

Khlopachev, G.A. and Girya, E.Y., 2010. *Secrets of ancient carvers of Eastern Europe and Siberia: Treatment techniques of ivory and reindeer antler in the Stone Age according to archaeological and experimental data.* Nauka Saint-Petersburg.

Knecht, H.D., 1991. *Technological innovation and design during the Early Upper Paleolithic: a study of organic projectile technologies*. Unpublished PhD thesis, University of New York.

Knecht, H., 1993. Early Upper Paleolithic approaches to bone and antler projectile technology. In G.L. Peterkin, H.M. Bricker & P. Mellars (eds.), *Hunting and Animal Exploitation in the Later Palaeolithic and Mesolithic of Europe.* Archeological Papers of the American Anthropological Association, 4, pp.33-47.

Knecht, H., 1993. Splits and wedges: the techniques and technology of early Aurignacian antler working. In R. White, H. Knecht & A. Pike-Tay (eds.), *Before Lascaux: The Complex Record of the Early Upper Paleolithic*, pp.137-162. CRC Press, Boca Raton.

Knecht, H., 1997. Projectile points of bone, antler, and stone. In H. Knecht (ed.), *Projectile technology* (pp. 191-212). Springer US.

Koch, G.W., Sillett, S.C., Jennings, G.M. and Davis, S.D., 2004. The limits to tree height. *Nature, 428*(6985), pp.851-854.

Koller, J., Baumer, U. and Mania, D., 2001. Pitch in the Palaeolithic-Investigations of the Middle Palaeolithic "resin remains" from Königsaue. In G.A. Wagner & D. Mania (eds), *Frühe Menschen in Mitteleuropa-Chronologie, Kultur & Umwelt*, pp.99-112.

Kozłowski, J.K., 2004. Early Upper Paleolithic Levallois-derived industries in the Balkans and in the Middle Danube basin. *Anthropologie (1962-)*, *42*(3), pp.263-280.

Kulin, R.M., Chen, P.Y., Jiang, F. and Vecchio, K.S., 2011. A study of the dynamic compressive behavior of elk antler. *Materials Science and Engineering: C*, *31*(5), pp.1030-1041.

Lartet, E., 1861. New research on the coexistence of man and large fossil mammals reputed to be characteristic of the last geological period. In *Annales des. Sci. natural* (Vol. 15, pp. 177-253).

La Porta, A., 2019. *Neanderthal stone-tipped spear technology: an experimental and archaeological investigation* (Unpublished PhD dissertation, University of Exeter).

Latta, F.F., 1949. *Handbook of the Yokuts Indians.* Exeter, CA: Brewer's Historical Press, Salinas.

Lazuén, T., 2012. European Neanderthal stone hunting weapons reveal complex behaviour long before the appearance of modern humans. *Journal of Archaeological Science*, *39*(7), pp.2304-2311.

Lloveras, L., Maroto, J., Soler, J., Thomas, R., Moreno-García, M., Nadal, J. and Soler, N., 2016. The role of small prey in human subsistence strategies from Early Upper Palaeolithic sites in Iberia: the rabbits from the Evolved Aurignacian level of Arbreda Cave. *Journal of Quaternary Science*, *31*(5), pp.458-471.

MacDonald, K., 2019. Strong Differences Between Neanderthals and AMHs Cannot Be Inferred from Ethnographic Evidence for Skill and Learning in Hunting. In Y. Nishiaki & O. Jöris (eds.), *Learning Among Neanderthals and Palaeolithic Modern Humans* (pp. 149-158). Replacement of Neanderthals by Modern Humans Series, Springer, Singapore.

Mannino, M.A., Di Salvo, R., Schimmenti, V., Di Patti, C., Incarbona, A., Sineo, L. and Richards, M.P., 2011. Upper Palaeolithic hunter-gatherer subsistence in Mediterranean coastal environments: an isotopic study of the diets of the earliest directly-dated humans from Sicily. *Journal of Archaeological Science*, *38*(11), pp.3094-3100.

Marquer, L., Otto, T., Nespoulet, R. and Chiotti, L., 2010. A new approach to study the fuel used in hearths by hunter-gatherers at the Upper Palaeolithic site of Abri Pataud (Dordogne, France). *Journal of Archaeological Science*, *37*(11), pp.2735-2746.

Mellars, P., 1973. The character of the Middle-Upper Palaeolithic transition in south-west France. In C. Renfrew (ed.), *The explanation of culture change: Models in prehistory*, pp.255-276. Duckworth, London.

Mellars, P., 2000. The archaeological records of the Neandertal-modern human transition in France. In O. Bar-Yosef & D. Pilbeam (eds.), *The Geography of Neandertals and Modern Humans in Europe and the Greater Mediterranean*. *Peabody Museum Bulletin*, 8, pp.35-47.

Mellars, P., 2002. The impact of climatic changes on the demography of late Neandertal and early anatomically modern populations in Europe. In T. Akazawa, K. Aoki & O. Bar-Yosef (eds.), *Neandertals and modern humans in Western Asia* (pp. 493-507). Springer US.

Mellars, P., 2004. Neanderthals and the modern human colonization of Europe. *Nature, 432*(7016), pp.461-465.

Mellars, P.A., 2004. Reindeer specialization in the early Upper Palaeolithic: the evidence from south west France. *Journal of archaeological science*, *31*(5), pp.613-617.

Mellars, P., 2006. Archeology and the dispersal of modern humans in Europe: Deconstructing the "Aurignacian". Evolutionary Anthropology, 15(5), pp.167-182.

Meyer, C., 1952, Carl Meyer's Account of the Indians in Trindad Bay in 1851. In *The Four Ages of Tsurai*, edited by R. E Heizer and J. Mills, pp. 119–134. University of California Press, Berkeley, California.

Milks, A., Parker, D. and Pope, M., 2019. External ballistics of Pleistocene hand-thrown spears: experimental performance data and implications for human evolution. *Scientific reports*, *9*(1), pp.1-11.

Moreau, L., Brandl, M., Filzmoser, P., Hauzenberger, C., Goemaere, É., Jadin, I., Collet, H., Hauzeur, A. and Schmitz, R.W., 2016. Geochemical sourcing of flint artifacts from western Belgium and the German Rhineland: testing hypotheses on Gravettian period mobility and raw material economy. *Geoarchaeology*, *31*(3), pp.229-243.

Moseley, H. N., 1877, On the Inhabitants of the Admiralty Islands. *Journal of the Anthropological Institute of Great Britain and Ireland* 6:379–429.

Mussi, M., Gioia, P. and Negrino, F., 2006. Ten small sites: the diversity of the Italian Aurignacian. In O. Bar-Yosef & J. Zilhão (eds.), *Towards a definition of the Aurignacian (Proceedings of the symposium held in Lisbon, Portugal, June 25-30, 2002),* pp.189-209. Trabalhos de Arqueologia 45, Instituto Português de Arqueologia, Lisbon.

Muttoni, G., Kent, D.V., Scardia, G. and Monesi, E., 2014. Migration of hominins with megaherbivores into Europe via the Danube-Po Gateway in the late Matuyama climate revolution.

Nelson, E. W, 1899, The Eskimo About Bering Strait. *Annual Report of the Bureau of American Ethnology for 1896–1897*, Volume 18.

Newcomer, M.H., 1974. Study and replication of bone tools from Ksar Akil (Lebanon). *World Archaeology*, *6*(2), pp.138-153.

Niven, L., 2007. From carcass to cave: large mammal exploitation during the Aurignacian at Vogelherd, Germany. *Journal of Human Evolution*, *53*(4), pp.362-382.

Noetling, F., 1911. Notes on the hunting sticks (lughkana), spears (perenna), and baskets (tughbrana) of the Tasmanian Aborigines. *Papers and Proceedings of the Royal Society of Tasmania* 1911 (pp. 64-106).

Nuzhnyi, D., 1998. The preliminary results of experiments with Aurignacian split based points production, hafting and usage. *Préhistoire européenne*, *13*, pp.117-132.

Olsen, S.L., 1989. Solutré: a theoretical approach to the reconstruction of Upper Palaeolithic hunting strategies. *Journal of Human Evolution*, *18*(4), pp.295-327.

Owen-Smith, N., 2013. Contrasts in the large herbivore faunas of the southern continents in the late Pleistocene and the ecological implications for human origins. *Journal of Biogeography*, *40*(7), pp.1215-1224.

Peissel, M., 1984. *The ants' gold: the discovery of the Greek El Dorado in the Himalayas*. Harvill Press.

Pétillon, J.M., 2003. Tir expérimental de pointes à base fourchue en bois de renne. In V. Dujardin (ed.), *Industrie Osseuse et Parures du Solutréen au Magdalénien en Europe* (*Table ronde sur le Paléolithique supérieur recent, Angoulême, March 2003),* (pp. p-243). Société préhistorique française, Mémoire 39.

Pétillon, J.M., Plisson, H. and Cattelain, P., 2016. Thirty years of experimental research on the breakage patterns of Stone Age osseous points. Overview, methodological problems and current perspectives. In *Multidisciplinary approaches to the study of Stone Age weaponry* (pp. 47-63). Springer, Dordrecht.

Peyrony, D., 1932. *Les Abris Lartet et du Poisson à Gorge-d'Enfer (Dordogne)*. Masson et Cie.

Peyrony, D., 1933. Les Industries «aurignaciennes». dans le bassin de la Vézère. *Bulletin de la Société préhistorique de France*, *30*(10), pp.543-559.

Peyrony, D., 1934. La Ferrassie: Moustérien – Pérgordien – Aurignacien. *Préhistoire III*, pp.1-92.

Piskorska, T., Stefaniak, K., Krajcarz, M. and Krajcarz, M.T., 2015. Reindeer during the Upper Palaeolithic in Poland: Aspects of variability and paleoecology. *Quaternary international*, *359*, pp.157-177.

Price, T.D., Bentley, R.A., Lüning, J., Gronenborn, D. and Wahl, J., 2001. Prehistoric human migration in the Linearbandkeramik of Central Europe. *Antiquity*, *75*(289), pp.593-603.

Price, T.D., Meiggs, D., Weber, M.J. and Pike-Tay, A., 2017. The migration of Late Pleistocene reindeer: isotopic evidence from northern Europe. *Archaeological and Anthropological Sciences*, *9*(3), pp.371-394.

Pokines, J.T., 1998. Experimental replication and use of Cantabrian Lower Magdalenian antler projectile points. *Journal of Archaeological Science*, *25*(9), pp.875-886.

Pryor, A.J.E., Pullen, A., Beresford-Jones, D.G., Svoboda, J.A. and Gamble, C.S., 2016. Reflections on Gravettian firewood procurement near the Pavlov Hills, Czech Republic. *Journal of Anthropological Archaeology*, *43*, pp.1-12.

Radmilli, A.M. and Boschian, G., 1996. *Gli scavi a Castel di Guido: il più antico giacimento di cacciatori del Paleolitico inferiore nell'Agro Romano*. Istituto italiano di preistoria e protostoria.

Rees, A.J., 2003. *An experimental analysis of Aurignacian Bone and Antler Spear points*. BA dissertation. University of Southampton.

Richards, MP, Taylor, G., Steele, T., McPherron, SP, Soressi, M., Jaubert, J., Orschiedt, J., Mallye, JB, Rendu, W. and Hublin, JJ, 2008. Isotopic dietary analysis of a Neanderthal and associated fauna from the site of Jonzac (Charente-Maritime), France. *Journal of Human Evolution*, *55* (1), pp. 179-185.

Richards, M.P. and Trinkaus, E., 2009. Isotopic evidence for the diets of European Neanderthals and early modern humans. *Proceedings of the National Academy of Sciences*, *106*(38), pp.16034-16039.

Řičánková, V.P., Robovský, J. and Riegert, J., 2014. Ecological structure of recent and last glacial mammalian faunas in northern Eurasia: the case of Altai-Sayan refugium. *PloS one*, *9*(1), .e85056 (doi:10.1371/journal.pone.0085056).

Riehl, S., Marinova, E., Deckers, K., Malina, M. and Conard, N.J., 2015. Plant use and local vegetation patterns during the second half of the Late Pleistocene in southwestern Germany. *Archaeological and Anthropological Sciences*, *7*(2), pp.151-167.

Ronen, A., 1976. The Upper Palaeolithic in northern Israel, Mt. Carmel and Galilee. In F. Wendorf (ed.), *Deuxième colloque sur la terminologie de la préhistoire du Proche-Orient (Colloque III, IX UISPP Congress, Nice, Sept. 1976),* (pp. 153-186).

Saarinen, J., Eronen, J., Fortelius, M., Seppä, H. and Lister, A.M., 2016. Patterns of diet and body mass of large ungulates from the Pleistocene of Western Europe, and their relation to vegetation. *Palaeontologia Electronica*, *19*(3.32), pp.1-58.

Sarig, R., Fornai, C., Pokhojaev, A., May, H., Hans, M., Latimer, B., Barzilai, O., Quam, R. and Weber, G.W., 2019. The dental remains from the Early Upper Paleolithic of Manot Cave, Israel. *Journal of Human Evolution*, p.102648.

Schenck, T. and Groom, P., 2018. The aceramic production of Betula pubescens (downy birch) bark tar using simple raised structures. A viable Neanderthal technique? *Archaeological and Anthropological Sciences*, *10*(1), pp.19-29.

Schmider, B., David, F. and Roblin-Jouve, A., 2004. Nouvelles données sur le Gravettien de la grotte du Renne à Arcy-sur-Cure (Yonne). In M. Dewez, P. Noiret & E. Teheux (eds.), Section 6: The Upper Palaeolithic (Act of the XIVth UISPP Congress, University of Liège, Sept. 2001), *BAR International Series*, *1240*, Oxford, pp.13-22.

Schmidt, I. and Zimmermann, A., 2019. Population dynamics and socio-spatial organization of the Aurignacian: Scalable quantitative demographic data for western and central Europe. *PloS one*, *14*(2): e0211562. (https://doi.org/10.1371/journal.pone.0211562.)

Schmitt, D., Churchill, S.E. and Hylander, W.L., 2003. Experimental evidence concerning spear use in Neandertals and early modern humans. *Journal of Archaeological Science*, *30*(1), pp.103-114.

Schreiner, E.J., 1959. Production of poplar timber in Europe and its significance and application in the United States. US Dept. of Agriculture, Forest Service; Washington D.C.

Schweingruber, F.H., 2007. *Wood structure and environment*. Springer Science & Business Media.

Shaw, A.D., Daffern, N. and Russell, O., 2016. The Palaeolithic in Worcestershire, UK. *Lithics–The Journal of the Lithic Studies Society*, (36), p.41.

Shea, J., Davis, Z. and Brown, K., 2001. Experimental tests of Middle Palaeolithic spear points using a calibrated crossbow. *Journal of Archaeological Science*, *28*(8), pp.807-816.

Smith, B.D., 2013. Modifying landscapes and mass kills: Human niche construction and communal ungulate harvests. *Quaternary International*, *297*, pp.8-12.

Spencer, B., 1914. *Aboriginals of Australia*. AJ Mullett, Government Printer.

Stenton, D.R., 1991. The adaptive significance of caribou winter clothing for arctic hunter-gatherers. *Etudes/Inuit/Studies*, 15(1), pp.3-28.

Stewart, J.R., Van Kolfschoten, M., Markova, A. and Musil, R., 2003. The mammalian faunas of Europe during oxygen isotope stage three. In T.H. van Andel & W. Davies (eds.), *Neanderthals and modern humans in the European landscape during the last glaciation*, *60*(000), pp.103-129. McDonald Institute Monographs, Cambridge.

Stewart, J.R., 2004. Neanderthal–modern human competition? A comparison between the mammals associated with Middle and Upper Palaeolithic industries in Europe during OIS 3. *International Journal of Osteoarchaeology*, *14*(3-4), pp.178-189.

Straus, L.G., 1992. *Iberia before the Iberians. Stone Age Prehistory of Cantabrian Spain.* University New Mexico Press, Alburquerque.

Stodiek, U., 1993. Zur Technologie der jungpaläolithischen Speerschleuder-Eine Studie auf der Basis archäologischer, ethnologischer und experimenteller Erkenntnisse. *Archäologische Informationen*, *16*(1), pp.138-139.

Sturdy, D.A., 1975. Some reindeer economies in prehistoric Europe. In E.S. Higgs (ed.), *Palaeoeconomy. Cambridge University Press, Cambridge, pp.55-95.*

Szmidt, C.C., Brou, L. and Jaccottey, L., 2010. Direct radiocarbon (AMS) dating of split-based points from the (Proto) Aurignacian of Trou de la Mère Clochette, Northeastern France. Implications for the characterization of the Aurignacian and the timing of technical innovations in Europe. *Journal of Archaeological Science, 37(*12), pp.3320-3337.

Tartar, E. and White, R., 2013. The manufacture of Aurignacian split-based points: an experimental challenge. *Journal of Archaeological Science, 40(6)*, pp.2723-2745.

TCV Practical Conservation Handbooks. (2017). *How to coppice trees - the art of managing hazel and other tree species*. [online] Available at: https://www.conservationhandbooks.com/how-coppice-trees/ [Accessed 20 Nov. 2020].

Tejero, J.M., 2016. Spanish Aurignacian projectile points: an example of the first European Paleolithic hunting weapons in osseous materials. In M.C. Langley (ed.), *Osseous Projectile Weaponry* (pp. 55-69). Springer Netherlands.

Théry-Parisot, I., 2002. Gathering of firewood during the Palaeolithic. *Charcoal Analysis. Methodological Approaches, Palaeoecological Results and Wood Uses.* In S. Thiébault (ed.), *Charcoal Analysis: Methodological approaches, palaeoecological results and wood uses (Proceedings of the second international meeting of anthracology, Paris, September 2000)*, *BAR International Series*, *1063*, Oxford, pp.243-249.

Thieme, H., 2005. The Lower Palaeolithic art of hunting. In C. Gamble & M. Porr (eds.), *The Hominid Individual in Context: Archaeological investigations of Lower and Middle Palaeolithic landscapes, locales and artefacts*, pp.115-132. Routledge, Abingdon.

Tomasso, A., Rots, V., Purdue, L., Beyries, S., Buckley, M., Cheval, C., Cnuts, D., Coppe, J., Julien, M.A., Grenet, M. and Lepers, C., 2018. Gravettian weaponry: 23,500-year-old evidence of a composite barbed point from Les Prés de Laure (France). *Journal of Archaeological Science*, *100*, pp.158-175.

Tromnau, G., 1975. *Neue Ausgrabungen im Ahrensburger Tunneltal: Ein beitrag zur erforschung des jungpaläolithikums im nordwesteuropäischen flachland*. Wachholtz.

Uzquiano, P., 2008. Domestic fires and vegetation cover among Neanderthalians and Anatomically Modern Human groups (> 53 to 30 Kyrs BP) in the Cantabrian Region (Cantabria, Northern Spain). In G. Fiorentino & D. Magri (eds.), *Charcoal from the Past: Cultural and Palaeoenvironmental implications (Proceedings of the Third International Meeting of Anthracology, Cavallino - Lecce (Italy), June 28th - July 1st 2004)*, pp.273-285. BAR International Series, 1807, Oxford.

Van Andel, T.H. and Tzedakis, P.C., 1996. Palaeolithic landscapes of Europe and environs, 150,000-25,000 years ago: an overview. *Quaternary Science Reviews*, *15*(5-6), pp.481-500.

Van Andel, T.H. and Davies, W., 2003. *Neanderthals and modern humans in the European landscape during the last glaciation: archaeological results of the Stage 3 Project*. McDonald Institute for Archaeological Research monographs, Cambridge.

Van Huissteden, K., Vandenberghe, J. and Pollard, D., 2003. Palaeotemperature reconstructions of the European permafrost zone during marine oxygen isotope Stage 3 compared with climate model results. *Journal of Quaternary Science*, *18*(5), pp.453-464.

Verpoorte, A., 2015. Caching and retooling in Potočka zijalka (Slovenia). Implications for Late Aurignacian land use strategies. *Archäologisches Korrespondenzblatt*, *42*(2), pp.135-151.

Villa, P. and D'errico, F., 2001. Bone and ivory points in the Lower and Middle Paleolithic of Europe. *Journal of Human Evolution*, *41*(2), pp.69-112.

Weinstock, J., 2002. Reindeer hunting in the Upper Palaeolithic: Sex ratios as a reflection of different procurement strategies. *Journal of Archaeological Science*, *29*(4), pp.365-377.

Wilkins, J., Schoville, B.J., Brown, K.S. and Chazan, M., 2012. Evidence for early hafted hunting technology. *Science*, *338*(6109), pp.942-946.

Wilkins, J., Schoville, B.J. and Brown, K.S., 2014. An experimental investigation of the functional hypothesis and evolutionary advantage of stone-tipped spears. *PloS one*, *9*(8), e104514. (https://doi.org/10.1371/journal.pone.0104514.)

Willis, K.J. and Van Andel, T.H., 2004. Trees or no trees? The environments of central and eastern Europe during the Last Glaciation. *Quaternary Science Reviews*, *23*(23), pp.2369-2387.

Wolf, S., Münzel, S.C., Dotzel, K., Barth, M.M. and Conard, N.J., 2016. Projectile weaponry from the Aurignacian to the Gravettian of the Swabian Jura (Southwest Germany): Raw materials, manufacturing and typology. In M.C. Langley (ed.), *Osseous Projectile Weaponry* (pp. 71-87). Springer Netherlands.

Wood, J. and Fitzhugh, B., 2018. Wound ballistics: The prey specific implications of penetrating trauma injuries from osseous, flaked stone, and composite inset microblade projectiles during the Pleistocene/Holocene transition, Alaska USA. *Journal of Archaeological Science*, *91*, pp.104-117.

Zilhão, J. and d'Errico, F., 2003. An Aurignacian «garden of Eden» in southern Germany? An alternative interpretation of the geissenklösterle and a critique of the Kulturpumpe model. *PALEO. Revue d'archéologie préhistorique*, (15).