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FROM THESE BARE BONES

Raw materials and the study of worked osseous objects

edited by

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Some Comments on the Identification of Cervid Species in Worked Antler

Steven P. Ashby

"…Variation in antler construction combines in the least reliable manner all the effects of sexual, developmental and individual variation that can be imagined" (Webb 2000: 62)

Research into objects of worked antler is characterised by a certain inconsistency of approach to raw material identification, particularly regarding identification to species level. Some workers routinely record species, while others do not, and it is apparent that a number of diagnostic criteria have been used, albeit often implicitly. This paper makes no claim to resolve this situation, but in outlining some of the potentials and many confounds of various microscopic and macroscopic techniques, the author hopes to inspire cautious enquiry into raw material exploitation, and to encourage further research into the introduced phenomena. Recently developed biomolecular approaches have the potential to transform the way we think about this material, but at present we are still reliant on sampling techniques that may not always be appropriate for application to the material in question. They may, however, provide an excellent complement to zooarchaeological approaches.

Keywords
Antler; artefacts; species; deer; combs; worked bone; raw material identification; microscopy; macrostructure.

Introduction

This article emerges from exploratory work undertaken in the course of the author's doctoral research at the University of York. It began in an attempt to address a long-standing question in Scottish archaeology: that of pre-Viking Age contact between northern Scotland and Scandinavia (see Barrett 2003; Myhre 1993). A key piece of evidence relates to the identification of certain combs of 'pre-Viking' form as being made from reindeer antler (*Rangifer tarandus*): a species alien to the British Isles since early prehistory (Clutton-Brock and MacGregor 1988). This issue has been investigated at length elsewhere (Weber 1992, 1993, 1994;

Ballin Smith 1995; Ashby 2006, 2009), but given that the means by which antler may be identified to species are not well known, the present paper provides an opportunity to introduce the issue of identification in a little further detail.

Initial work in this field (Weber 1992, 1993, 1994; Ballin Smith 1995) stated that it was possible to confidently identify the antler in combs to species level (i.e. *Cervus elaphus* vs *Rangifer tarandus*). This research was dependent on the identifications of an experienced zooarchaeologist, Rolf Lie, curator of the zoological museum at the University of Bergen. Unfortunately, detailed accounts of Dr Lie's identification criteria have not been published, and this has led to some

scepticism amongst archaeologists of Atlantic Scotland (see Graham-Campbell and Batey 1998, 23; Smith 2000, 185). The key information we have is as follows:

> "… the combs show very clearly the spongy structure characteristic of reindeer antler. In this spongy part the pores are larger; elsewhere the bones are very solid with nearly invisible pores. The antler of red deer has at its base a spongy part similar to that of the bones; elsewhere it looks very solid and heavier than reindeer antler. Elk antler has for the most no spongy parts; it is very hard and has a glassy look." (Lie 1993)

This is a useful start, but clearly further empirical work is needed. Independent of the work published by Weber, a number of specialists have published short statements on identification methods (see Ambrosiani 1981, 102–109; Carlé *et al.* 1976; Ilkjaer 1993, 316–319; Stephan 1994). Most notably, Dr Lyuba Smirnova (2005, 9–15), a Russian archaeologist studying worked bone and antler from medieval Novgorod, recently devised a macroscopic system for the recognition of red deer (*Cervus elaphus*), reindeer (*Rangifer tarandus*), and European elk (*Alces alces*) antler. This proved effective in the recognition both of waste products and of finished combs (Smirnova 2002). However, while Ambrosiani, Smirnova *et al.* outlined their identification criteria in some detail, these methods have yet to be subjected to independent investigation. One objective of the present author's doctoral research was to critically consider these approaches and to build upon the insights they provided, in order to develop a new, systematic protocol for the identification of worked antler to species, and to offer some suggestions for further work. This paper provides some reflections on these issues.

The experience with antler fragments and manufacturing waste that Smirnova gathered in the course of her original Ph.D research (Smirnova 1997) helped lay the groundwork for the identification of antler to species in simple and composite combs; a task she undertook as part of a second thesis (Smirnova 2002, subsequently published as Smirnova 2005). Smirnova was kind enough to demonstrate her approach, some elements of which have been adapted and incorporated into the methods discussed below (embellished with observations from the author's personal collection and the reference material at the British Museum (Natural History)). It should be noted that the following material does not contain the findings of controlled investigations or quantitative analyses. Rather, it provides a number of observations which may prove useful as rules-of-thumb, or as starting points (null hypotheses?) for finer-grained zoological analyses.

Gross and surface morphology

It is now appropriate to briefly highlight the basic differences in gross antler morphology between the three cervid species at the centre of this paper. Such information is invaluable in the study of craft debitage, semi-manufactures, and other waste material, as well as a prerequisite for the study of finished objects. In what follows, the key morphological characteristics of red deer (*C. elaphus*), reindeer (*R. tarandus*) and elk (*A. alces*) antler are outlined (Fig. 20.1).

The antlers of the red deer (*C. elaphus*) are highly variable, but can be defined briefly by the presence of a few characteristics, most notably a marked branching and lack of palmation. However, in rare cases, *C. elaphus* may also develop palmation in the crown. In the British Isles this trait is generally, though not exclusively, related to interbreeding with Sika (*Cervus nippon*), a cervid that was recently introduced to Britain (for a detailed discussion see Lowe and Gardiner 1975).

Continental red deer antlers may reach 120 cm in length, and have up to 20 points, but in Scotland 90 cm and 14 points would be considered good development (Krzyskowska 1990, 60). The beam has a much greater radius than that of reindeer (*R. tarandus*), but fragments could be confused with elk (*A. alces*) where evidence of tines or palmation is not preserved. However, the pedicle, consisting entirely of compact bone, is much longer in red deer than in elk, and the shape of the bony coronet is oval, whereas in elk it is roughly circular (Smirnova pers. comm.), with a 'beaded' surface texture.

The surface of red deer antler is usually very rough, and marked by deep channels, though there is some variability between (and even within) the antlers of *Cervus* individuals. For instance, upper tines are often smoother than the main beam, perhaps due to brushing (rubbing against vegetation in order to accelerate the shedding of velvet) (Krzyskowska 1990, 60). Nonetheless, where present, the rough outer surface is diagnostic (see Fig. 20.2). Unfortunately, it is usually removed prior to the manufacture of objects (see MacGregor 1985, 58), but may occasionally be preserved even in worked artefacts.

The antlers of *A. alces* lack a brow tine, and tend to have a large round burr (see Fig. 20.1). Most notably, they are large and heavily palmated, reaching up to 2m in span (Huffman 2003). Though less palmated examples are known (see Saether and Haagenrud 1985, 985), they are nonetheless distinctive
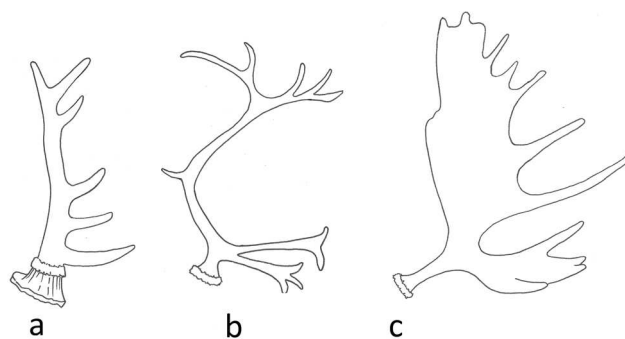

Figure 20.1 Gross morphology of (a) Cervus elaphus, *(b)* Rangifer tarandus, *male, (c)* Alces alces *(drawings: Hayley Saul).*

Figure 20.2 Surface texture of (a) Cervus elaphus*, (b)* Rangifer tarandus*, (c)* Alces alces *(photographs: S. Ashby).*

in form, size, and weight. The surface of elk antler features broad guttering, but this can be differentiated from red deer antler, principally by means of scale (Fig. 20.2).

Reindeer (*R. tarandus*) antlers are quite distinctive (Fig. 20.1). They are markedly asymmetrical, relatively thin in cross-section, and have a characteristic rough, outer surface (which is grey in fresh material). The males also bear distinctive 'snow shovels' for brow tines. Also of note is the fact that *R. tarandus* pedicles may be less than 5mm long (Lie *et al.* 2003, 335). The antlers of male and female reindeer are easily distinguished, bull antler being much more elaborate and massive than cow antler. Nonetheless, there is variation within sexes, and it is possible that a rack from a young male may be confused with that of a mature female. More importantly, however, the antlers of reindeer as a whole are sufficiently distinctive so that they are very unlikely to be mistaken for those of another species. The natural outer surface of reindeer antler is somewhat less rough than that of red deer or elk. It lacks the distinctive channelling, although isolated grooves are occasionally present (Fig. 20.2).

Macrostructure and small-scale variation

In objects, the task of isolating consistently preserved distinctive features is obviously more difficult. Occasionally, it is impossible to categorically differentiate elk and red deer, but Smirnova claims that in her experience it is always possible to identify reindeer antler, providing that a variety of criteria are investigated in combination (see Smirnova 2002, 19). Polish, texture, dimensions and compact structure can be valuable clues, but none of these properties are sufficiently diagnostic to be used as anything more than supporting criteria.

Identification of the raw materials used in highly worked objects such as dress pins and composite combs can prove challenging, as in many cases all traces of porous material and surface texture have been systematically removed as part of the manufacturing process. However, in the less closely-worked areas of artefacts, one may occasionally discern small zones

Figure 20.3 Macrostructural preservation in archaeological material: a) core and core-compacta margin revealed in longitudinal section, on reverse of an early-medieval comb connecting plate from Burdale, Yorkshire: probably C. elaphus; b) core preserved in transverse section on back edge of an early-medieval comb toothplate from Birka, Sweden, indeterminate species (photographs: S. Ashby, courtesy Julian D. Richards (a) and Statens Historiska Museet (b)).

of visible macrostructure, and these often prove valuable in material characterisation and identification. On single-sided composite combs, for example, inspection of the back surface (the surface running along the upper edge of the comb at approximately 90° to the front face of the connecting plate) is frequently instructive. This area may render visible the rough interior surfaces of the toothplates clamped between connecting plates. Breakages also facilitate identification, as they often reveal the cross-sections of connecting plates in which distinctive features of internal macrostructure may be visible (Fig. 20.3). In particular, one may observe the distinctive characteristics of (1) outer areas of compact antler; (2) porous core, composed of cancellous tissue; and (3) the margin between these two zones.

Compact antler

Both Ambrosiani (1981, 103) and Smirnova (2005, 11) have suggested that the compact material that makes up the outer portion of an antler contains certain diagnostic features. Smirnova has suggested that there are species-diagnostic differences in the degree of 'organisation' of blood vessels in the compacta which has implications for the roughness of the texture. Similarly, Ambrosiani points out that elk antler preserves the 'black thread' traces of blood vessels in its compacta, which is itself less 'regular' than that seen in red deer antler. However, this author found it difficult to characterise either modern or archaeological material in this way, and no diagnostic characteristics could be identified under low magnification (up to 10×). To a certain degree the compact structure of red deer antler does seem more regular and organised than that of reindeer, but this is not easily quantified, and the degree of overlap is so marked that any attempt to delineate a fixed watershed between the two species would be something of an arbitrary contrivance. Moreover, the compact structure of elk was very difficult to observe (even at a magnification of 10×, with a movable light source). All in all, I found that the structure of compact tissue in modern antler could not be readily used as a means of species differentiation. It is possible that diagenetic staining would render identification more straightforward, and future investigations involving quantitative image analysis might facilitate more precise characterisation of the antler compacta of different species, but at the present time, there appears no justification for the application of this methodology in isolation.

Porous core and 'transition zone'

A number of researchers (e.g. Ambrosiani 1981; Smirnova 2005) have noted distinctive features of the porous core and its margin with outer compact antler in red deer, reindeer, and elk. Notwithstanding the fact that these phenomena are not easily quantified, they offer potential as diagnostic criteria that could be recorded on a qualitative basis, providing that the protocols of recording were sufficiently rigorous, and undertaken with the use of a reference collection. They thus merit further investigation herein.

To summarise, the porous core of elk antler is very distinctive, containing fine, elongated pores that are often only clearly visible with the aid of a microscope. In material previously seen by the author, palmated areas evidenced a distinctive spongy core, in which the porosity was clearly visible, but nonetheless markedly finer than that typical for red deer (Fig. 20.4a). No attempt at quantification was made; this is perhaps an area that would merit further investigation. In the material examined in the present study (which was relatively small in size, and not well-palmated), the core was very finely porous throughout, such that individual pores were not easily identifiable with the naked eye (Fig. 20.4b). Indeed, in the distal areas such as the

tines of *A. alces* antler, the core areas themselves were invisible without magnification. This is no doubt the phenomenon to which Penniman (1952, 37) refers when he notes that "elk seems to be closer-grained than reindeer".

Red deer and reindeer antler are relatively easily distinguished from elk, as the pores are much rounder in *Cervus* and *Rangifer* than in *Alces*. Reindeer antler core is typically very fine, but the primary difference between *Cervus* and *Rangifer* lies in the gradation to compacta. In reindeer this is extremely gentle and diffuse with a semi-porous zone (no doubt Lie's 'spongy structure'), while the boundary is much more discrete in red deer (Smirnova 2002) (Fig. 20.5).

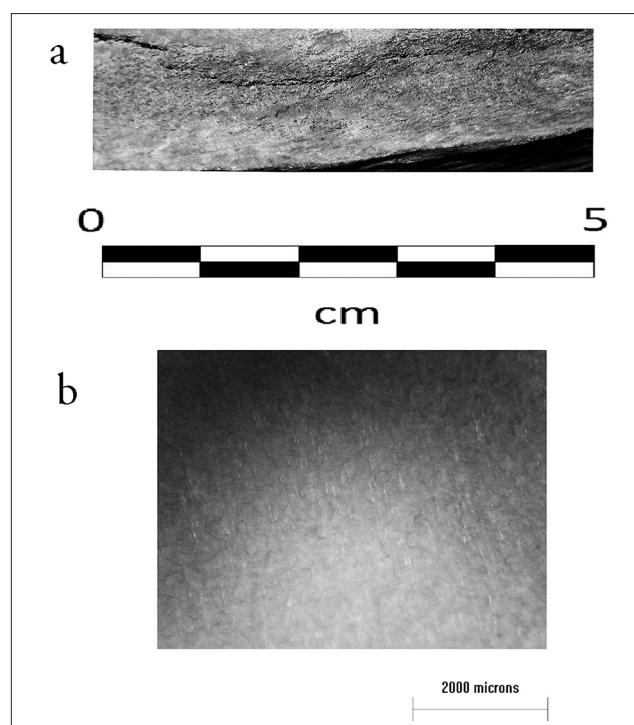*Figure 20.4 Core structure in* Alces alces*: a) open, spongy structure visible in palmated areas; early medieval material from Birka, Sweden; b) finer structure in relatively unpalmated modern material (photographs: S. Ashby, (a) courtesy Statens Historiska Museet).*
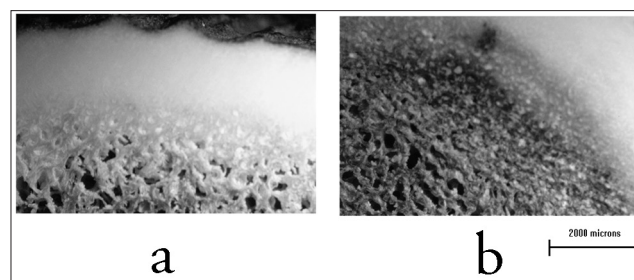

Figure 20.5 Core-compacta transition in a) Cervus elaphus*, b)* Rangifer tarandus*. Modern material (photographs: S. Ashby).*

These criteria have been shown to be useful in the study of antler waste and artefacts (Smirnova 1997, 2002); they were, after all, developed in order to be of use in the analysis of archaeological material. One might hope that the application of such criteria to other corpora should prove possible; given that the techniques appear to have been effective as aids in the study of highly worked objects such as composite combs, one may suppose that they might be easily applied to a wide range of other objects (such as handles, pegs, vessels, toggles, buckleplates and strap-ends), if not to very highly-worked pieces such as decorative pins. Nonetheless, Smirnova's criteria are grounded in personal experience rather than empirical testing. More importantly, given that these techniques were developed through the study of, and in preparation for, the recording of material from Novgorod, it may be that the particular preservation quality of the material from this corpus lends itself to fine-grained analysis. Thus, we should consider whether Smirnova's criteria (or her application of confidence qualifiers) may require modification in order to account for differences in preservation at other sites. In particular, it is important to consider the possibility of distinctive macrostructures being generated (or influenced) by factors other than species. In the following, I review existing literature on the relationship between antler growth and a number of variables: individual maturity; sex, environment, and phase of antlerogenesis. I then offer some preliminary thoughts on the potential of these (and other) variables to confound attempts to identify species on macrostructural grounds.

Existing work on the process of antler growth

The key factors likely to affect antler growth and development are discussed below. These factors are inter-related, rather than being truly independent variables. For example, the relationship between environment and nutrition must be a close (but complex) one, and it may also be that different sexes respond to malnutrition in different ways (see for instance Clutton-Brock 1989, 2; Horwitz and Smith 1990).

Individual confounds

Many physical attributes of deer vary considerably between individual animals (Mitchell *et al.* 1977, 41). For example, the age of the animal from which antler was taken may have an influence. Age is related to overall morphology, as antler size and complexity increase until a peak is reached (at around 9–11 years in *C. elaphus*), before the beginning of a slow decline known as 'going back' (see Mitchell *et al.* 1977, 39, table 8). Clearly then, we must consider the possibility that age also affects internal structure.

Related to this is the developmental stage of the antler itself. As antler grows afresh each year, its gross morphology goes

through a period of change (see MacEwen 1920; Chapman 1975, 135–141). Thus, antler taken from deer via hunting may vary in its properties depending upon the point in the antler cycle at which the animal was slaughtered. In practice, it could be argued that this is unlikely to present a major problem, as in Western Europe at least, most archaeological deposits of manufacturing waste consist very largely of shed antler, and therefore represent a roughly uniform state of annual development. However, given the ambiguity as to the proportion of original waste build up that these deposits represent, it is worth considering this variable more closely. It is also notable that waste deposits from medieval Novgorod, Russia, are dominated by antler from butchered animals (Smirnova 1997, 139), and one might expect a similar phenomenon to prevail in medieval Norway, where reindeer hunting is evidenced both historically and archaeologically (chiefly in the form of extensive trapping systems and associated activity sites) (see Indrelid and Huftammer 2011; Jordhøy 2008).

In most species of deer, only males normally bear antlers. However, in reindeer these structures are present in both males (bulls), and females (cows). The reason for this is unclear (although see Li *et al.* 2003), but it nonetheless represents another component of morphological – and possibly structural – variation that must be accounted for. Hormonal cycles affect bone growth in many taxa (e.g. Horwitz and Smith 1990), and hormones clearly have an important role in antlerogenesis (Harrison Matthews 1971, 376–377; Chapman 1975; Goss 1995). Thus, in female reindeer it is possible that pregnancy and lactation may have an effect on antler formation, though a search of the zoological literature uncovered few studies of such phenomena. Penniman (1952, 35–36) does consider such influences to be important in the formation of antler, but his evidence is rather anecdotal. Nonetheless, it is a variable that must be borne in mind when considering any differences between the antlers of individual female reindeer.

Hormones are of course also important agents in the development of male deer, and as castration is known to have an impact on the overall growth of antlers, it may also affect internal structure and histology (see for instance MacEwen 1920, 32, 104–105; Bubenik 1990, 281–283; Goss 1995; Kierdorf *et al.* 1995, 38–39). This should therefore be taken into consideration, but again Penniman (1952, 35–36) appears to be one of only a few scholars to have considered the importance of such phenomena to the antiquarian or archaeologist. Nonetheless, although there are anthropological accounts of castration being employed by present day reindeer pastoralists (see Took 2004, 7–8), I know of no record of early medieval deer castration, and any such level of park management seems unlikely to have developed in Europe prior to the second millennium AD at the earliest. Indeed, archaeological analyses of prehistoric and medieval reindeer exploitation have stressed the importance of wild animals

as opposed to domestic stock (e.g. Hambleton and Rowley-Conwy 1997; papers in Jackson and Thacker 1997), and although there are ethnohistoric allusions to the herding of 'tame' reindeer (Ross 1940, 20–21), I have yet to find explicit historical references to castration, while Odner (1985, 5) claims that the 'subsistence pattern of reindeer-herding belongs to the Post-Reformation Period'(see Storli 1993, and associated comments).

Disease and trauma can also affect antler morphology. Apart from direct damage to the antlers and pedicles themselves (MacEwen 1920, 23–26), abnormality occasionally seems to be related to genital damage or under-development. The swept-back morphology of cromie antlers (*ibid.*, 27–31), and the soft, unmineralised overgrowths that characterise perruque heads (Page 1971, 39; Luxmoore 1980, 59–60) may form in this way. Furthermore, parasites such as liver fluke may affect antlerogenesis. Corkscrew antlers are often thought to be related to such endoparasitic infestation (Luxmoore 1980, 60), though some studies have refuted this, and it has been suggested that they are the result of a 'hereditary disturbance in calcium metabolism' (see Chapman 1975, 151). All in all, it seems that the subject is not well understood, and while some pathological malformation may be identifiable, less clear cut cases might be relatively common and not recognised as abnormal (cf. King and Ulijaszek 1999, 175–176; Eveleth and Tanner 1990, 191–192).

Population-level confounds

There is also a great deal of variation at the inter-population level. Comparative studies of populations across the globe have demonstrated that there is much variation in antler size and gross morphology within *Cervus elaphus*; notably there is a north-west to south-east increase in both body and antler size across Europe. While some of this variation may be genotypic, it seems likely that at least some component of antler development is environmentally linked (Mitchell *et al.* 1977, 2–3; Luxmoore 1980, 61; Clutton-Brock 1989, 13, 71). Indeed, environment has been demonstrated to have an effect on the growth and development of antler (Asleson *et al.* 1997; Schmidt *et al.* 2001), and it is notable that many of the relatively small red deer of Britain live in areas of atypical habitat. In Scotland they tend to occupy exposed, highland areas with poor soils, and young animals removed and reared away from this environment have been seen to reach greater sizes (Mitchell *et al.* 1977, 5, 9; Clutton-Brock 1989, 2). Moreover, Scottish red deer populations from woodland and park habitats have been reported to grow larger antlers than those that occupy the hills (Whitehead 1964; Mitchell *et al.* 1977, 41; Clutton-Brock 1989, 59).

It may be that nutrition has a very marked impact on antler formation (see, for example, Azorit *et al.* 2002; Kruuk *et al.* 2002), particularly as antlers have a low growth priority relative to other elements of a deer's body (Clutton-Brock 1989, 62;

see also Chapman 1975, 141–145). However, the relationship between nutrition and antlerogenesis is not well understood. Asleson *et al.* (1997) found that protein restriction had no consistent effect on the number of points, degree of spread, main beam length or circumference in their sample population of white-tailed deer (*Odocoileus virginianus*). However, it is likely that other nutritional components, such as calcium and phosphorous, are important in antler growth (Chapman 1975, 141; Mitchell *et al.* 1977, 9; see also Goss 1995; Asleson *et al.* 1996; Kierdorf *et al.* 2000).

It has been suggested that red deer stags with extremely well-developed antlers and supernumary points may owe such morphology to a high plane of nutrition (see for example Chapman 1975, 152; Whitehead 1964, 62). Controlled experimental work has shown that an increase in nutritional plane at a formative period may lead to accelerated and amplified antler growth (Arman 1971, cited in Mitchell *et al.* 1977, 44; Clutton-Brock 1989, 59, 62). Contrary to popular sporting belief (see, for example, Luxmoore 1980, 60), it has also been postulated that the reason for the hummel's lack of antlers is not genetic, but relates to poor nutrition in the early stages of life, and a consequent failure to grow pedicles (Clutton-Brock 1989, 62; Lincoln and Fletcher 1984). Chapman (1975, 132) has also noted that harsh environmental conditions may lead to delayed pedicle formation.

Nutrition is thus clearly important, but reaching a consensus is difficult, as much of the evidence is anecdotal, while laboratory experiments do not always adequately account for the effects of weather and outside activity (Mitchell *et al.* 1977, 10). This is a problem, as while climate clearly affects the availability and quality of food in an area (see Clutton-Brock 1989, 79–83, 135–136), it may also have a more direct effect on deer development. Temperature and weather conditions impact metabolism, as well as activity and shelter-seeking behaviour, which in turn have implications for energy consumption and heat stress (Mitchell *et al.* 1977, 16–17; see also Clutton-Brock 1989, 59, 89–91). Population density and competition for resources may also conceivably be important (Mitchell *et al.* 1977, 19, 45; Schmidt *et al.* 2001; Clutton-Brock *et al.* 1984; but see Clutton-Brock 1989, 113; Azorit *et al.* 2002). The effect of such phenomena on an animal's condition and performance, and in particular how stress might impact antler growth, are relatively poorly understood.

Exposure to sunlight may be an important factor, as photoperiod is known to be an important consideration in the hormonal and behavioural cycles of deer (Goss 1969; Chapman 1975, 148; Mitchell *et al.* 1977, 3). Indeed, this factor is bound up with that of nutrition, as the deer's food intake seems to fluctuate seasonally (Mitchell *et al.* 1977, 9; Luxmoore 1980, 20–26; see also Muir and Sykes 1988). Indeed, it may be that inter-population differences in nutrition are lost beneath this seasonal imprint.

In certain situations it appears that red deer may hybridise with Sika deer (*Cervus nippon*). This has been observed in

captivity and in the wild, in various countries, most notably in the Lake District of northern England (Lowe and Gardiner 1975) and the Scottish highlands (McNally 1969; Clutton-Brock 1989, 173–175). Indeed, some have raised concerns as to the long-term genetic purity of Scottish stock as a whole (Clutton-Brock 1989, 177). However, it is difficult to assess the level of interbreeding, given the inadequate documentation of introductions and translocations, and the lack of understanding of the consequences of hybridisation in deer (Mitchell *et al*. 1977, 2; see also Whitehead 1964, 371–395).

A number of other variables may be considered to be of interest, although their influence is arguably marginal. For instance, it might be claimed that shed antler and antler from butchered individuals progress through a variety of taphonomic pathways, perhaps relating to the period during which they are exposed to the elements, or to the closing of blood vessels (recall that Ambrosiani [1981, figs 54–57] noted that blood vessels were still visible in elk antler years after shedding). However, it seems unlikely that such influences would have a significant effect on internal structure, and, given the constraints placed on this research by its origin as a component of a much wider doctoral research project, they are not explored in depth here. Moreover, in what follows, it has only been possible to consider in detail some of the questions discussed above, although it is hoped that this represents a useful first research step.

Characterising antler

In order to test the techniques defined by Smirnova, and to identify any further useful criteria, or problems, a small qualitative investigation was undertaken of the macrostructural variation in the three species of interest. A collection of modern antler was subjected to microscopic and 'by eye' analysis (see Tables 20.1 and 20.2). In the context of this study, it was not possible to control for the factors of age, pathology, or environment to any realistic extent given the nature of the materials available and the ethical constraints of modern zoological research. Nonetheless, some level of control was achieved, and the results are of some interest, while further verification of the techniques of identification has been established through blind test replications (detailed in Ashby 2009). In what follows, the key characteristics of *C. elaphus*, *R. tarandus*, and *A. alces* antler are described, with particular attention paid to the degree to which identifying criteria may be characterised as diagnostic. The discussion incorporates reference to both published literature and the author's own investigations. Table 20.2 summarises the observed impact of each variable upon phenomena that offer potential for use in identification, and the following text treats the same issues in a more discursive manner.

Morphological position

The first influence upon macrostructure relates to the possibility of variation within a single antler, based on morphological position. With this in mind, a like-for-like analysis of material was undertaken. Thus, the form, dimensions, and macrostructural phenomena of material taken from the burrs of *C. elaphus* antler were compared with their expression in basal and upper beam sections, with tine bases and tips, and with palmated areas. The same procedure was applied to samples of reindeer and elk antler.

In all three species, one may discern some infilling at the burr, causing a somewhat diffuse core-compacta boundary (this appears to have been previously noted by Rolf Lie; see above). However, elsewhere in the antler, the boundary between core and compacta is consistent, and though the quantity of useable compacta diminishes as the beam as a whole thins, the ratio of core to compacta thickness does not appear to change significantly in areas other than the tine tips (Figs 20.6–20.8).

Age/Size

Comparison of burrs from old and young animals of each species (and then for basal beams, upper beams, tine bases and tips, and palmated areas) allowed the investigation of patterning according to size/maturity. Unfortunately, it was not feasible to attribute individual age on the basis of antler size or morphology; given the complexity of life-long antler development, such estimates are known to be simplistic and problematic. However, by dividing the sample into broad categories (in accordance with evidence for a clear bimodality in size distribution, based on antlers for which total length was known; see Ashby 2006, appendix 3), and calibrating this with a number of antlers from animals of known age and shed at a known date, it was possible to categorise the material according to 'development classes'.

In red deer, no consistent macrostructural differences are apparent between poorly and well developed antlers. In the sample examined, there was no macrostructural difference between the two groups; such phenomena are simply present on different scales. The very coarse porosity visible in the cores of some large, well-developed antlers is not present in more poorly developed specimens, but the fundamental structure is identical. Moreover, the discrete boundary between core and compacta is a constant.

In reindeer, although some antlers belonging to the 'poorly developed' category have a finely porous core, in these cases they are still distinguishable from that of elk, chiefly because the semi-porous transition zone is always present. Comparing those reindeer of known age (two antlers from the same 7-year old male, and three antlers from three 4-year old female individuals), macrostructure is consistent between the two divisions, notwithstanding obvious differences in size and gross morphology. While superficial characteristics

Table 20.1 Modern antler used in investigation.

Antler ref. no.	Source	Species	Sex	Age (years)	Development category
1	Raby Castle	Red Deer	M	Unknown	Good
2	Raby Castle	Red Deer	M	Unknown	Good
3	Raby Castle	Red Deer	M	Unknown	Poor
4	Raby Castle	Red Deer	M	Unknown	Poor
5	Raby Castle	Red Deer	M	Unknown	Poor
6	Raby Castle	Red Deer	M	Unknown	Poor
7	Cairngorm Reindeer Centre	Reindeer	M	Unknown	Poor
8	Cairngorm Reindeer Centre	Reindeer	F	Unknown	Good
9	Cairngorm Reindeer Centre	Red Deer	M	Unknown	Poor
10	Marwell Zoo	Reindeer	M	7	Poor
11	Marwell Zoo	Reindeer	M	7	Poor
12	Paradise Wildlife Park	Reindeer	F	4	Poor
13	Paradise Wildlife Park	Reindeer	F	4	Poor
14	Paradise Wildlife Park	Reindeer	F	4	Poor
15	Skanes Djurpark	Elk	M	2–3	Poor
16	Skanes Djurpark	Elk	M	2–3	Poor
17	Skanes Djurpark	Elk	M	Unknown	?
18	Skanes Djurpark	Elk	M	Unknown	?
19	Skanes Djurpark	Elk	M	Unknown	?
20	Skanes Djurpark	Elk	M	Unknown	Poor
21	Skanes Djurpark	Elk	M	Unknown	?
22	Selsey Lodge	Red Deer	M	3	Poor
23	Cairngorm Reindeer Centre	Red Deer	M	Unknown	Poor
24	Cairngorm Reindeer Centre	Reindeer	M	Unknown	Good
25	Cairngorm Reindeer Centre	Reindeer	F	Unknown	Poor
26	Highland Wildlife Park	Reindeer	M	Unknown	Good
27	Highland Wildlife Park	Reindeer	M	Unknown	Good
28	Highland Wildlife Park	Reindeer	F	Unknown	Good
29	Highland Wildlife Park	Reindeer	F	Unknown	Good
30	Highland Wildlife Park	Reindeer	F	Unknown	Good
31	Highland Wildlife Park	Red Deer	M	Unknown	Good
32	Highland Wildlife Park	Red Deer	M	Unknown	Good
33	Highland Wildlife Park	Red Deer	M	Unknown	Good
34	Donington Park	Red Deer	M	Unknown	Good
35	Donington Park	Red Deer	M	Unknown	Good

Table 20.2 Summary of results.

Variable	Visible effect upon compacta-core transition	Other perceived effects
Morphological Position	Infilling at burr	Dimensions
Age	None	Dimensions, morphological complexity, compacta mottling
Sex	None	Dimensions, complexity
Environment	None	Dimensions, complexity
Pathology	None	?

of young antlers are distinctive (notably a darker mottling in the compacta), structure and relative proportions show no consistent differences.

In elk, antler exhibits a dark ring around the edge of the core area, probably relating to the extent of blood vessels. A limited sample meant that it was impossible to test the degree to which this was subject to age-related variation, but superficial phenomena such as these are anyway of limited utility to the archaeologist, and macrostructural phenomena are of greater interest. As it stands, there is no reason to suspect that age has any major effect on core structure, but further work is necessary before it may be accepted without reservation as a criterion of identification.

Sex

Females grow antlers only in reindeer. Reindeer cow antler is, in the main, smaller, and less strongly built than bull antler. It has a smaller cross section, and is frequently both much shorter in length and less complex in morphology than the antler of mature males. However, like-for-like investigation of burrs, basal beams, upper beams, tine bases and tips, and palmated areas for this species show that ratios of core to compacta thickness are similar in male and female examples, while the transition from porous core to compacta seems to be diffuse in both.

Environment

To note the effect of variations in environmental conditions such as climate, nutrition and population pressure, and genetic influences such as isolation, interbreeding and hybridisation, antler material was next compared according to its provenance. Comparison of material from individual sources failed to demonstrate the existence of consistent patterns relating to particular parks. Consideration within a wider frame of reference made it clear that in this sample Scottish examples tended to be relatively large and well-developed in terms of gross morphology. This may simply result from the sampling strategy of the collectors from whom material was acquired, though it is more likely an artefact of differences in habitat and mode of captivity. Notwithstanding any insecurity regarding the root of this disparity in gross morphology and overall development, it is significant that this is not echoed in internal macrostructure.
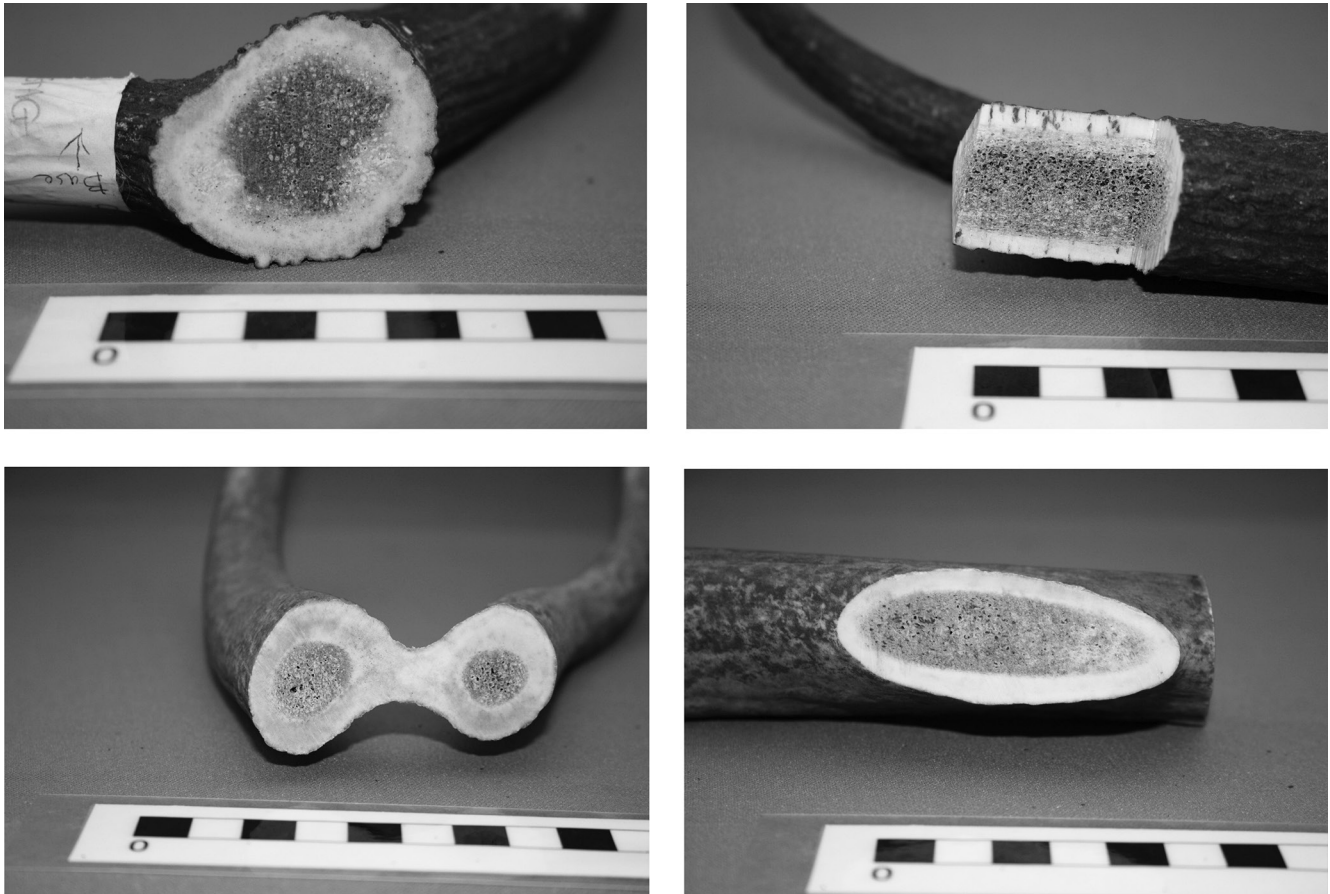

Figure 20.6 Macrostructure at various points along the length of a single Cervus elaphus *antler. Modern material (photographs: S. Ashby).*

Concerning reindeer, the English sample size was small, but examples from Scotland nonetheless seem much more complex in terms of gross morphology than those in southern England. This may relate to environmental factors, as it is generally acknowledged that the area in which the animals can roam in the highlands of Scotland is greater than the restricted parkland available to English populations. Once again, however, internal macrostructure is identical in English and Scottish material.

Thus, there is no evidence of geographical variation in the macrostructure of British red deer or reindeer antler. Furthermore, no significant structural differences were noted between British and Swedish-sourced reindeer antler. This is of course only a preliminary, qualitative investigation, and sample sizes are small with little control, but there is little evidence to suggest that geographical provenance has any important bearing on internal macrostructure in the antler of these species. Detailed investigation of this phenomenon in elk antler material was not possible in these investigations, but would benefit from research.

It is also important to assess the impact of hormonal or pathological influences upon antler growth. There is an extensive literature on this (see also below), and, given the ethical implications of undertaking such work today, it is neither possible nor desirable to further pursue this avenue through controlled investigation. In the sample used in the present study, no significant malformation, pathology, or symptoms of hormonal disturbance were noted, but it is of course possible that any such insult could impact upon macrostructural phenomena.

Antlerogenesis

It is conceivable that antler macrostructure is not immutable, and that it is subject to seasonal variation, just as antler morphology develops through the year. In shed antler, this does not cause a problem, as all such material represents the material completion of the annual cycle of antler growth. However, antler from butchered animals may be taken from the deer at any point in its period of development, such that the 'age at death' of a given antler may introduce a confound to any attempt to identify it to species. The single example of butchered antler in the collection (red deer no. 23, date of kill unknown) displayed a very distinctive surface texture, with a deep surface colour and a marked, consistent surface channelling. More important, though, is the fact that the internal macrostructure seemed identical to that
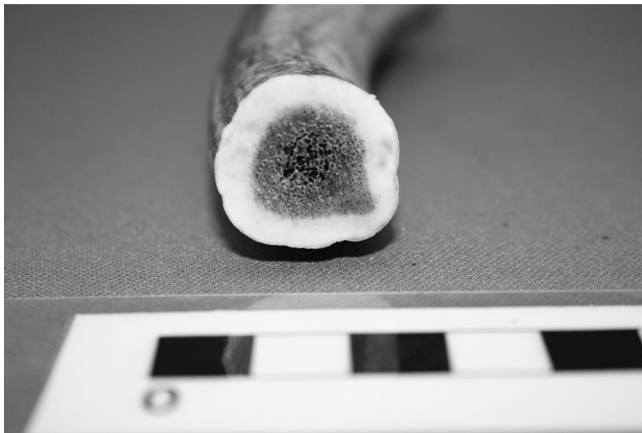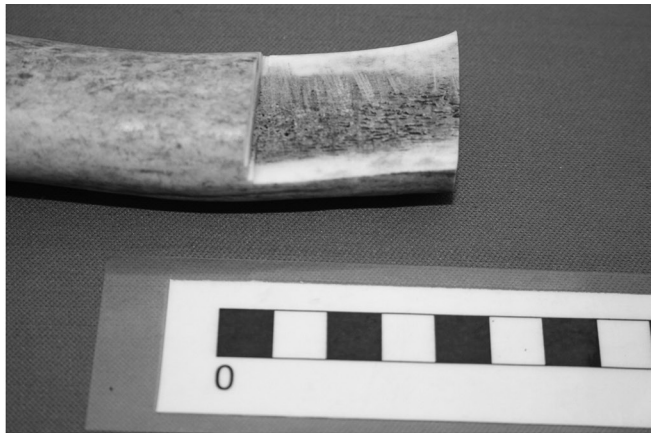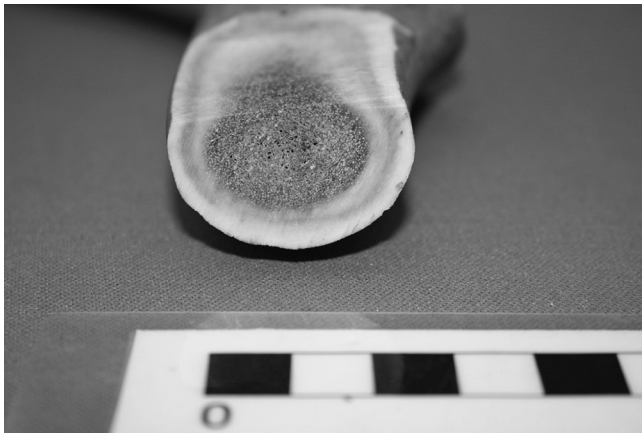

Figure 20.7 Macrostructure at various points along the length of a single Rangifer tarandus *antler. Modern material (photographs: S. Ashby).*
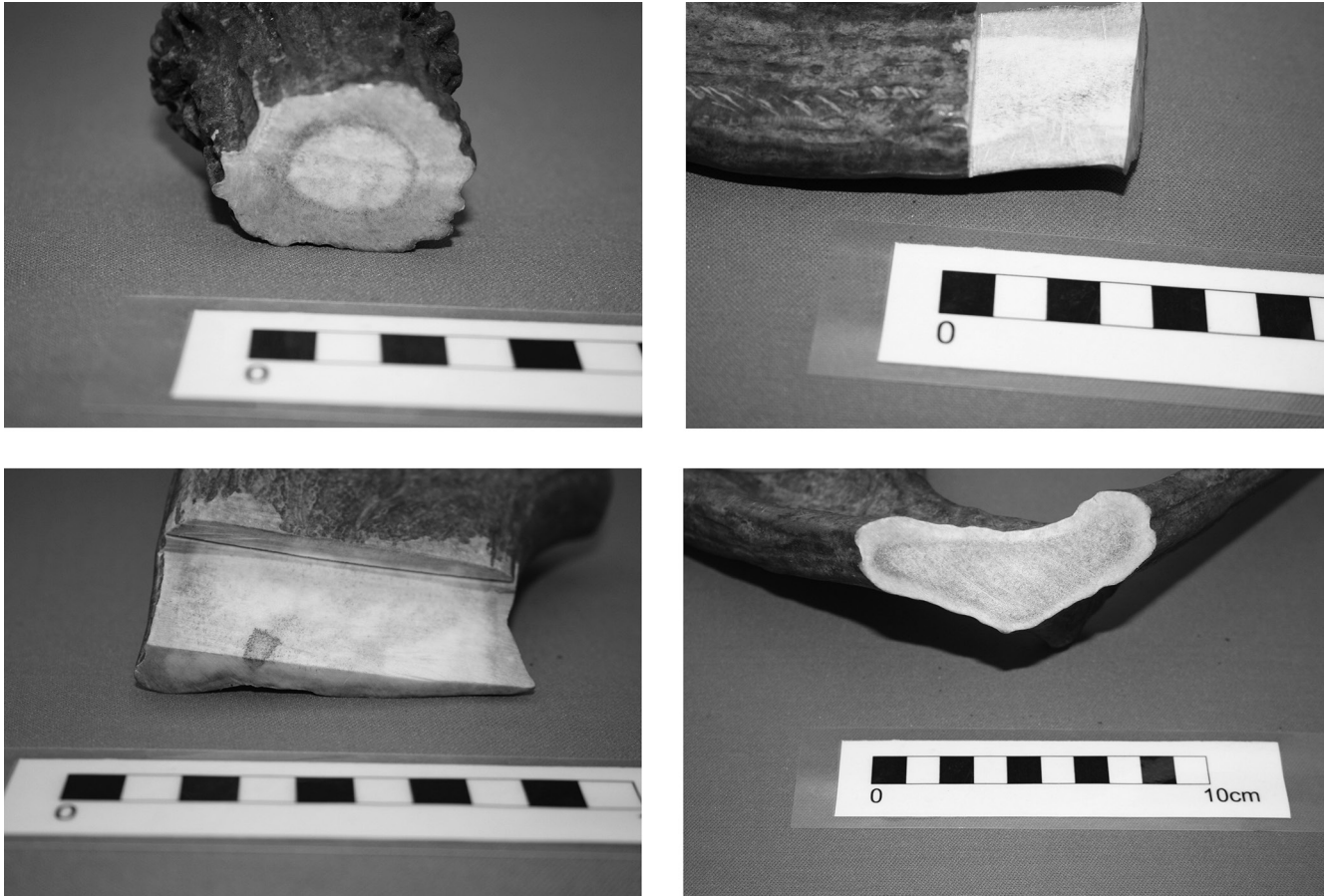
Figure 20.8 Macrostructure at various points along the length of a single Alces alces *antler. Modern material (photographs: S. Ashby).*

of shed antler. Obviously, it is impossible to categorically state that macrostructure does not develop or change during antlerogenesis; such a statement would necessarily be based on controlled analysis of antler representing known stages of development. Such investigation more properly lies within the remit of zoology and biology, rather than archaeology, and there is a wide literature on the relationship between antlerogenesis and various environmental and other constraints (e.g. Asleson *et al*. 1996, 1997; Azorit *et al*. 2002; Kierdorf *et al*. 2000, 1995; Lincoln and Fletcher 1984; MacEwen 1920; Smith 1998). Nonetheless, nothing in the present investigations (limited as they are) or existing literature suggests that species-level distinction on macrostructural grounds would be seriously undermined by antlerogenic confounds.

Discussion

In sum, it seems that our basic identification criteria stand up at least to this base-level analysis. Characterisation of surface texture provides a reliable manner of differentiating species,

as red deer, reindeer, and elk textures are diagnostic. However, such features are not frequently preserved in artefacts, and other criteria must often be utilised.

Diagnostic features within the structure of antler compacta could not be confidently identified, casting doubt on the suggestion that the structure of compact tissue in modern antler may be easily used as a criterion for species distinction, at least in the context of currently available methods and materials. Conversely, the nature of the porous core seems reliable as a distinguishing criterion. For example, the fine porosity of elk antler core material is distinctive, and the apparent absence of visible porosity in the tines of elk antler is particularly diagnostic (see Smirnova 2005, 11). However, differentiation between the cores of red deer and reindeer is more difficult, as no consistently observable characteristics are apparent (although, as above, quantification via image analysis may ultimately prove valuable). Thus, the presence of a semi-porous transition zone in reindeer and its absence in red deer show the greatest potential at present. Problems with this criterion include the possibility of confusion between the semi-porous zone in reindeer and the core itself in distal

areas of elk antler, such as the tines. If the preserved areas of core and core-compacta margin are sufficiently large, the two species may be distinguished. However, if only vestiges are preserved in artefacts and the morphology of the core itself is not visible, then there is potential for uncertainty.

Given that the presence or absence of a 'transition' zone is a matter of degree rather than one of absolutes, there is of course the possibility of occasional inaccurate identification, and for this reason identification should be restricted to material in which macrostructural phenomena are both very well preserved and clearly visible. Furthermore, any identification made solely on the basis of this criterion should be qualified by the term 'probable'. With these caveats in mind, it may be instructive to discuss the limits of certainty in a little more detail. On reflection, the misidentification of red deer antler as reindeer is conceivable, as the cut of an antler object may render small areas of marginal core material visually similar to the semi-porous transition zone characteristic of reindeer. In contrast, where the core-compacta margin is clearly discrete, one can have some confidence that the material in question is red deer antler (or, depending on scale, elk). Superficially then, the mistaking of red deer for reindeer seems a more likely problem than the converse.

Palmate areas of elk antler have a coarser porosity than that present in the tines, and one which – when only present in small quantities – could be mistaken for the peripheral areas of red deer or reindeer core. Where worked fragments of such palmated material are the subject of study, identification must be one of probability rather than one of absolutes. Thus, a small reference collection is essential in differentiating species, and one must always err on the side of caution. Identifications should be qualified with terms such as 'probably', and supporting criteria should be used where possible (e.g. size of component, surface texture, compacta structure etc.).

Another difficulty is created by the fact that near the burr of all species, resorption from the pedicle may take place, resulting in a sort of secondary infilling. Should this be seen in red deer antler, it may be mistaken for the semi-porous zone in reindeer. Again, this should only occur if sufficient morphology is not preserved, as the phenomena may be obscured in small fragments, or in those that have been cut obliquely across the edge of the core area. However, consistent recurrence of semi-porosity in many objects would, on the basis of probability, suggest the use of reindeer antler, as the resorption phenomena occur only at the antler base and pedicle.

Thus, all in all, a tripartite system of identification seems appropriate (Fig. 20.9). Where the gross external morphology or outer surface texture of the antler are preserved, a *definite* species identification may be provided. Where surface texture is not present, but core or transition zone macrostructure is well-preserved and visible, a *probable* identification should be made. Criteria such as component size, compacta structure, texture and colour may be used to support such assertions, but are insufficient criteria for identification in their own
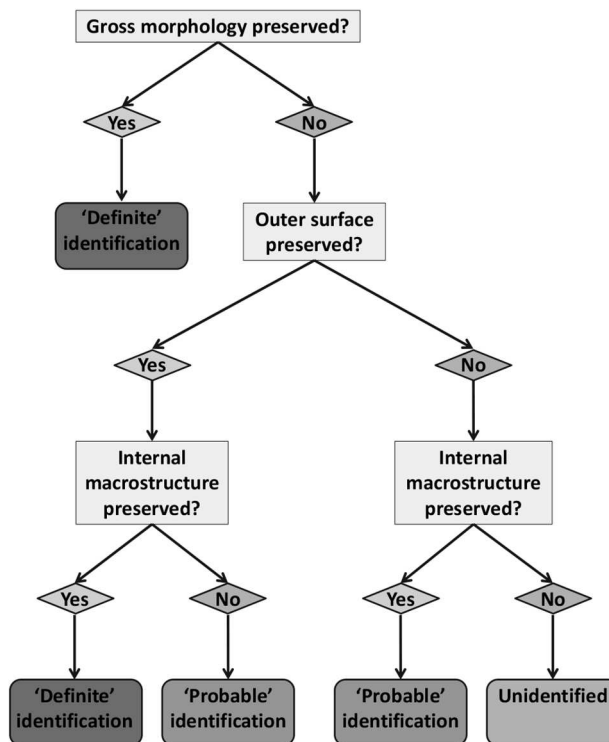

Figure 20.9 A schematic representation of the approach to antler identification suggested here (S. Ashby).

right. Thus, where gross morphology, surface texture, or core-compacta macrostructure are not preserved, an *indeterminate* assignation should be made. In many cases, a characterisation of a material as *indeterminate antler* (rather than bone) is all that may be achieved, and in many cases even this is not possible (see O'Connor 1987, 1999).

Conclusions

On the basis of a qualitative assessment of modern material, it has been suggested here that the zooarchaeological basis for the species-level identification of antler is fundamentally sound, subject to a number of important caveats. In the absence of any large-scale study of the impact of these potential confounds, the most powerful measures of the validity of this methodology come in the form of blind-testing of modern material (Ashby 2009, 18–20), and in the calibration of these methods using biomolecular (proteomic or genetic) techniques (see von Holstein *et al.* in prep; see *Postscript*). Nonetheless, it is argued here that the application of these identification criteria are justified in the characterisation of large or well preserved fragments. In smaller, more highly-worked, or taphonomically degraded pieces, these base-level methods may be of utility, but are best exploited as part of an initial,

evaluative assessment undertaken in advance of more rigorous characterisation procedures, such as those that exploit genetic or biomolecular technologies.

Postscript: next generation approaches

Ultimately, it is of course desirable to move beyond 'probable' identifications. Recent developments in biomolecular archaeology now allow some measure of certainty in their identifications, and sampling methods are now minimally destructive, so for the first time such techniques constitute a viable alternative to macroscopic identification.

To provide a little detail, the development of a peptide mass fingerprinting method known as *ZooMS* (Zooarchaeology by Mass Spectrometry) constitutes a significant breakthrough in rapid, minimally destructive, high-throughput analysis of organic materials (Buckley *et al.* 2009). This method facilitates species-level identification of any material containing collagen (the principal protein in bone and antler). Collagen is extracted by demineralisation, trypsinated, fractionated, and analysed by time-of-flight mass spectrometry, and the resultant fingerprint may then be compared to a reference library of previously analysed species. In this way, combs that might not be readily identified on macroscopic grounds can nonetheless be precisely characterised. The rapid rate of throughput possible, together with the small size of samples required (1 mg) means that large numbers of specimens might be analysed, while the technique's use of collagen (which is extremely robust) means that analyses are rarely seriously inhibited or undermined by taphonomic constraints.

A recent application of this approach in the analysis of samples from Scottish Iron Age, Viking-Age and medieval comb teeth yielded promising results (von Holstein *et al.* 2014), and showed the technique to have a higher success rate than either genetic (aDNA) analysis or the macroscopic approach outlined above. However, such analyses, no matter how minimally destructive, may not be applicable in all cases, and, given their relative effectiveness at different scales, it is likely that it is in a judicious combination of these techniques that the most effective way forward will be found.

Acknowledgements

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