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3. Distinguishing bone fat exploitation from other taphonomic processes: what caused the high level of bone fragmentation at the Middle Neolithic site of Ajvide, Gotland?

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The importance of bone fats as a resource is briefly discussed. The Middle Neolithic site of Ajvide, Gotland is described. The character of the bone assemblages from this site is discussed and the changes in subsistence economy on the island are outlined. Details of the methods used to study fracture and fragmentation patterns are given and an example of the use of such methods to identify bone marrow and grease extraction is presented. This example relates to the Paleo-Eskimo, Saqqaq Culture site of Itivnera, Western Greenland. The results of two similar analyses of samples from different parts of the Ajvide site are presented and discussed. It is concluded that bone marrow was exploited to some degree, but grease rendering was not carried out to any significant degree. The reasons why grease rendering may not have been carried out at Ajvide are explained in terms of the seasonal round at the site.

Introduction

The potential importance of bone fats to many hunter-gatherer and subsistence economies is well established (see Marshall and Pilgram 1991; Blumenschine and Madrigal 1993; Brink 1997; Outram 1998; 1999; 2001; 2003; in press). Fat, itself, is important because of the high calorific value it has (Mead *et al.* 1986; Erasmus 1986), the essential fatty acids and fat-soluble vitamins it carries (Mead *et al.* 1986) and, crucially, its ability to stave off dangerous 'protein-poisoning' processes in diets high in protein but very low in carbohydrates (Speth and Spielmann 1983; Speth 1983; 1987; 1991). This last point is particularly relevant in northern latitudes where hunter-gatherers and pastoralists are often very dependent upon animal products and hence have few sources of carbohydrates. Bone fats, specifically, are important because bones represent a very reliable source of fat even at times when animals are otherwise incredibly lean (Cheatum 1949; Brookes *et al.* 1977; Peterson *et al.* 1982; Davis *et al.* 1987; Blumenschine and Madrigal 1993; Outram 2000). Ethnographies of bone fat exploitation by hunter-gatherer peoples are very numerous and relate to groups living in very different environments. Fat exploitation activities range from the extraction of bone marrow from the shafts of long bones to the arduous extraction of grease from appendicular epiphyses through comminution and rendering. Rendering tends to be restricted to colder climates and results in highly fragmented bone debris. The fullest account of such activities can be found in Binford's (1978) study of the Nunamiut, but other excellent accounts can be found in Leechman (1951; 1954) and Wilson (1924). The identification of bone marrow and grease extraction requires detailed study of the precise nature of bone fracture and fragmentation patterns and Outram (1998; 2001; 2002) has recently developed a methodology for such studies. The taphonomic history of most bone assemblages is very complex indeed and, hence, it is very important to carry out sufficiently detailed analyses to be able to see the differences between patterns resulting from different processes that might otherwise look superficially the same.

Ajvide and its faunal assemblages

The site of Ajvide is located on the western coast of Gotland in the Ekstra Parish. It covers an area of about 200,000 square metres and was occupied from the Late Mesolithic through to the mid Bronze Age (Burenhult

1997). The majority of the activity on the site took place during the Middle Neolithic period (3100 – 2700 Cal. BC). This phase of activity belongs to the 'Pitted Ware Culture'. Some time around 2900 Cal. BC the site suffered from a brief marine transgression (Burenhult 1997). The principal feature of the site is a burial ground containing some 54 graves. In some cases the graves are occupied by more than one individual, whilst others are possibly cenotaphs. Most of the graves date to slightly later than the main phase of 'Pitted Ware' activity. Adjacent to the cemetery, to the east, is an area of very dark soil that contains a mixture of artefacts, pottery and bone fragments (Burenhult 1997). It is thought that this area (referred to as the 'black area' below) could possibly have had a ceremonial function (Burenhult 1997). However, Österholm (1997), noting the excavators' observations of the strong smell of marine oil and stickiness of the soil, has suggested that the area may have been used for the processing of seal train oil. This remains only a suggestion as chemical analyses to back up the observation have not been undertaken.

The site has yielded a considerable faunal assemblage (Rowley-Conwy and Storå 1997; Lindqvist and Possnert 1997). In the late Mesolithic the economy was apparently based upon the hunting of grey, ringed and harp seals, porpoise and considerable amounts of fishing. At the start of the Neolithic, cattle, sheep and pigs were introduced to the island but the Middle Neolithic sees resurgence in seal hunting and fishing (Lindqvist and Possnert 1997). During the Middle Neolithic there is evidence of considerable amounts of fishing and sealing. Cattle and sheep are no longer apparent, but there is still significant exploitation of pigs (Rowley-Conwy and Storå 1997, tables 1 and 2). The late Neolithic/Bronze Age sees the return of cattle and sheep. Studies of $\delta^{13}C$ levels in human bones supports this pattern, showing a strongly marine signal in the Mesolithic, a mixed marine/terrestrial signal in the Middle Neolithic and more terrestrial values in the Late Neolithic/Bronze Age (Lindqvist and Possnert 1997, 29). Rowley-Conwy and Storå (1997) strongly argue that the pigs, which remain on Gotland during the 'Pitted Ware' phase, are wild/feral and were being hunted, not herded. In other words, they argue for a reversion to hunting and gathering, not just a renewed interest in marine resources during this period.

The majority of the bone studied by Rowley-Conwy and Storå came from Test Area 1 to the west of the cemetery, where significant cultural horizons were found. Rowley-Conwy and Storå (pers. comm.) noted that the assemblage was rather fragmented. For the fracture and fragmentation study presented below, a sample of some 1,121 fragments was taken from this deposit. A larger sample of 4,675 bone fragments from the extremely comminuted 'black layer' deposit was also studied.

Methods

Below, the methodology for establishing the extent and nature of bone marrow and grease exploitation, from the study of bone fracture and fragmentation, will be briefly outlined. Detailed discussion of various aspects of the methodology can be found in Outram (1998; 2001; 2002).

Patterns of bone fat exploitation

The exploitation of bone marrow is very simple; one breaks into the medullary cavity of a long bone or mandible. This will generally occur whilst the bone is still relatively fresh. As a result, the fracture pattern created will be helical and at the point of impact there will be a dynamic impact scar (see Morlan 1984; Johnson 1985; Outram 2002). The resulting pattern will be one of undamaged appendicular articulations and axial elements with helically fractured splinters of shaft bone.

In order to exploit bone grease, one renders the fat from the cancellous bone found in epiphyses and axial elements. In most ethnographic examples, e.g. the Nunamiut (Binford 1978), the Hidatsa (Wilson 1924) and the Loucheux (Leechman 1951, 1954), this is carried out by hoarding appropriate elements until there are sufficient to warrant processing, then comminuting them and rendering the fragments in boiling water. As the water cools (usually helped by the addition of snow or cold water) the fat solidifies and can be skimmed from the surface. The resulting pattern will be large numbers of small pieces of cancellous bone accompanied by larger, helically fractured shaft splinters.

Extent and intensity of exploitation will be reflected by how much of the assemblage has been fragmented in this way. Level of marrow fat exploitation can be assessed by noting the number of shaft cylinders left unbroken and assessing the extent to which shaft breakage was the result of deliberate helical fracture. One can assess the intensity of grease processing by establishing how much cancellous bone has been left unprocessed (i.e. not broken up). In some cases of incomplete exploitation a certain proportion of grease-bearing elements may have been left unprocessed. In other cases, there may have been a deliberate selection for certain types of grease. The grease from axial and appendicular elements is different in nature (Binford 1978, 159) and people may select to exploit one in preference to the other. Particular elements may be avoided since they are not worth the effort, or because they do not offer the desired quality of fat.

In order to identify such patterns archaeologically, the level of fragmentation in the assemblage must be established. This study must take into account which types of bone (in terms of marrow and grease utility) are fragmented and which potential sources of fat have been left unprocessed. The evidence for deliberate fracture also needs to be assessed through recording fracture types. One must also record instances of other taphonomic effects that could lead to attrition, so that the level of deliberate, human-induced fragmentation can be compared to that caused by other taphonomic processes. All these data must be considered holistically.

Fragmentation levels

The method used for recording fragmentation levels at Ajvide is as follows. Marine mammal bone was separated out from the samples. It is very different in nature from land mammal bone in terms of its physical make-up, nature of fat and fat utility and is generally not exploited for its fat content (see Outram 1999, p115). The low melting point of seal oils (Shahidi *et al.* 1994, 233) would make it difficult to render, the presence of vast amounts of blubber on the seal would make their bones a very marginal resource of fat in comparison and the author has found no examples of rendering seal bone in the ethnographic record. Balicki (1970, 85) actually states that seal bones are not exploited by the Netsilik Eskimo. Marine mammal bones are, therefore, considered separately, as the state of preservation of seal bones is a useful taphonomic indicator. Since there are good grounds for believing that seal bones are not rendered for grease nor broken for marrow, they can form a useful taphonomic control sample. The relevance of the exploitation of sea mammal fats will also form part of later discussion.

All land mammal fragments must be studied together (almost all pig), whether identifiable to element or not. Whilst identification to element may not be possible, such fragments still carry valuable information in the form of their size, fracture patterns and bone type. It is possible to tell cancellous bone from diaphysis bone on even very small fragments and such information is very important in the context of this study. The entire assemblage was divided into size classes (by maximum dimension). The size classes used were <20mm, 20–29mm, 30–39mm, 40–49mm, 50–59mm, 60–79mm, 80–99mm, 100+mm, part and whole bones. Whole bones clearly have not been exploited for grease at all. Part bones include bones that are not whole but represent whole units that could have been exploited for grease but were not broken up. Part bones include entire epiphyses and complete vertebral centra.

Quantification of the size classes was by number of fragments and mass. Whilst numerical data was collected, only the mass data are displayed in this paper. Mass data are more meaningful because they represent actual amounts of bone present. Clearly one unbroken large bone represents the same amount of potential fat as a similar element broken into many pieces, yet the latter would be represented by many hundreds on a numerical count. By mass, both would be suitably equal. Brink (1997), in his study of bison, concluded that dry bone mass was an accurate predictor of elements' bone grease utility.

For each size class, a distinction is made between whether the bone is cancellous or cortical in nature. For larger size classes, distinction was made between cranial bone, axial cancellous bone, epiphysis bone from appendicular elements and diaphysis bone. This enables one to see, in terms of bone fat utility, which types of bone had been fragmented and to what level.

Fracture types

When dynamically fractured in a fresh state, dense shaft bone creates a very distinctive fracture pattern. Such fractures are characterized by helical fracture lines radiating out from the point of impact. The fracture surface will form either an acute or obtuse angle to the cortical surface of the bone. This fracture surface will also tend to be smooth in texture (Johnson 1985; Morlan 1984; Outram 1998; 2001; 2002). As bones dry out they develop small cracks that interfere with the line of fracture, creating roughness or steps, hence affecting the fracture's outline and surface texture. As bones dry out and loose their organic content they react differently to force. Loss of elasticity results in bones snapping in straight lines that tend to be perpendicular to the cortical surface. A largely mineralized bone will break with a straight, rough edge that is close to being at right-angles to the cortical surface.

The three criteria of fracture outline (shape), fracture angle (to cortical surface) and fracture texture (smooth or rough) can be used to characterize large assemblages of fragments in terms of the amount of deliberate fracturing of fresh bones versus levels of post-depositional breakage of dry bones (Villa and Mahieu 1991; Outram 1998; 2001; 2002). The indexing method used in this study was developed and tested experimentally by Outram (1998; 2002).

All diaphysis fragments of 30mm or more in length were studied for fracture type providing that preservation was good enough. Occasionally, fragments have eroded edges and fracture features are indistinct. Such fragments were disregarded, but were also very uncommon in all assemblages studied. For each of the three criteria a score of 0, 1 or 2 was awarded. In broad terms, a score of 0 denotes that that criterion is consistent with fracture of a fresh bone, a score of one denotes a mixture of fresh and unfresh features (but with fresh still dominating) and 2 denotes that unfresh features are dominant. Much greater detail is available in Outram (2002). Shape, angle and roughness are all estimated by eye. This is essential to make assessments of large samples practical. Individual misjudgements will be irrelevant as the method is being employed to characterize the assemblage in general and sample sizes are large. The angle and outline characteristics are fairly easily defined, but assessment of roughness is more subjective and relies upon the analyst having a good mental template (like much zooarchaeological analysis) of the possible range.

When the scores are added together one ends up with a score from 0 to 6 for each fragment, called the Fracture Freshness Index (FFI) score (Outram 2001; 2002). Scores of 0, 1 and 2 will represent bones broken in a relatively fresh state. Scores of 3, 4, 5 represent either bones that were broken when becoming fairly dry (unlikely to be for fat extraction) or bones which had some fresh fracture on them but were further fragmented when unfresh. A score of 6 represents a bone with no evidence of fresh fracture. The profile of scores and overall average for a sample can be displayed.

New breaks (caused by excavation or storage) are easy to spot as the fracture surfaces will be an obviously different colour. These were noted. Dynamic impact scars, created at the point of impact on a fresh bone, can also be recorded as evidence of deliberate fracture, much like bulbs of percussion on flints. If the bone cylinder was broken on an anvil, there may be a rebound scar due to the opposing force of the anvil (see Outram 2002, fig. 6.8).

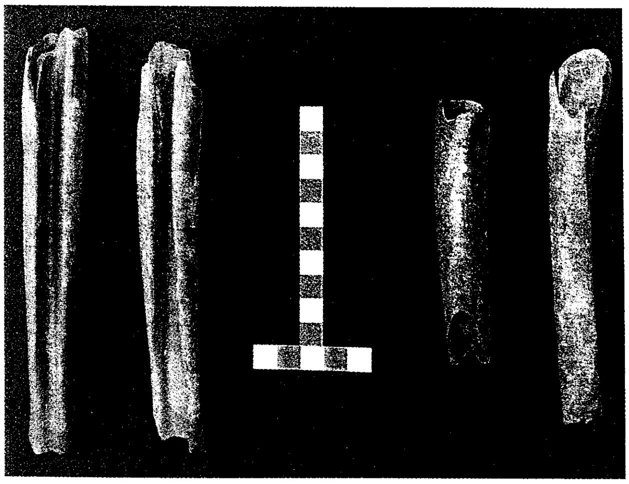

Fig. 1. Caribou metatarsal and tibia shaft cylinders from the Saqqaq Culture site of Itivnera, Western Greenland.

Other taphonomic indicators

Several other criteria are important for understanding the taphonomic history of the assemblage. The above shaft fragments are also studied for evidence of animal gnawing and butchery (chops, cuts, polish and sawing). Numbers of burnt fragments are counted for the entire sample at the level of size class and bone type. Butchery can clearly add to the overall level of deliberate breakage, however, the breakage of bones for butchery purposes will be restricted to particular elements for a particular purpose, such as an alternative to disarticulating a difficult joint. There is also likely to be a difference between the fractures produced by chopping through meat and bone and those created by direct impact to the bone. It is essential that all indicators (fragmentation level, bone types, fracture patterns, gnawing, butchery and burning) are considered holistically to effect a successful interpretation and avoid pitfalls of equifinality.

An unambiguous example of bone fat exploitation

Before considering the results from Ajvide it is worth briefly considering what an unambiguous, archaeological example of bone fat exploitation looks like. The example to be used is the Paleo-Eskimo site of Itivnera (Outram 1999). This site belongs to the Saqqaq Culture and has been dated to 2960±100 BP (Møhl 1972) and is located in the Godhåbsfjord complex in Western Greenland. The bones were originally studied by Møhl (1972) who found that caribou dominated the assemblage (95%) with small numbers of seals and birds present. The site was not sieved, but recovery was good. However, there may be some underestimation of the smallest size classes. The sample studied by Outram (1999) came from a previously unexamined midden deposit and consisted of 1,370 fragments. Bone preservation at the site is excellent and the site has not been used since the abandonment of the prehistoric settlement.

Møhl (1972, 12) noted that there was a very distinctive pattern in the treatment of long bone shafts. He noted many instances of shaft splinters bearing the scars of dynamic impacts, but also noted how, in many cases, epiphyses had been deliberately separated from complete shaft cylinders. Outram (1999, 112) noted the same phenomenon (see Fig. 1). This pattern is exactly the same as that witnessed by Binford (1978) when observing the Nunamiut remove epiphyses in this way so that they could be stored up for later rendering for fat. The marrow can, of course, be poked out of the remaining cylinder with ease.

Fig. 2 shows the masses of bone fragments at Itivnera in each of the size classes. It can be seen that whole bones are a small proportion of the assemblage by total mass. If one viewed this graph in numerical terms, the 'whole' category would be totally dwarfed. This is an assemblage where there is a fairly high degree of fragmentation, but with some survival of whole or part bones. Fig. 3 shows that, apart from the whole and part bones, the assemblage is dominated by shaft bone. Proportions of cancellous bone increase towards the smaller size classes. Something has led to the comminution of most of the spongy bone leaving just those elements that survive whole and large splinters and cylinders from long bone shafts. Fig. 4 shows the bones as classified by FFI score. It can be seen that almost all fractures occurred whilst the bone was in a fresh state and there is no evidence of fragmentation occurring when the bone had become thoroughly dried out. About 15% of fragments displayed dynamic impact scars, a high percentage given that such scars are only found at the point of impact on shafts. Instances of burning, dog gnawing, modern breaks etc. were very low. One can strongly argue that there was

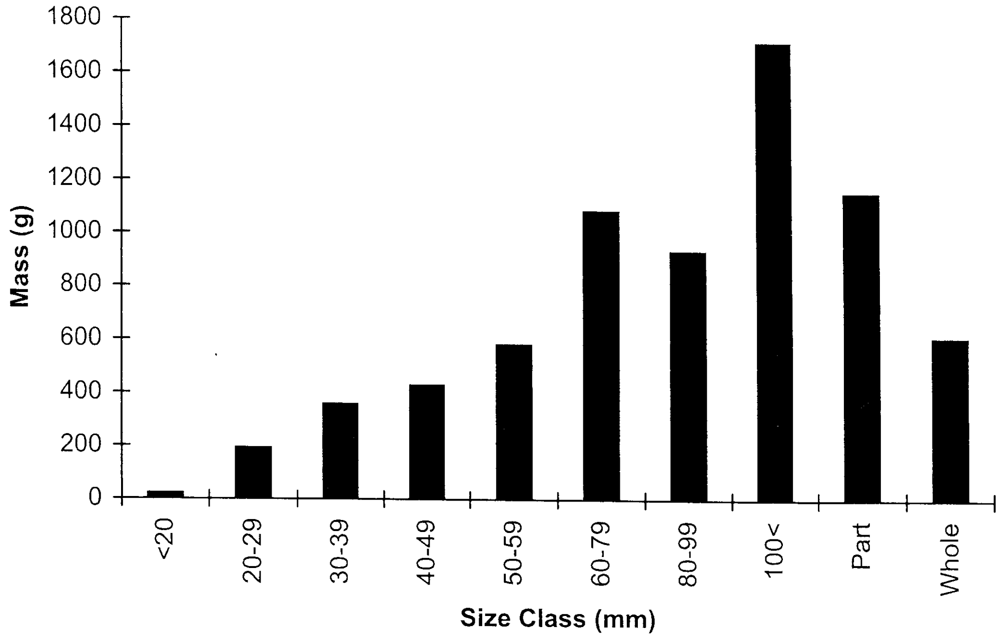

Fig. 2. A graph to show the masses of bone fragments in different size classes from the Saqqaq Culture site of Itivnera, Western Greenland.

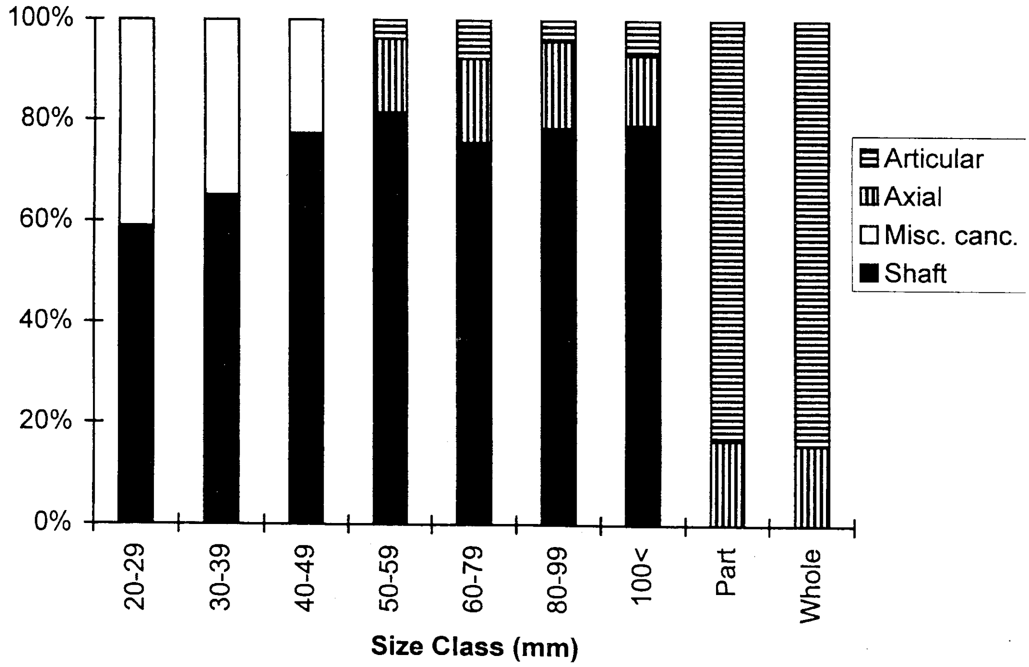

Fig. 3. A graph to show the proportions of different types of bone fragments in different size classes from the Saqqaq Culture site of Itivnera, Western Greenland.

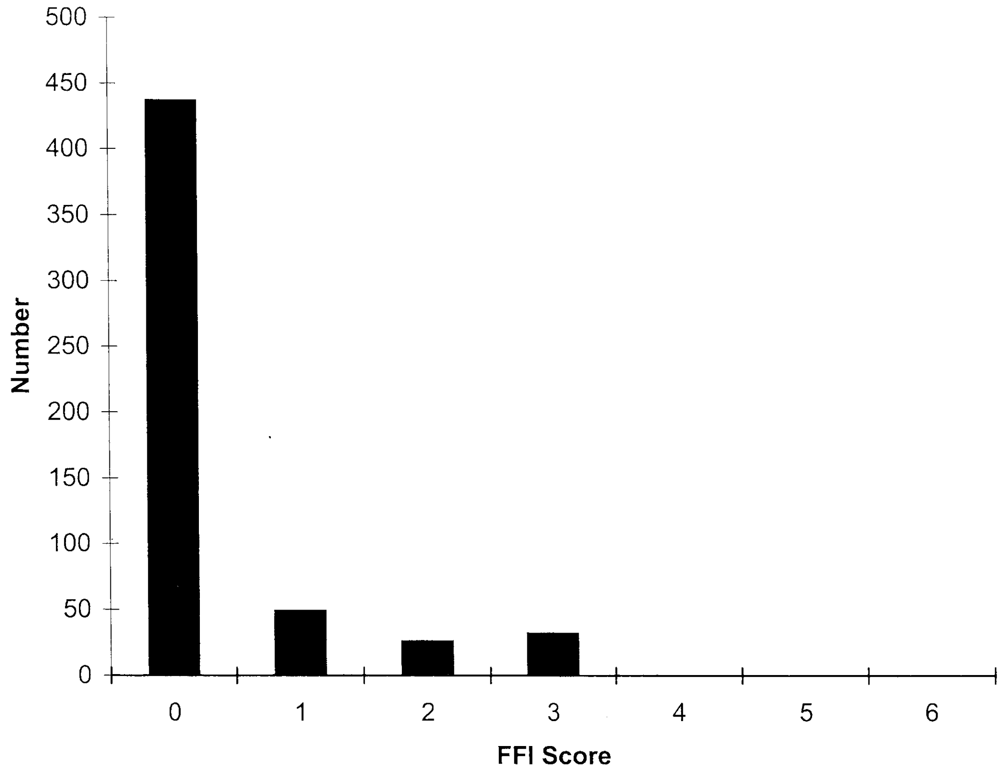

Fig. 4. A graph to show the Fracture Freshness Index scores of bone fragments from the Saqqaq Culture site of Itivnera, Western Greenland.

very little evidence for post-depositional fragmentation and attrition and that most fragmentation was the result of human action when the bones were fresh. Outram's (1999) interpretation was that there was extensive marrow fracturing and the general loss of spongy bone was the result of comminution for grease rendering. It is clear that the Saqqaq peoples did not process everything, however, and left some bones unbroken. This example shows how the holistic study of fragmentation levels, classification of what is most fragmented, fracture types and a range of indicators of post-depositional attrition can lead to a strong argument for the identification of bone fat exploitation.

Results from Ajvide

The same range of information will now be considered with regard to the two Ajvide samples.

Test area 1

Fig. 5 shows the masses of fragments in each size class for the land mammal bone (mainly pig). One can see that the fragmentation levels in Test Area 1 are even higher than those at Itivnera. A few elements survive in part or whole condition. The pattern for bone types in each size class (Fig. 6) looks very different, however. Very large amounts of cancellous bone, particularly axial bone, survive in all size classes and have clearly not been comminuted. The FFI index results (Fig. 7) show that there is a great mixture of fracture types, but very few that indicate fracture of the bone whilst it was totally fresh (none scored 0). There is evidence for some deliberate fracture. 5.2% of shaft splinters display dynamic impact scars, however, most of these bones were broken again sometime after they dried thus creating many FFI scores of 3. 8.2% of fragments display signs of carnivore gnawing and between about 20% (in larger size classes) and 40% (in smaller size classes) of fragments showed some signs of burning.

Whilst the level of fragmentation is high in Test Area 1, it seems that much of this fragmentation was caused by post-depositional attrition, carnivores or burning. The dynamic impact scars show that it is highly likely that some marrow fracturing did take place, but the high proportion of spongy bone surviving in large portions suggests that grease rendering was not carried out to any great extent. This interpretation is supported by looking at the fragmentation levels in the marine mammal bone (Fig. 8). One can see that the fragmentation pattern of the marine mammal bone is virtually the same as the land mammal bone. One would expect to see much better survival of the seal bone if land mammal bone was being selectively rendered for fat. An example of this can be seen in Outram's (1999) study of Greenlandic bone

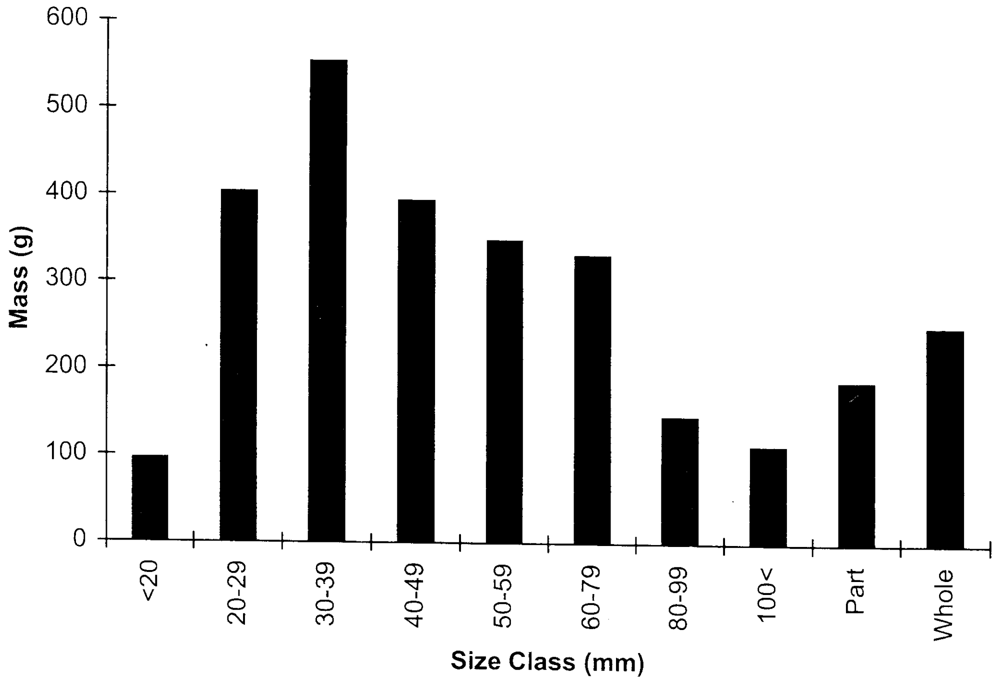

Fig. 5. A graph to show the masses of land mammal bone fragments in different size classes from Test Area 1, Ajvide, Gotland.

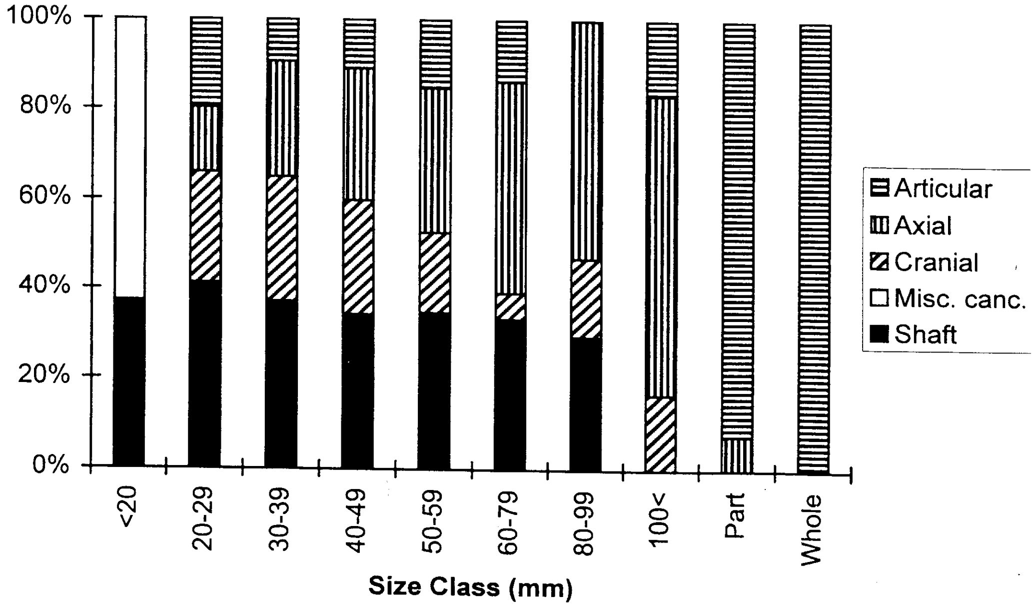

Fig. 6. A graph to show the proportions of different types of land mammal bone fragments in different size classes from Test Area 1, Ajvide, Gotland.

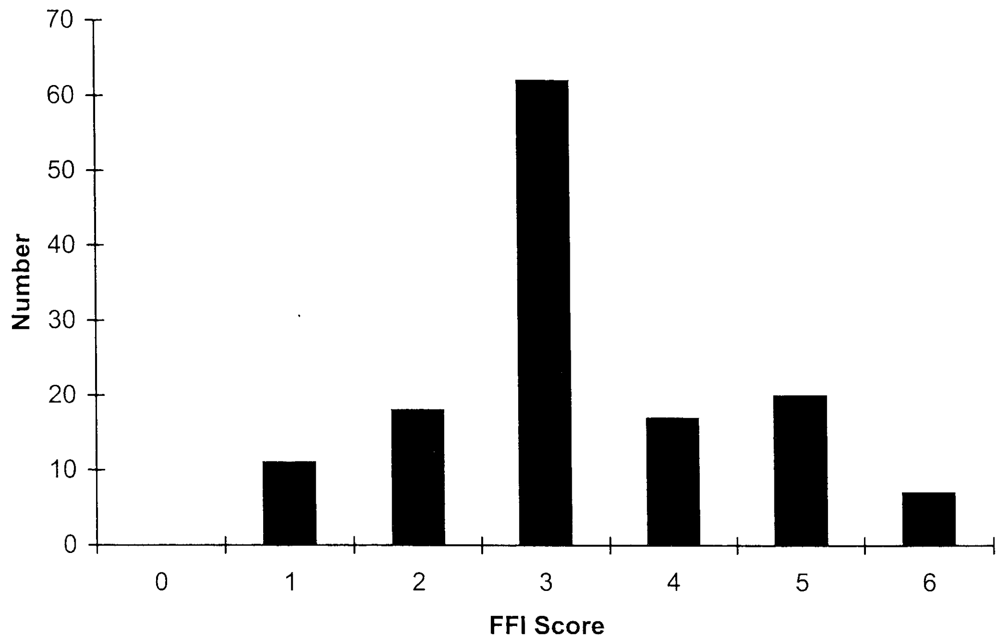

Fig. 7. A graph to show the Fracture Freshness Index scores of land mammal bone fragments from Test Area 1, Ajvide, Gotland.

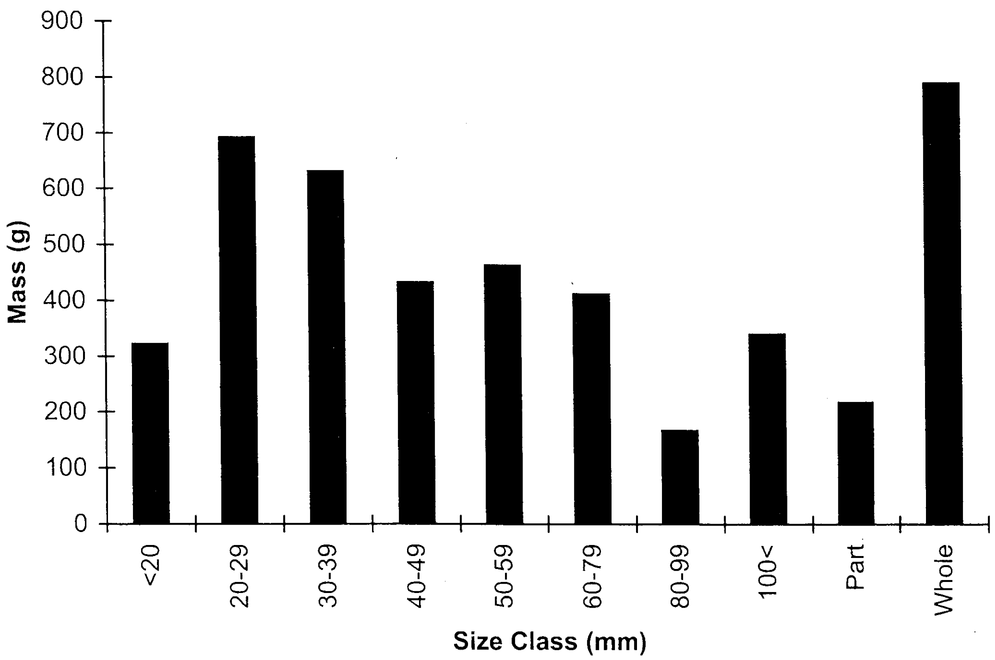

Fig. 8. A graph to show the masses of sea mammal bone fragments in different size classes from Test Area 1, Ajvide, Gotland.

Fig. 9. The typical appearance of a sample of bone fragments from the 'black layer' at Ajvide, Gotland.

rendering practices. As such, it is likely that neither land nor marine bones suffered comminution for rendering, but rather they underwent the same post-depostional processes. The relatively larger number of whole seal bones could possibly be the result of marrow extraction from land mammals leaving fewer bones intact.

The black layer

Figure 9 shows the general condition of the bone assemblage from the black layer. Figure 10 shows graphically just how extremely fragmented the land mammal bone from the black layer is. Very few elements survive whole, or in 'part', and the vast majority of the assemblage is in very small pieces. The larger size classes are dominated by shaft bone, with a larger proportion of cancellous material being present in the smaller size classes (Fig. 11). Sample sizes in the larger size classes are very small, hence, the slightly misleading appearance of the 80–99mm class which represents just one single piece of axial bone. So far, this pattern is quite consistent with what one would expect from intensive rendering of bones for fat, however, the FFI scores (Fig. 12) tell a different story. They show that the vast majority of fracture took place once bones were dry and there would be no fat utility left. There were two possible examples of dynamic impact scars, showing some possible marrow extraction. Gnawing levels were at 3.5%. Burning levels range from over 50% in the smallest size class to below 10% in larger classes. Seal bones are also very fragmented (Fig. 13). Whilst the fragmentation pattern of the land mammal

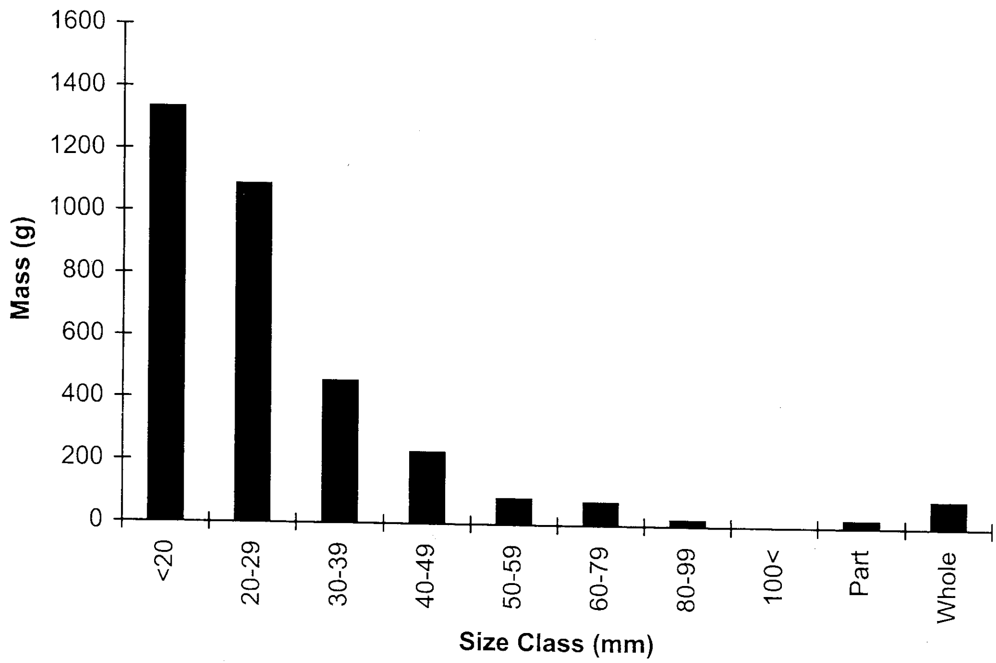

Fig. 10. A graph to show the masses of land mammal bone fragments in different size classes from the 'black layer' at Ajvide, Gotland.

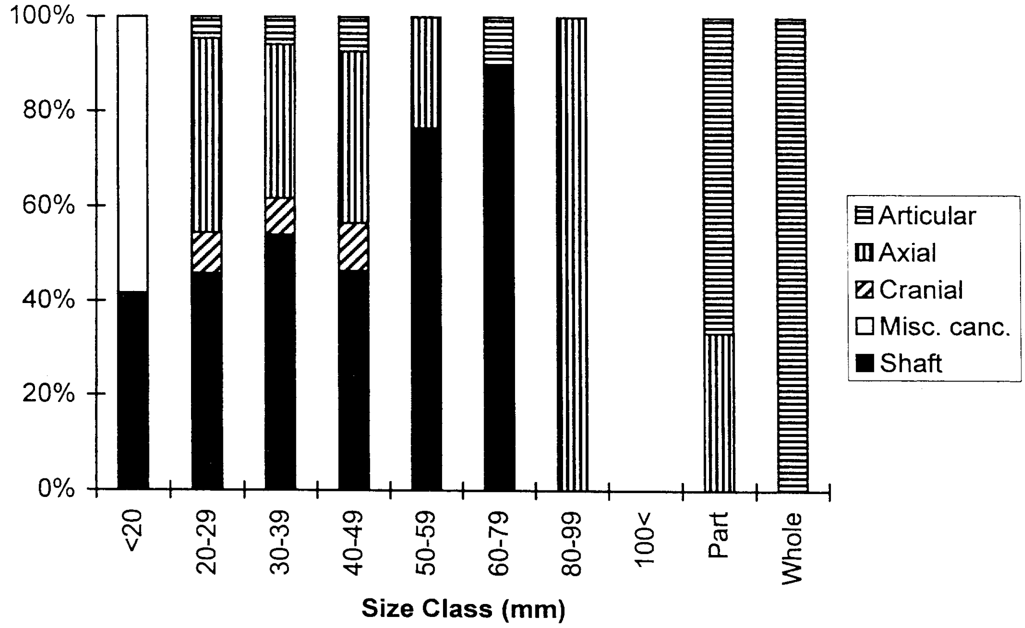

Fig. 11. A graph to show the proportions of different types of land mammal bone fragments in different size classes from the 'black layer' at Ajvide, Gòtland.

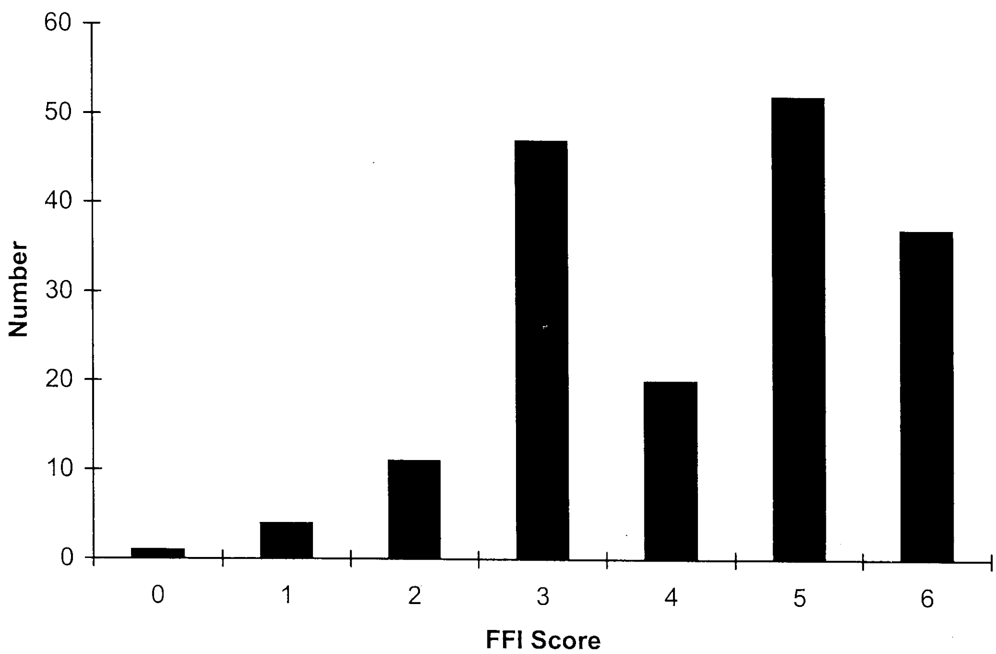

Fig. 12. A graph to show the Fracture Freshness Index scores of land mammal bone fragments from the 'black layer' at Ajvide, Gotland.

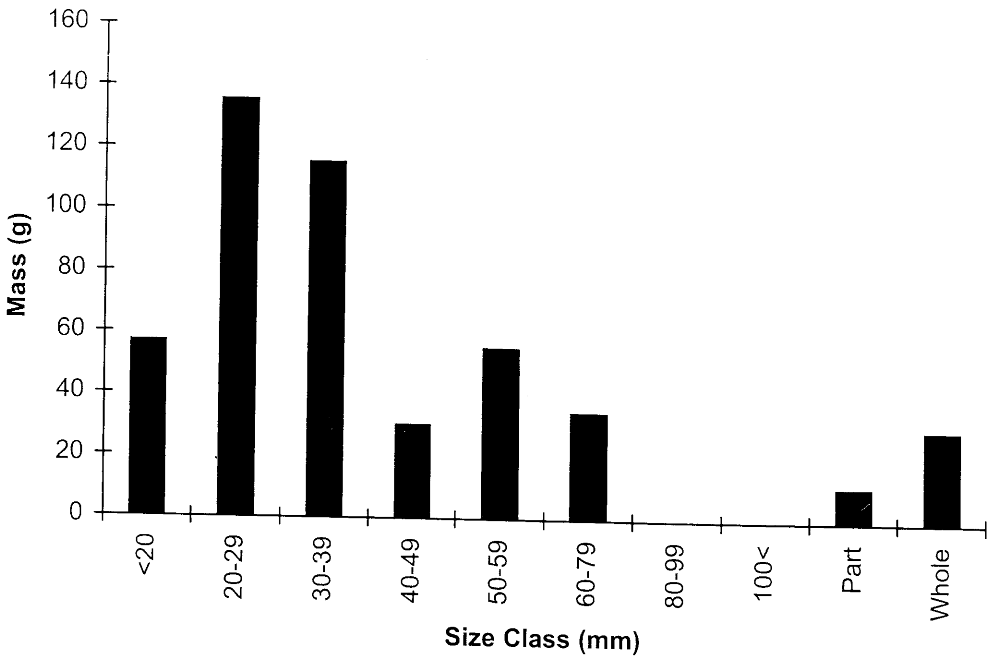

Fig. 13. A graph to show the masses of sea mammal bone fragments in different size classes from the 'black layer' at Ajvide, Gotland.

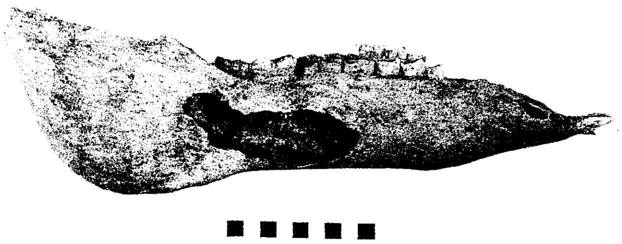

Fig. 14. An example of a pig mandible from a grave at Ajvide that displays evidence for the exploitation of its medullary cavity.

bone looks like possible grease rendering, there would appear to be other causes for the fragmentation in this case. This fragmentation appears to apply to both the land mammal and seal remains, alike.

Discussion

It seems likely, from some instances of helical fracture and the presence of dynamic impact scars, that some bone marrow extraction look place at Ajvide. This interpretation is further supported by the presence of a number of pig mandibles, found in some of the graves, which bare obvious signs of deliberate access being made to the large marrow cavities to be found in that element on pigs (Fig. 14). The patterns observed do not appear to indicate the extraction of bone grease in any quantity. Clearly, the rendering of bones for grease is a very arduous task (Binford 1978) and is only undertaken if needed, whereas, the extraction of bone marrow is easy. Critical deficits in the availability of fat are likely to lead to practices like bone grease rendering and such needs are likely to be seasonal in nature (Binford 1978; Speth and Spielmann 1983; Speth 1987; Outram 1999, 2000; 2003, in press). Is there such a seasonal deficit within the seasonal round of the occupants of Ajvide? Rowley-Conwy and Storå (1997) have been able to establish hunting seasons for both pigs and seal at Ajvide. From metrical analysis of growth, it appears that ringed seals were killed in the late winter/spring and harp seals from autumn to spring. From both metrical studies and age data from jaws, it seems that pigs were hunted between the months of September to January. It is clear that from early autumn till spring the occupants of Ajvide would have had access to plentiful sources of fat from pigs, but more importantly, seals with all their blubber. During the summer there was copious fishing and porpoise hunting. It does not seem that the seasonal round of the 'Pitted Ware' culture Gotlanders contained any period of dietary stress or dearth in fat sources. Hence, the apparent lack of bone grease extraction is entirely understandable.

Conclusion

Through the holistic and detailed study of bone fracture and fragmentation patterns and other taphonomic indicators, it is possible to identify bone marrow and grease extraction. It is also often possible to tell the difference between such practices and other processes that result in high levels of fragmentation. Interpretations relating to the exploitation of bone fats are best considered alongside other data that provides us with a clear picture of the resources available within the seasonal round.

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