The identification and Palaeoeconomic context of prehistoric bone marrow and grease exploitation.

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THE IDENTIFICATION AND PALAEOECONOMIC CONTEXT OF PREHISTORIC BONE MARROW AND GREASE EXPLOITATION

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THESIS ABSTRACT

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THE IDENTIFICATION AND PALAEOECONOMIC CONTEXT OF PREHISTORIC BONE MARROW AND GREASE EXPLOITATION

The reasons for studying bone marrow and grease use, through the analysis of bone fracture and fragmentation in archaeological assemblages, are introduced. Information and methodologies pertinent to the study of prehistoric bone fat use are discussed. These include consideration of ethnographic information, the dietary significance of fat, lipid chemistry, the economic anatomy of animals, the potential application of optimal foraging theory, our current knowledge regarding bone fracture and methods of assessing bone fragmentation levels. A method of indexing bone fracture freshness is created and tried out on a range of laboratory generated bone fractures. A methodology for identifying levels of bone fat exploitation on archaeological sites is formulated along with models for the recognition of various bone fat exploitation patterns. This methodology is tested on a number of archaeological sites. These sites are Mondeval de Sora (a Mesolithic Italian site), Wallsend Roman site, four sites in West Greenland (two Palaeo-Eskimo sites and two Norse sites), Ajvide (Gotlandic Middle Neolithic site) and Uxbridge (early post-glacial site near London). At the last of these sites, a spatial element is introduced into the analysis. The methodology appears to be successful in identifying different patterns of bone fat exploitation and different levels of post-depositional damage. The methodological and archaeological issues raised by the case stüdies are discussed and suggestions for future research in this field are made.

TABLE OF CONTENTS

Chapter Seven: Choosing the Methodological Approach to be Used in the Case Studies **159**

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

Mand.	mandible
Scap.	scapula
Hum.	humerus
Rad.	radius
Carp.	carpals
M'c.	metacarpal
Fem.	femur
Tib.	tibia
Tars.	tarsals
Calc.	calcaneum
Ast.	astragalus
M't.	metatarsal
Phal	phalanges
Vert.	vertebrae
Cerv.	cervical
Thor.	thoracic
Lum.	lumbar
Pelv.	pelvis
P.	proximal
D.	distal
Indet.	indeterminate
Canc.	cancellous
App.	appendicular
Artic	articular
FFI	fracture freshness index
Frag.	fragment

DECLARATION

I, Alan Keith Outram, confirm that no part of this thesis has previously been submitted by me for a degree in this or any other University. If material has been generated through joint work, my independent contribution has been clearly indicated. In all other cases, material from the work of others has been acknowledged and quotations and paraphrases suitably indicated.

STATEMENT OF COPYRIGHT

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INTRODUCTION

The stimulus for undertaking the following piece of research is the combined effect of three factors. One factor is the general theoretical outlook of the author and the other two stem from observations of possible current shortcomings in zooarchaeological practice.

Initially, let us consider the first of these methodological shortcomings. For some time I have been concerned about that category in archaeological bone assemblages commonly referred to as "indeterminate". Such bone fragments are indeterminate for a number of reasons. It is usually because they are not considered to be "diagnostic", and by diagnostic the zooarchaeologist usually means that the fragment cannot be assigned to species and skeletal element. Alternatively they may not come from "diagnostic zones"; those areas considered to provide interesting information. In many faunal reports indeterminate fragments will be dismissed after brief quantification (a simple count or a weight), but usually they will not be mentioned at all.

This approach can easily be justified in terms of a simple ratio of effort and return. One appreciates that archaeology is severely limited in financial terms. Environmental analyses tend to be a particularly expensive part of any post-excavation brief. One must, therefore, attempt to gain as much as one can for one's time and money. This means the development of strategies to decide what is worth examining and what is not. But is the indeterminate class truly "undiagnostic"? Does it really tell us nothing?

Furthermore, the indeterminate class is growing. This is not because the zooarchaeologist is becoming more selective, but rather because excavation recovery is improving. Wet sieving is now a widespread practice and could be considered essential on earlier prehistoric sites. The result of such sieving operations is that small "diagnostic" bones (small elements like phalanges, small mammals, birds and fish) are found but so are vast quantities of small "indeterminate" fragments. This is an untapped resource. These tiny pieces may hold the key to many taphonomic questions. These fragments are the last vestiges of elements that did not make it to be counted; elements that were present (still are present) but do not attain the dizzy heights of an NISP (number of identifiable specimens) value. If one is missing humeri on a given site, were they really never there or are they sitting at the bottom of a residue sieve waiting to be diligently picked out from the grit with tweezers, dried, weighed, bagged and forgotten? This is all just so much rhetorical posturing unless it really is possible to get some meaning from these scraps. This is stimulus factor one.

The second observation on zooarchaeological method concerns the identification of within-bone nutrient exploitation. With respect to bone marrow use, reports are frequently very limited in their discussion. All too commonly marrow exploitation will be dealt with in a single sentence, which will read something like this: "the presence of deliberate fracturing of limb bones indicates that marrow was being exploited". In itself there is nothing wrong with such a statement, but the statement is often not supported. There is frequently little discussion of the criteria used to identify the practice of bone marrow exploitation. Fracture types may be mentioned but definitions tend to be loose. There are certainly some exceptions but, in almost all cases, there is no effort to quantify the levels of marrow extraction in the assemblage. Bone grease extraction is often treated in the same scant fashion. We are told something like "the high levels of fragmentation in the assemblage suggest that bones were being rendered for grease", but the level or nature of the fragmentation is rarely scrutinised let alone quantified.

Zooarchaeologists have detailed models for examining the exploitation of meat and secondary products but many (not all) appear less interested in fat, despite its dietary significance. Perhaps this is the effect of the age we live in; an age where fat, either in foodstuffs or on people, is deeply unfashionable. We, perhaps, tend to forget its past dietary significance which for some was a matter of life and death.

With regard to theoretical perspective, I consider it of utmost importance, when dealing with prehistory, to establish all that we can, through uniformitarian principles, before venturing further speculation. In the zooarchaeological study of hunter/gatherers and early farmers this means gaining the maximum understanding of past people's palaeoeconomics, their means and level of subsistence. This is established through our current knowledge of animal anatomy, physiology and behaviour, the physical and chemical properties of bone, the dietary needs of humans and the reconstruction of resource landscapes as moderated by seasonal and long-term climatic change. It is of little use knowing all about one resource and nothing of others. Archaeology is often referred to as a jig-saw with many of the pieces missing

(Trad.), but it is vitally important to gain as many of the pieces as possible. In the case of palaeoeconomic study we are lucky in having so many data available to us that can be evaluated against models derived from uniformitarian principles, replicative actualistic studies and, of course, ethnographic studies. Bone fats are an important resource of food and, as such, are a useful piece to place correctly in our jig-saw of the past.

Once archaeologists have studied how people gained their basic subsistence they are far better placed to address culture, ritual and religion. As anyone who puts together jig-saws knows, it is best to start with the known and work from there. The easiest pieces are the corners, then the edge pieces. Palaeoeconomic "pieces" are very often present in our incomplete set and can often be placed accurately. Cultural and religious "pieces", for instance, are somewhat more difficult to fit and may be missing altogether.

So, the three stimuli for this study are the need to study the indeterminate class of bone fragments in greater depth, to take the identification and interpretation of bone fat exploitation more seriously and to establish as much as we can about past people's palaeoeconomics through uniformitarian principles. These three factors underlie the reasons for studying prehistoric bone marrow and grease extraction through the analysis of bone fracture and the nature of bone fragmentation. Such a study needs to address many issues. Our ethnographic knowledge of bone marrow and grease use must be reviewed, as must our knowledge of bone fat as a dietary resource. Uniformitarian principles must be established for the identification of marrow and grease exploitation, which will include research into the mechanical properties of bone and the ways in which the nature and level of fragmentation can be characterised and quantified. Such a study of fragmentation should include due consideration of indeterminate fragments and what information can be gleaned from them. The theoretical perspectives surrounding the interpretation and implications of marrow fat and bone grease exploitation patterns should be discussed.

To sum up, the aims of this thesis are to, firstly, establish the background knowledge and theoretical framework necessary for understanding within-bone nutrients as a resource, particularly in prehistory. Secondly, a methodology for identifying such practices will be derived, taking all recovered fragments into account. Thirdly, this methodology will be tried out in a number of case studies, which will hopefully, in addition to testing the methodology to find its limits, lead to some interesting archaeological conclusions. Finally, the methodology and general approach will be reviewed and potential future application discussed.

This volume is, therefore, arranged in three principal sections, as follows. Chapters one to three form the first section. This section is designed to provide an overview of what we know about bone fat as a resource and its context within palaeoeconomic theory. There is consideration of ethnography, fat chemistry, the economic anatomy of different food species (including a worked example), optimal foraging theory and how such information might be applied in an archaeological context. The second section, chapters four to seven, considers how bone marrow and grease exploitation might be identified on archaeological sites. This includes discussion of current knowledge and zooarchaeological practice regarding the study of fracture and fragmentation patterns. A new methodology for fracture study is established and tested on experimentally fractured bone specimens and a new approach to fragmentation studies is also outlined. Having established methodology the remainder of the volume is dedicated to archaeological case studies. These case studies are principally designed to test the fracture and fragmentation methodology established in the preceding chapters, rather than the various palaeoeconomic methods and indices discussed earlier in the volume. The first part of this volume is essential as a theoretical backdrop to the case studies, however, and is very relevant to the final interpretation of those sites. Without the first section, the second and third sections would be meaningless.

CHAPTER ONE

A BRIEF ETHNOGRAPHY OF BONE MARROW AND BONE GREASE EXPLOITATION

1.1 Introduction

Initially, let us define what we are discussing. Bone marrow is the fatty material that is found in the hollow part of long bone shafts (the medullary cavity) and the lower jaw. Bone grease, on the other hand, is the fat that can be extracted from within spongy (cancellous) bone such as long bone epiphyses and axial elements. Before one can consider the identification and importance of bone marrow and grease exploitation in the archaeological record, it is clearly necessary to gain an understanding of the ways in which this resource has been exploited by extant populations and historically recorded peoples of the recent past. Such an ethnographic study is important for a number of reasons. In order to establish a methodology for the identification of bone marrow and grease extraction it is essential to survey as wide a variety of possible extraction techniques as possible. These extraction techniques must be carefully considered with reference to the level of technology available. It is also important to understand the value attached to bone fat, as a dietary resource, by a variety of peoples, if useful insights into past subsistence economics are going to be made from the archaeological study of this resource. It will also be useful to note aspects of bone fat utilisation related to the ethnographic informant's taste. Whilst it will be necessary to form some generalised theory regarding the use of bone fat as a resource, it is also necessary to acknowledge individual and cultural variability. Such variability may be related to matters such as taste, but it may also be related to varying levels of technology and varying environmental and climatic settings. It is particularly important to note the differences in the exploitation of bone fat between peoples with different environmental settings. Such matters as the use of fat in craft activities also needs to be noted.

Despite the clear importance of building up a large amount of ethnographic data on bone marrow and grease exploitation, this is a far from simple task. By far the best information available comes from a very small number of studies carried out with the zooarchaeologist in mind. These form the basis of much that is said below. Gleaning relevant information from anthropological works on traditional peoples is more problematic. Whilst there is a vast wealth of ethnographic accounts, it is decidedly hit and miss as to whether a given account will give details of marrow and grease exploitation. Detailed accounts of hunting practice, butchery and food sharing abound, but references to bone fat are frequently absent or brief and undetailed. The principal problem facing this researcher is that it was impossible to read every account available in order to find those which might provide the detail required. As such it is conceivable that some good accounts have been missed. In particular, the search is still on for even a single good account of marrow fat and grease use amongst subsistence agriculturalists!

1.2 Bone Marrow Extraction and Consumption

By far the most detailed account of hunter-gatherer marrow exploitation is that given by Binford (1978) on the Nunamiut Inuit. It is worth spending some time summarising his observations. Binford (ibid. p152) notes that processing at a base camp varies from processing in the field, at kill sites or hunting stands. Let us first address the domestic consumption of marrow at a base camp.

The basic diet of the Nunamiut tends to be strips of meat in a stew (ibid. p145) and it was noted that if the stew was rich in fat then marrow might not be consumed. If the stew is less rich in fat, however, whole marrow bones are passed around to those dining. Before individual consumers cracked their marrow bones they often warmed them near the fire or in the stew pot itself. The women usually abstained from marrow consumption at communal meals.

The bones cracked for marrow at these meals tended to be the major limb bones. Metapodials and phalanges are treated differently. The "white marrow" in the more distal limb bones is preferred in terms of taste. It can also be used for waterproofing skins and treating bow strings (ibid. p24). Metapodials are processed separately for the production of "marrow cakes" (ibid. p147). There is a special method used for breaking metapodials which is not applied to other elements. They are split longitudinally by cleaving them from the centre of the proximal articulation with a knife struck by a maul. This is carried out on an anvil. Such longitudinal splitting would produce a clear pattern in the archaeological record. Phalanges, containing very little marrow, are not always processed. The decision on whether to process phalanges or not is based on two variables. If the foot has not already been skinned then processing for marrow is less likely because the total processing time will be too long. Processing of phalanges is made more likely if the individual concerned is worried about the camp's current level of fat supplies. The marrow in phalanges is good tasting, however, and when it is consumed the phalanges are usually stewed first, broken in two and the contents sucked out (ibid. p148).

The marrow cavities of mandibles are considered a more marginal resource. When they are utilised the mandible is often first stewed before the mandibular hinge and the incisors are removed by hitting below the third molar and down between the incisors and the premolars, leaving just the tooth row (ibid. p149). The mandible is not exploited if times are good (ibid. p150). In fact, Binford quotes an old saying to demonstrate this:

"The wolf moves when he hears the Eskimo breaking mandible for marrow."

(Trad. in Binford 1978, p150)

Nunamiut hunters sometimes consume some marrow whilst at kill sites or hunting stands. This is sometimes done in a very expedient fashion while the bones are still articulated. If this is the case the meat is cleaned from the shaft of the target bone, which has often been warmed next to a fire. The periosteum is then scraped from the shaft before it is broken. The bone is broken mid-shaft with blows from a suitable object; often the handle of a hunting knife (ibid. p153). Bones are only broken mid-shaft if they are articulated.

With disarticulated bones, more time is spent cleaning. The bone is warmed, as before, and is picked completely clean of tissue, including the articular ends. Such cleaning often leaves marks like butchery marks. The periosteum is scraped off before breaking, leaving clear scrape marks (ibid. p153). The cleaning takes about 4.5 minutes per bone. The breaking, which tends to take about 5 minutes, is carried out by holding the bone in one hand and striking the bone (in the same way as striking a flint) with "hammer" tool of some description. The bone is hit near both articulations. The result is two articular ends, often with shaft splinters attached, a shaft cylinder and many smaller splinters and chips. The marrow is then poked out, very often with a willow twig (ibid. p155). Shaft fragments are usually discarded but articular ends are retained for further processing (see bone grease below).

Spiess (1979, 25) has also commented upon the exploitation of marrow in the cold regions of the North. He says that the humerus, radius, femur, tibia, metapodials and mandible are usually exploited for marrow. He makes the general statement that marrow bones are best processed by cracking them mid-shaft with a cobble and then parting the two ends with a twisting action. Flakes of 10cm to 4cm wide are created in this way. It is not clear whether Spiess observed this method in action or whether he happened upon it himself. Binford goes to some length to stress that he never witnessed the Nunamiut using this method (Binford 1978, 155) and the present author has never read an account of a twisting method having been witnessed. This is not to say that it is not a viable method. Spiess (1979, p158) comments, in agreement with Binford, that mandibles are utilised when other fat resources are becoming exhausted.

Burch (1972, p362) briefly deals with uses of marrow in his study of caribou as a resource in North America. He states that natives of that area boil the caribou femur before splitting it for marrow. In north-western Alaska, caribou bones are saved up to provide a resource of fat through times of food scarcity. Fat is also used as a fuel for lighting.

Fat is a resource of particular importance to those living in very cold environments and marrow features as a food resource almost universally in accounts of such people. Marrow is considered a particular delicacy by people living in Siberia (Levin and Potapov (eds.) 1964; p636 and p708) and is usually eaten raw, fresh from the still warm carcass of the animal (ibid. 155, p636). It is also used by peoples in Siberia in the process of tanning (ibid. p575).

Marrow is also a much utilised resource of hunter-gatherers in much warmer climates. O'Connell and Hawks (1988) give a clear description of marrow processing by the Hadza of Northern Tanzania. The Hadza might consume marrow at the kill site, a butchery station, the base camp or anywhere in between and discard their waste at any of these locations. The bones are usually warmed near a fire before they are cracked (ibid. p118) and once defleshed are broken mid-shaft with a blow from a stone or knife handle. It should be noted that the periosteum is not removed (ibid. p120). The bones processed are the humerus, radius, femur, tibia and metapodials. The reason for mid-shaft attack rather than the removal of the articulations, as the Inuit did, probably relates to the fact that the Hadza do not retain the articulations for further processing. As such, breaking the mid-shaft of the bone is probably the more expedient method.

Another major African hunting and gathering group is that of the Kalahari Bushmen. Kent (1993, 336-8) relates the exploitation of marrow by a group of sedentary San Bushmen. Marrow bones are generally heated, before they are cracked, in the embers of a fire, but not to the extent that the bone is charred in any way. The articular ends are chopped off with an axe and the contents sucked out. The bone is usually seated against a wooden anvil while it is broken. Marrow is sometimes extracted at the kill/butchery site but bones are frequently transported back to a camp for this purpose. It is interesting that the bones of relatively small animals such as steenbok and springbok are transported and processed for their marrow content (ibid.).

Yellen (1991, p19) confirms that the !Kung Bushmen of the Kalahari exploit the marrow from the bones of small animals as well as large ones. Quite small ungulates like steenbok and duiker have most of their marrow bones exploited down to and including their metapodials. The metapodials, like in the Nunamiut example, are split longitudinally. Bones are heated in boiling water prior to the consumption of marrow to make it of a more appetising consistency. The informants claimed that roasting the bone, however, made the marrow too "thin" (ibid. p13). The marrow from the mandibles of small animals is apparently not worth exploiting. However, marrow is exploited from major long bones of animals as small as the porcupine (ibid. p9).

The Alyawara of central Australia exploit the marrow from kangaroos (O'Connell and Marshall 1989, p396). They roast the kangaroo in a pit, but prior to putting the carcass in the roasting pit the tail and rear foot (tarsals, metatarsals and phalanges) are cut off. These are put into the pit to roast too, but are dug out early and the bones are cracked and the marrow sucked or picked out (ibid.). The metatarsal of a kangaroo is a large bone which is likely to have a large marrow cavity.

Although a suitable account of marrow utilisation has not been forthcoming for a subsistence farming culture, it is clear that pastoralists, with their domesticated stock, fully exploit marrow as a resource. Brain (1981,15) states that all marrow bones are broken by the goat-keeping Hottentot pastoralists of the Namib Desert. The method was to rest the bone against a stone anvil and break it transversely mid-shaft with a hammer stone.

1.3 The Production and Consumption of Bone Grease

After the marrow has been extracted from a bone, more valuable fat can be extracted by boiling the bone for bone grease. Once again, it is Binford (1978, p158) who gives the best account of such an activity. The Nunamiut do not discard the articular ends of marrow bones, after they have been processed for marrow, but store them up in buckets in the cold outside their hut doors. The spongy bone in the head of the bone contains much fat and when sufficient articular ends have been stored up they will be processed for this resource. They are smashed up into tiny pieces with a hammer on a flat stone. The fragments are then boiled in an iron kettle. The fat which floats to the top of the water is solidified by the addition of snow. The solidified fat is then skimmed off and the process repeated. In the days before iron kettles, which can be heated directly over a fire, the processing was done in wooden buckets and the water was brought to the boil by the addition of pre-heated stones (ibid. p159).

Bone grease production is very labour intensive and Nunamiut processing sessions often last one to three days. Binford (ibid.) carried out a time and motion study for the processing of one batch of bone in a 5 gallon wooden bucket. 60.9 pounds of heating stones had to be collected, 3 back-loads of firewood were used and the batch took 2 hours for 2 women for a yield of just 7 ounces of fat. The processing waste of grease extraction is unmistakable. It leaves a large pile of pulverised bone and heat cracked stones (ibid.). In times of desperation the Nunamiut resort to processing shaft fragments for bone grease as well (ibid. p146). In the summer, when articular ends cannot be preserved for as long, some small-scale grease production is carried out on fresh material (ibid. p164).

Wilson (1924, quoted in Davis and Fisher 1990, p263) outlines the processing of bones for grease by the Hidatsa American Indians. They also boil the axial skeleton for grease but keep this process separate from the extraction of grease from long bones. The Hidatsa find the grease of long bones of higher quality because it stays a good consistency. The grease made from backbones and shoulder bones apparently goes hard. The best grease is called "footbone grease" which backs up the observation that Binford made regarding the marrow and fat of more distal bones being considered better.

Leechman (1951, p355; 1954, p7-9), in his studies of the Loucheux people in northern Yukon, gives a very similar account of bone grease manufacture to

Binford's. The bones of caribou and moose were broken on a stone anvil into fragments “as big as fingernails”. They were fractured with the back of an axe (before axes were available the informant said that stone hammers were used). The fragments were boiled in a kettle and the fat extracted in the same way as in Binford’s account. The Loucheux people, however, always processed the bones within two or three days of butchering the animal. If left longer, its taste apparently became unpleasantly strong. Once extracted, fat is stored inside a caribou’s stomach where it is said it will keep for two or three years. The bone grease is used for making “pemmican” (a mixture of dried meat strips and fat made into cakes) and for daily cooking. Leechman (ibid.) was told it was used much as we use butter. It is interesting that the Loucheux people used a similar method for extracting grease from fish guts (ibid.).

Leechman (1951, p355) also refers to other accounts of bone grease production. The general method of extraction and use of bone grease seems fairly uniform across the colder regions of North America. One account quoted says that the fat is kept in bladders and the bones of two buffaloes will produce about twelve pounds of grease (ibid.).

The current author has not seen an account of bone grease manufacture for hunter-gatherers living in a warmer climate. This is probably due to an inability to keep the fat in stored up bones from going rancid in the heat. It appears that the Loucheux, above, had something of a problem with storage in the Yukon, though it was unclear what season of the year was being referred to. The sedentary San, in their very hot climate, certainly appear to put bones in their stews so as to make use of some of the fat that way (Kent 1993). There is no systematic extraction of grease, however.

1.4 Seasonal Need for Fat in the Diet

Speth and Spielmann (1983) outline several ethnographic accounts of the particular need for sources of fat during the late winter and spring in temperate, subarctic and arctic environments. Accounts of the Kutchin people in Alaska, the Copper Eskimo and several accounts of 19th Century pioneer hunters all suggest that, during the winter and spring, sources of fat were particularly sought after in preference to protein (ibid. p4). During this season, prey animals tend to have little fat in their meat because they, too, are dietarily stressed. Eating too much lean meat without having other energy sources (i.e. fat or carbohydrate) can lead to "protein poisoning" (Speth and Spielmann 1983; Speth 1983, chapt. 7; Speth 1991). Hunters' preference for "fat" animals is not limited to winter in cold climates, however. Most hunting peoples of the world tend to choose fatter quarry over lean quarry. This can be seen in accounts of the Kalahari San, the Miskito of Nicaragua, the Pitjandjara of Australia, the Cree of Canada and Hidatsa of the North American Plains, for example (Speth 1983, p146).

The dietary importance of fat is discussed in detail in Chapter 2.

1.5 Points for Discussion

The above summary of within-bone nutrient exploitation by some different cultural groups in different resource landscapes raises several important points for discussion which are relevant to interpreting archaeological bone assemblages where within-bone nutrients may have been utilised.

1.5.1 Indication of Resource Stress

It is clear that the level to which a people will exploit bones for their internal nutrients will depend very much upon their individual needs for the supply of fat. There is a point at which it will seem impractical, to a given people, to exploit bones further for marrow and grease because it requires too much work, and more resource could be obtained in some other activity. This crucial point will change depending upon the resource environment (see Chapter 2.1).

The study of the Nunamiut (Binford 1978) demonstrates this point well. In very good times, when meat, and therefore the stew, is fatty it is possible that no marrow is consumed at all. In good times phalanges may be ignored if they seem too much effort. In bad times it is necessary to process mandibles and in desperate times to boil shaft fragments for grease. Very often the level of fat obtainable is related to the condition, not just the availability, of the animals.

People in harsher resource environments may well consider quite low-yield sources of fat worth exploiting. The !Kung example (Yellen 1991) shows that small animals are utilised but the extent to which their bones are cracked for marrow declines the smaller the animal in question. It might be concluded, therefore, that levels of resource stress might be indicated by the degree of exploitation occurring for within-bone nutrients in terms of anatomical part and size of animal being exploited.

1.5.2 A Matter of Taste

It is important to note that choices in processing are not simply affected by an aim of maximum yield but also an aim for quality and desirability. The Nunamiut (Binford 1978) and the Hidatsa (Wilson 1924) both showed preference for the marrow and grease of distal limbs., for instance. This is probably due to differences in fat chemistry (see Chapter 2.3).

1.5.3 Snacking and Bone Deposition

Most of the accounts above show that some processing and consumption of bone fats will occur away from base camps at hunting stands, butchery sites and kill sites themselves. This means that some marrow exploitation will not be visible in the bone assemblage at a camp site because it took place elsewhere and the bones were discarded elsewhere.

Bunn, Bartrum and Kroll (1988) argue that snacking amongst the Hadza is not always predictable or logical. Hunters will sometimes take the trouble to carry a bone most of the way back to the base camp and then snack from it very close to the site and discard it there (ibid. p442). Such a bone has been discarded at no particular type of site at all and to all intents and purposes is lost to the archaeological record! Snacking practices are not uniform from hunter to hunter or even from hunting trip to hunting trip by the same hunter. In other words, we must allow for a certain random factor in bone transport and deposition decisions.

1.5.4 Bone Heating

Although some bones in the above accounts are processed entirely fresh, most marrow extraction occurs after bones have been warmed in some way. In many accounts this warming is very gentle, just to soften the marrow. Often the maximum temperature reached is 100°C, since the bones are placed in boiling water. In other cases, when the bone is in or near a fire, the bones may be subjected to higher temperatures for a short time. None of the above accounts, however, suggests severe heating or cooking as such.

Such treatments of bone, before fracture for marrow, may affect the way the bone breaks (see Chapters 3.1 and 4). This would change the criteria upon which bone marrow exploitation might be identified in archaeological bone assemblages.

1.5.5 Variation in Breakage Method

In the above accounts, several different methods of cracking the bone were outlined. To what extent do these create different types of break and debris? Some bones are broken mid-shaft whilst others are broken near the articulation. It is worth paying particular note to this in archaeological assemblages, since these different practices may be related to different intentions for future use. For instance, breaking at articulations appears to be linked to bone grease production whilst mid-shaft cracking seems more expedient if the bone is then to be discarded.

1.5.6 Issues Relating to Bone Grease Production

The debris left by the mass production of bone grease should be relatively easy to identify in the archaeological record. The absence of this practice need not be taken to mean that the fat was surplus to the requirements of that people. There are at least two other reasons why bone grease extraction might not occur. Firstly, if the climate (or season) is too warm to allow for the satisfactory storage of bone in non-rancid condition then it is unlikely sufficient material could be massed at one time to warrant large scale production of grease. One must, therefore, assess the past climate of the site in question. Secondly, grease production requires a certain level of technology and resource. Boiling of water must be sustained for quite a period of time requiring much labour and firewood. The more primitive the technology, the more difficult the process will be and, therefore, may seem less worth doing to the people in question.

1.6 Conclusion

It is clearly important to take note of the ethnographic variability we have seen in the accounts above. In interpreting the information relating to within-bone nutrient extraction on an archaeological site it seems necessary to juggle many possible variables at once. There will be no general, all-applicable model to work to. Instead, each site will have to be considered individually in terms of its resource environment, climate, culture demography and possible seasonality.

CHAPTER TWO

UNDERSTANDING BONE MARROW AND GREASE AS A RESOURCE

2.1 Optimal Foraging Theory

2.1.1 Introduction

If one is to draw wider economic and social inferences from the study of bone marrow and grease as a resource, then one must have a suitable theoretical framework for understanding the relevance of resource use choices within subsistence economies. Just such a theoretical underpinning is available in the form of "optimal foraging theory". Optimal foraging theory was adopted by anthropologists from biology. It basically asserts, in the way it is used in anthropology, that in certain arenas humans will attempt to maximise their net rate of energetic gain. This will involve choices in diet, foraging location, foraging group size, foraging time and settlement pattern (Bettinger 1991, chapt. 4).

The application of models of optimal behaviour, such as utility indices (see 2.2), to the archaeological record has frequently been criticised for being overly predictive and deterministic. Indeed, if optimal models are used purely as a deterministic tool, this criticism is valid. However, as Higgs and Jarman (1975, p2) noted, and this is irrefutable, "...ultimately all human culture and society is based upon and only made possible by biological and economic viability." Our species must operate within economic, biological and, therefore, environmental constraints. It is useful to define these constraints for any given situation under archaeological or anthropological study. The lower constraining limit is the minimum of food and warmth a human requires to live. The upper constraining limit is the optimal model for the given environment and demography.

In the above sense, optimal models are deterministic, and correctly so. They should not, however, be constructed to be predictive of human behaviour within the limits of viability outlined above. One should not necessarily expect to observe optimal behaviour, but, instead, the optimal model should be seen as a measuring stick against which behaviour can be evaluated. As Foley (1985, p222) stresses, "...behaviours should not conform to the template, but...it provides a standard measurement and comparison against which deviations can be assessed."

Optimal foraging theory is still quite rarely applied in archaeology and has received criticism from Binford (1983a, p219). Binford, however, is not consistent in his arguments against optimal foraging theory. There is certainly a strong argument that optimal foraging theory is a form of middle-range theory in exactly the way Binford proposes it (Bettinger 1991, p107)! It can certainly be argued that Binford's (1978) modelling of bone transportation by hunters is a form of optimal foraging theory (ibid.).

Below, two approaches within optimal foraging theory will be considered in detail and adapted so as to be specifically relevant to the subject in hand; the use of bone marrow and grease as a resource. These two approaches are "marginal value theorem" and "diet breadth" modelling.

2.1.2 Marginal Value Theorem

Marginal value theorem (Charnov 1976; Bettinger 1991) is designed to predict how long a forager will spend in a given resource patch. Anyone who has experience in collecting berries from wild hedgerows has a clear understanding of marginal value theorem. The berry picker has to decide at what point it is worth leaving a given bush to find another. This time of leaving is rarely when all the berries have been picked off that bush, but is at a time when one will clearly have greater success by moving on to another bush. Marginal value theorem dictates that the optimal time to leave a foraging patch is when the net energetic gain from that patch falls below the mean net energetic gain for the surrounding environment (and this will include the time it takes to find another patch) (ibid.).

Figure 2.1 shows marginal value theorem in a graphical form. The solid line on this graph represents the energy acquired in the patch. The rate of energy acquisition decreases over time as the resource is used up. The optimal time to depart from the patch is when the rate of energy acquisition falls below that of the surrounding environment (the dotted line) (i.e. where the environment line forms a tangent with the patch curve). If the environment is one of meagre resources, the gradient of the environment line will be shallow and will create a tangent further along the patch curve than the steep line of a rich environment. Hence, this indicates that it is worth spending longer in the patch if the surrounding environment is poor. Furthermore, the point at which the environment line intersects the x-axis, on the left hand side of the y-axis, will indicate the acceptable level of travelling time. As stands to reason, in a resource-poor environment, with a shallow environment line, the acceptable travelling time will be greater.

Marginal value theorem can be adapted to answer a similar question in relation to the use of animal resources. Having stalked and killed their prey, hunters of larger mammals are faced with the task of transporting their quarry back to their camp. They have to decide whether all the parts of the animal are worth transporting, and, if not, which ones are of greatest value to them. Such decisions will be affected by the food value of given skeletal elements. This food value will be in the form of meat, bone marrow and grease. If the use of bone marrow and grease as resources are to be studied, it is important to understand the decisions made by hunters regarding which elements are transported to the camp and which are then processed for marrow. Marginal value theorem can be used to model hunters' transport choices in terms of food energy acquired. Having produced an optimal model, one can discuss other possible influences of transport decisions such as hunters' personal tastes, craft uses of animal products, hunters' immediate needs (i.e. snacking at the kill site), hunting group size and settlement patterns.

Figure 2.2 shows an adaptation of the graphical solution of marginal value theorem for use in understanding hunters' bone transportation choices. "Time" now represents the time spent on disarticulating elements and transporting them from the kill site, with the in-built assumption that the elements will be removed in rank order according to their energetic food value. Therefore, if the mean energetic intake for the environment (i.e. the mean return from hunting, butchering and transporting a kill) is low (i.e. huntable animals are scarce) then it will be worth spending longer processing and transporting a particular kill. Hence, more elements of lower food value will be transported (and vice-versa).

There is a further consideration regarding animal element transport, however, which is total need. In considering the foraging of plant foods an infinite need is assumed. This works quite acceptably for plant foods. Large animals, however, provide a very large amount of food in one go. A level of total need might be reached which affects the transport pattern. If the total calorific requirement of a hunting party is higher than the optimal cut-off point dictated by the environment line (as in the case of total need A in fig. 2.2) then the model is unchanged. However, if the hunters have more limited needs (such as in total need B), at a level below optimal cut-off point (A), then the new optimal cut-off will be at the point where the hunters' need is fulfilled. This is the point where the energy from the kill-site curve intersects the horizontal line of total need (B) (cut-off B, fig. 2.2).

It is worth noting a, perhaps much rarer, limit which might affect element transport decisions. Occasionally there will be a time limit which might create a cut-off point prior to that suggested by marginal value theorem. Binford (1978, chapt. 2) gives an example where the pattern of element transport from a Nunamiut hunting stand, Anavik, was affected by the breaking up of ice flows. There was insufficient time for the hunters to carry out their normal and intended butchery and transport practices. They were unable to tranport all the elements they would have liked to.

2.1.3 Diet Breadth

In modelling diet breadth, one is concerned with finding the optimum number of different types of food items, that should be present in a diet, to maximize energy returns (Bettinger 1991, p84; MacArthur and Pianka 1966, p603). A forager is confronted with a vast array of potential dietary items. These different items will have different abundances, different food values and require different levels of processing. A foraging community is faced with deciding just how many dietary items are worth exploiting.

An optimal solution (in terms of energetic gain) to this problem is presented in figure 2.3. Here dietary items are arranged along the x-axis in decreasing order of food value of the item. Food value, in this case, is energy yield divided by processing time. Something which is both easy to process and of high calorific value will rank highly (such as a large soft fruit, rich in sugar). An item with little calorific yield which is hard to process (such as a particularly hard shelled small nut) will rank well down the list. The advantage of having a large number of different items in one's diet is that it will take less time to find items to eat, since one has a higher probability of encountering a food item on a foraging trip. This is represented by the "search time" line in figure 2.3. However, as the number of items is increased, more items which require a lot of processing will be included. The result is shown in the "handling time" line, which goes up as diet breadth increases. The optimal diet breadth is represented by the best compromise between search time and handling time. This is shown in the "overall foraging time" line, which combines the two factors. The optimal diet breadth is where there is the smallest amount of time expended to acquire a unit of energy.

This model provides one with the optimal diet breadth for the environment. Therefore, deviations from the optimum are likely to be indicative of some social or cultural decision or necessity. Deviations may be particularly indicative of demographic pressures on the environment.

This model is very easily adapted to consider decisions related to the utilisation of bone marrow and grease. Figure 2.4 shows this adaptation. Animal marrow sources are now put in order along the x-axis. The largest, easiest to process marrow bones will rank highest followed by less productive ones. Bone grease production will rank lower since it requires much processing and the desperate boiling of bone shaft fragments for grease would probably rank last. Otherwise, the model works in exactly the same way.

2.1.4 Conclusion

It can be seen that optimal foraging theory can be very useful in understanding hunters' and food processors' decisions. Before one can consider processing of bones for their fat content on archaeological sites, it is clearly essential to understand the decisions that dictate which skeletal elements reach that site. In the application of marginal value theorem to this question, the total food value of each item must be considered (protein and fat). Once bones have reached a processing site, diet breadth modelling can be useful in understanding which bones are processed for bone marrow and grease. Unexpected levels of bone transport and bone processing, within a given environmental setting, have great potential to tell us much about cultural or demographic situations. If humans are not behaving according to an environmental and biological optimum (and humans frequently do not) it is important to ask why. Such enquiry may reveal interesting social dynamics or hidden economic pressures which would not have otherwise come to light.

It is rarely possible, particularly when dealing with the archaeological record, to have all the data needed to get full use out of optimal foraging theory. It is often possible to make more relative statements using optimal foraging theory as an underpinning, however. It is with this theoretical underpinning that many of the conclusions in later chapters will be made.

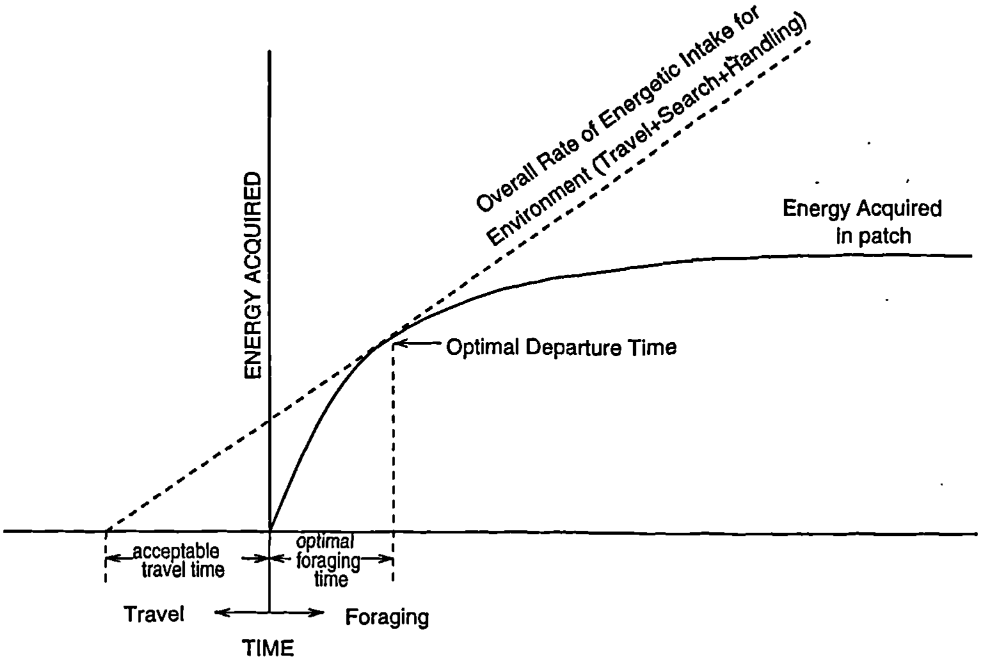


Figure 2.1 - A visual representation of Marginal Value Theorem (after Charnov 1976; Bettinger 1991)

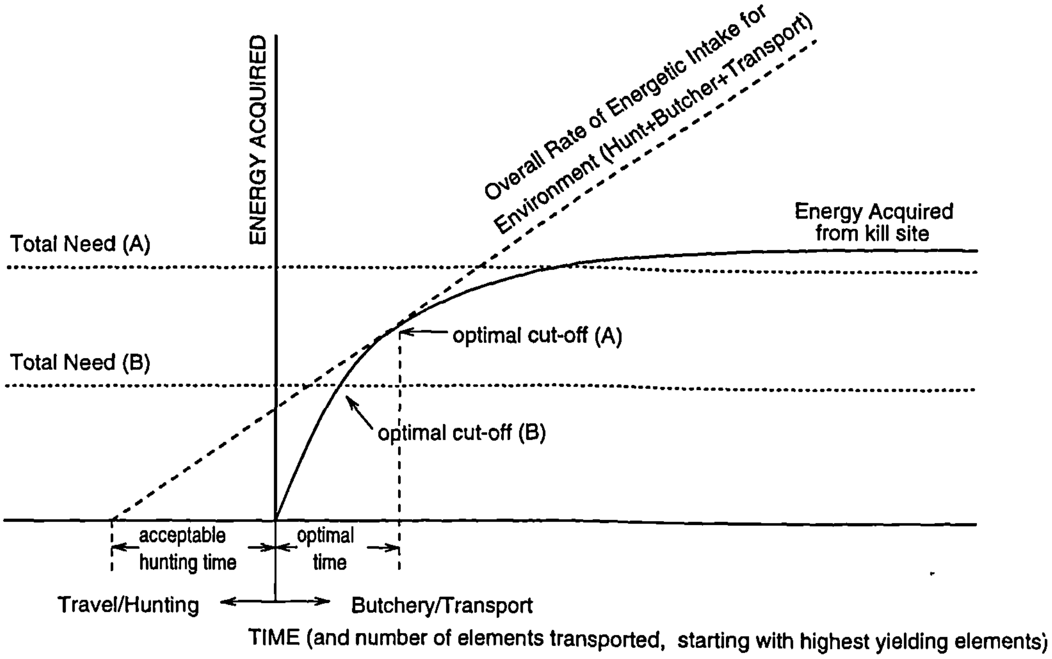


Figure 2.2 - A visual representation of Marginal Value Theorem as adapted to the consideration of hunters' element transport choices

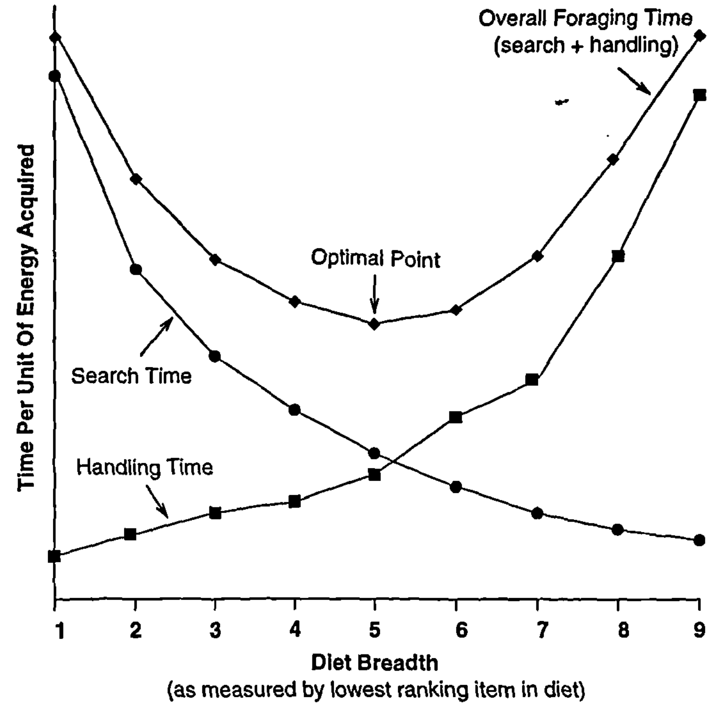


Figure 2.3 - A visual representation of a Diet Breadth Model (after MacArthur and Pianka 1966; Bettinger 1991)

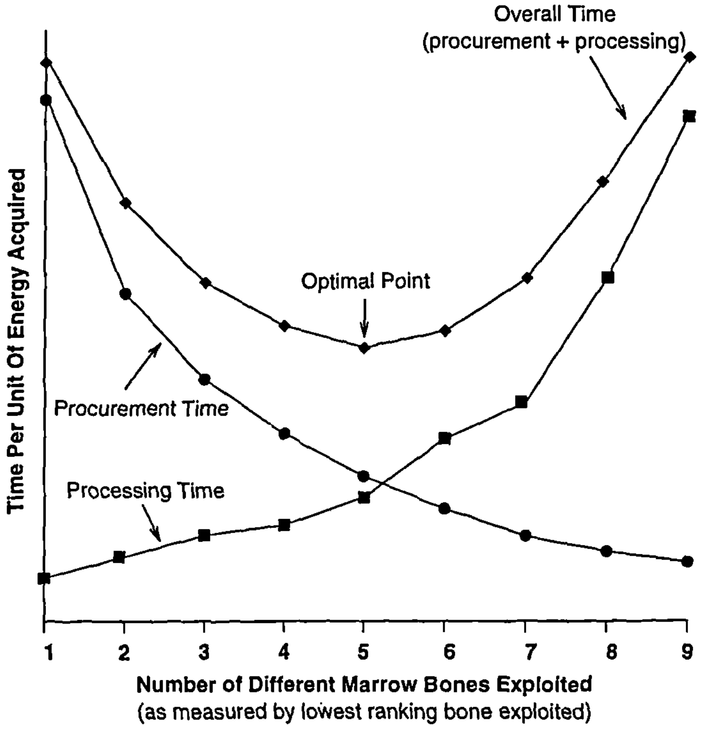


Figure 2.4 - A visual representation of a Diet Breadth Model as adapted to the consideration of marrow bone exploitation choices

2.2 The Construction of Bone Marrow and Grease Indices

2.2.1 Introducing Utility Indices

In order to study hunters' transport and processing choices or to apply optimal foraging theory it is essential to have a clear understanding of animals' anatomy in economic terms. Many issues relating to past choices in subsistence economics are lost to us. Matters such as taste in foodstuffs can only be speculated upon. Environments can, to a certain extent, be reconstructed with great effort and some uncertainty. The amount of food value available on different elements of different animals can, however, be ascertained from studying living animals. Such data, derived from uniformitarian principles, are invaluable in giving us something tangible in the past around which theories can be hung.

Lewis Binford (1978), during his study of the Nunamiut Inuit, was one of the first anthropologically minded archaeologists to attempt to create detailed indices of the relative food values of animal parts. He created indices for the value of meat (MUI: Meat Utility Index), marrow (MI: Marrow Index) and grease (WGI: White Grease Index) for the different elements of sheep and caribou. He combined these together to create a general utility index (GUI) (ibid.). Many more indices have now been created by other zooarchaeologists for other species of animal, although there is still much scope for more work in this field. Below is a summary of the most important work on indices of bone marrow and grease.

2.2.2. Marrow Indices

During the construction of his marrow index, Binford (1978, chapt 2) took several factors into account. He was of the opinion that the Nunamiut informants had a preference for marrow with a lower melting point. Such marrow tends to be found in the distal limbs (ibid. p23). He had a chemical assay carried out to assess marrow quality. The melting point is dictated by the proportion of the low melting point fatty acid, oleic acid (see chapter 2.4). In general, more oleic acid is to be found in the hind limb than the fore limb and the amount increases the further down each leg one goes (ibid. p24)(see fig. 2.5).

Next Binford measured the size of marrow cavities. In sheep the femur had the largest volume followed by tibia, humerus, radius, metatarsal, metacarpal, mandible and finally phalanges. In caribou the hind limb was even more dominant in marrow cavity volume, with tibia having the largest cavity followed by the femur, metatarsal, humerus, metacarpal, mandible and phalanges. He next calculated the efficiency of the extraction of marrow by dividing the cavity volume value by the time it took an informant to extract the marrow (ibid.). This has little effect on the rank order of the elements. This efficiency measure can be seen in figure 2.6.

To complete the index Binford applied some mathematical modifications to the efficiency and the oleic acid assay (discussed below) and multiplied the two together (ibid. p26):

$$\textbf{Marrow Index} = \sqrt{}(\text{Vol/ET}) \times 100(\text{OAA})^2$$

where VOL = Cavity Volume, ET = Extraction Time, OAA = Oleic Acid Assay.

Binford went on to test his index and found he had a good statistical correlation between his index and the actual choices made by the Nunamiut for marrow processing (ibid. p31).

Jones and Metcalfe (1988) carried out a re-examination of the index and its correlation to Nunamiut marrow bone choices. They criticized the involved and complicated nature of Binford's index: "...due to the complexity of the formula we are still not certain precisely what the marrow index, as designed by Binford, measures" (ibid. p417). This sentiment is echoed by Outram (in press, a) who examines the precise effect of Binford's mathematical functions. These criticisms will be expounded here. Binford squared the oleic acid assay before dividing it by 100 in order to have "...the effect of compressing or lowering the scale of variability..." and depress the relative values of parts with low levels of oleic acid (Binford 1978, p25). He then took the square root of the efficiency which, once again, if indirectly, favours bones with high oleic acid content (ibid. p26).

Outram (ibid.) criticizes Binford for applying discretionary modifiers which lead one to the belief that his index represents, rather than a combination of measured observable variables, simply Binford's own opinion on marrow value! The true effect of his mathematical modifications can be seen if his index is compared to one with the functions removed (i.e. **(VOL/ET) x OAA**) as calculated by the present author from Binford's data (see figs. 2.7 and 2.8). We see a significant bias towards the distal limbs that contain high proportions of oleic acid but, as can be seen from the efficiency graph (fig. 2.6) yield very little marrow.

Jones and Metcalfe (1988) found that simpler indices were much better. They were able to obtain a stronger correlation with Nunamiut bone choice with an index of marrow cavity volume alone (ibid. p418). Volume multiplied by oleic acid assay produced a good correlation, but not as strong as just volume alone, whilst the oleic acid assay itself produced a mildly negative relationship (ibid. p419). This seems to indicate that Binford may have been seriously overestimating the importance of marrow quality over sheer quantity. Jones and Metcalfe (1988, p421) go on to calculate the marrow value of elements in terms of the numbers of calories that can be extracted in an hour's work (see fig. 2.9). They observe that under normal circumstances the Nunamiut avoid elements that provide below 500 kcal/hr. They also suggest (ibid. p419) that when applying marrow indices to archaeological assemblages that they should not be standardized first (as most of the data for figures in this text are for comparative purposes) but left as raw data. This way allowance is automatically made for different size of animals and their absolute marrow yields.

Blumenschine and Madrigal (1993) carried out a detailed study of bone marrow yields from many examples of different East African ungulate species in order to assess variability. They demonstrated that an animal's size was not the only factor affecting marrow yields. Figure. 2.10 shows some of the mean total marrow yields of different species plotted against body mass. It can be seen that there is not a simple linear relationship between size of animal and marrow yield in all species. Several of the species, which are closely related, do show a relationship between size and marrow yield but others do not. Warthog and wildebeest do not lie on the "best fit" line of the graph and zebra is extremely anomalous (ibid. p562). The marrow cavities of some species are differently structured and there seems to be a particular difference between artiodactyls and perrisodactyls.

With regard to different elements, Blumenschine and Madrigal (1993, p562) find that "...little interspecific uniformity in the skeletal distribution of marrow wet weights is apparent in either small or medium-sized ungulates." It can be seen that the relative distribution of marrow in limb bones varies considerably from species to species (fig. 2.11) and the rank order of different elements (indicated above the chart bars in fig. 2.11) actually changes and not just the degree of separation of elements within a set rank order. These differences in marrow distribution are attributed to locomotor differences (ibid. p570).

The skeletal distribution of marrow is also different in neonatal animals or very young juveniles where more fat tends to be deposited in the distal limbs (ibid. p568). Stress can also affect the distribution of marrow (see below, 2.2.4). The message from Blumenschine and Madrigal's study is clear. Few generalizations can be made about marrow utility from the study of just a few animals because variability is too great. If marrow utility indices are to be used in any detailed analysis then the correct index for the species of animal in question should be employed. If such an index is not available then care must be taken that interpretations are based only upon that which can be upheld generally.

2.2.3 Grease Utility Indices

Binford (1978, p33) also created an index for evaluating elements in terms of bone grease utility. He went about the creation of this index in a very similar fashion to his marrow index. For the bone grease index he considers almost all elements of the body, not just marrow bones, since all bones can be boiled to extract fat. In the construction of the index he treats bone volumes as accurately reflecting the quantity of grease extractable from the bone (see fig. 2.12 for standardized caribou element volumes). He treats density (bone volume/mass) as representing the level of difficulty each element would present in terms of processing time. Once again, oleic acid assays are incorporated in the index since Binford (ibid. p32) notes that grease, like marrow, is favoured if it contains more oleic fatty acid. The formula for his index, with added mathematical modifiers, is as follows:

$$\mathbf{GREASE\ INDEX = (OAA^2/100D) \times (VOL/100)}$$

where OAA = Oleic Acid Assay, D = Bone Density, VOL = Bone Volume.

This index can be criticized in very much the same way as Binford's marrow index. If one compares the volume graph (fig. 2.12) with Binford's grease index (fig. 2.13) one can see that his index is severely biased against the axial skeleton. This is due to the heavy weighting of the oleic acid assay and to the mathematical modifications he makes. The effect of these modifications can be seen if his index is compared to one with the modifiers removed: **(OAA/D) x VOL**. This is displayed graphically in figure 2.13 where it is plain that the applied mathematical functions depress the values of axial elements whilst having a positive effect on the distal appendicular skeleton.

In order to test his index Binford splits the elements into two groups; those that are used by the Nunamiut to make "white grease" (the appendicular) and those that make "yellow grease" (the axial) (ibid. p34). He then tests the index for white grease production. He does not test the yellow grease index. This is unfortunate because we are left unable to ascertain whether his assumptions about grease quality and the axial skeleton were correct. Just because the informants preferred white grease does not immediately suggest that they do not produce yellow grease in quantity and consume it. A person may prefer chicken breast but that does not suggest that they will not eat the leg!

He compares the white grease index against the percentage of given elements selected for processing by the Nunamiut on two separate occasions (one in June and one in April) (ibid. p36). He finds a positive correlation but with some outlyers. These are the carpals and phalanges which the Nunamiut clearly did not think worth processing at all (ibid.). He eliminates these from the equation and then is able to produce a coefficient of correlation of 0.95 for June and 0.91 for April (ibid.). These are very strong relationships but is it justifiable to remove part of the data set to improve one's results!

It is not clear how Binford calculated his coefficients or which coefficient of correlation he employed, but the present writer was unable to match the high correlation when a product-moment coefficient of correlation (PMCC) and a Spearman's coefficient were calculated for the same comparison (for the June data set). The PMCC was 0.78 and Spearman's was 0.75. These are positive and significant correlations but not as impressive as the ones quoted by Binford. If the full data set is employed (for June), including the carpals and phalanges PMCC drops to 0.75 and Spearman's to 0.66. In view of Jones and Metcalfe's (1988) findings it seems of value to compare raw volume data with the June selection data. For the full data set PMCC was 0.79 and Spearman's was 0.73 which are values marginally more positive than Binford's index. For the data set excluding carpals and phalanges Binford's index produces marginally better results than raw volume data (volume produced a PMCC of 0.75 and a Spearman's of 0.69). It certainly seems that, as with the marrow index, using a simple but relevant raw data set (volume) was of as much, if not greater, use as a predicator of behaviour than was Binford's highly complex index. A Spearman's coefficient (on the full data set) comparing Binford's grease value data (oleic acid assay) with elements selected for processing produces a weak, but probably significant, negative correlation of -0.47. Again, this is similar to the findings of Jones and Metcalfe (1988) for marrow. The same test applied using the density data compared to selections produced no significant correlation (-0.19).

Brink (1997) carried out a comprehensive study of the fat content of bison leg bones. For this study fat was chemically extracted from the bones. Weight and percentage of fat were calculated for each end of each long bone. The rank order of elements, in terms of fat yield, was, in descending order, proximal humerus, distal femur, proximal tibia, proximal radius/ulna, proximal femur, distal humerus, distal radius/ulna, distal metatarsal, distal metacarpal, distal tibia, proximal metatarsal and proximal metacarpal (Brink 1997, table 3). It was also found that bone grease weight was accurately predicted by dry bone weight, bone volume and denisty (ibid. p259). Brink is also very critical of Binford's grease index and stresses that it is over-complex (ibid. 266).

All in all, the criticisms of Binford's marrow index can be echoed for his grease index. It just goes to underline the difficulties involved in index construction and the care that should be taken in their construction and testing.

2.2.4 Effects of Stress and Season on the Use of Within-Bone Nutrient Indices

Nutritional stress in animals causes them to mobilize their fat reserves. One of the body's best fat reserves is bone marrow. The depletion of fat in the body follows a fairly set sequence. In the limb bones, the sequence is to mobilize fat from the proximal limbs first. This effect is well documented in many zoological papers (Cheatum 1949, Brookes *et al* 1977, Davis *et al* 1987, Peterson *et al* 1982 to mention but a few) and it is used by wildlife managers to help judge an animal's well-being. The effect is fairly universal but is seen more acutely in some species than others:

> "Fat mobilization was first evident in the limbs of moose in the femur and humerus, then the tibia and metatarsus, and finally the radius and metacarpus. Differences among bones caused by progressive fat mobilization were not as great in moose as in some African ungulates (Brookes *et al* 1977) and white tailed deer (Cheatum 1949). Those studies indicated that femur marrow could be fat-depleted and the animal dead from malnutrition with distal bones still containing considerable fat."
>
> (Peterson, Allen and Dietz 1982, p550)

This effect was noticed in practice during Blumenschine and Madrigal's marrow yield study (1993, p568). Two examples of the effect, taken from their study, can be seen in figures 2.14 and 2.15. Figure 2.14 contrasts a healthy adult Grant's gazelle with a stressed juvenile, whilst figure 2.15 contrasts a relatively healthy adult wildebeest with a stressed adult wildebeest. The marrow yields are expressed by Blumenschine and Madrigal (ibid.) in terms of the energy value of the marrow extracted. They note that unstressed subadults can produce better marrow yields than stressed adults (ibid. p569). They also note that some extremely stressed animals have apparently similar skeletal distribution of marrow fat to unstressed animals but this is because there is little fat anywhere in the body at all (ibid. p570).

Clearly it is of some importance to the application of marrow and grease indices to be aware of the effects of stress. Malnutrition in an animal population in many regions will obviously be closely related to the season of the year. In cold climates stress is usually seen in the winter and spring months and in hot areas in the dry season. This adds a distinct seasonal dimension to the interpretation of marrow use in archaeological assemblages.

Speth (1987) points out the important effects seasonality and nutritional stress in animals has on human populations. He argues, with the support of ethnographic data, that when animals are stressed, and only carry lean meat, care has to be taken to keep enough fat and/or carbohydrate in the diet. An over heavy reliance on lean meat can lead to protein poisoning (ibid.). The acquisition of fat in times of lean meat supply is therefore an important activity. The marrow cavities contain the best supply of fat once meat has become lean. Marrow exploitation may be of greater importance in times of stress, therefore, unless fat has been stored up from processing in an earlier season or body fat reserves alleviate the problem as Bunn and Ezzo (1993) have argued.

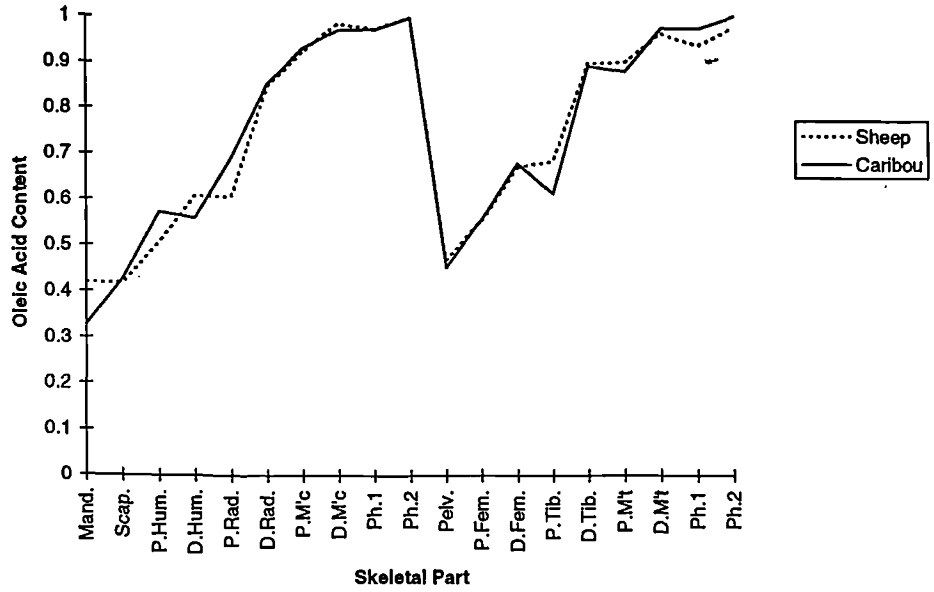


Figure 2.5 - A graph to show the relative Oleic Acid content of marrow in different elements of sheep and caribou (values derived from Binford 1978, table 1.6)

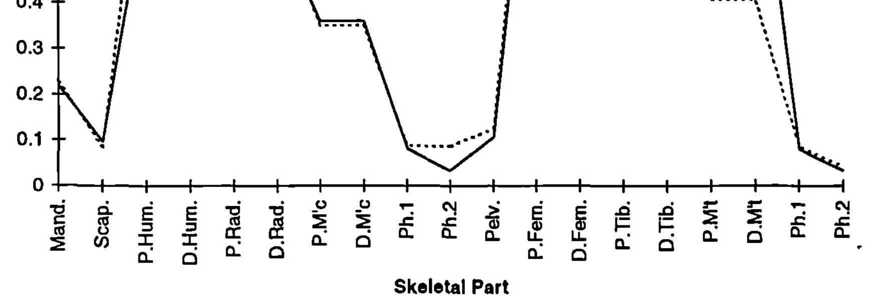


Figure 2.6 - A graph to show the relative efficiency of marrow extraction from different elements of sheep and caribou (values derived from Binford 1978, tables 1.7 and 1.8)

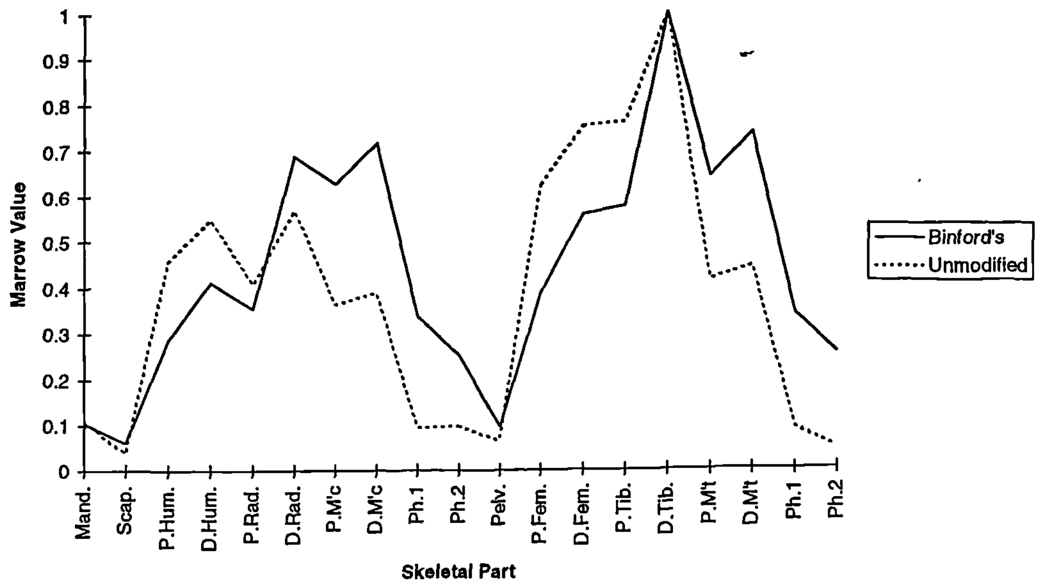


Figure 2.7 - A graph to show a comparison of Binford's sheep marrow index with an unmodified version (values derived from Binford 1978, tables 1.6 - 1.9)

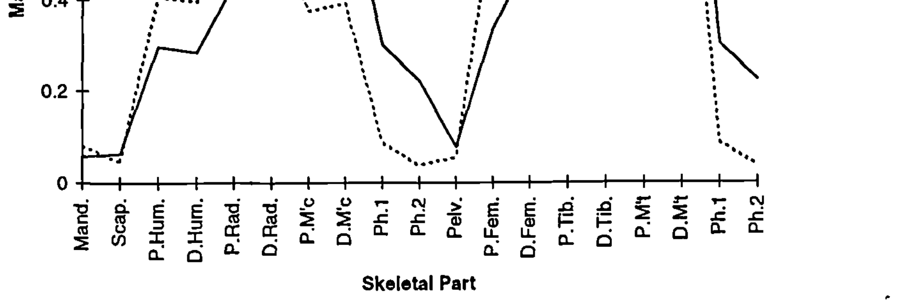


Figure 2.8 - A graph to show a comparison of Binford's caribou marrow index with an unmodified version (values derived from Binford 1978, tables 1.6 - 1.9)

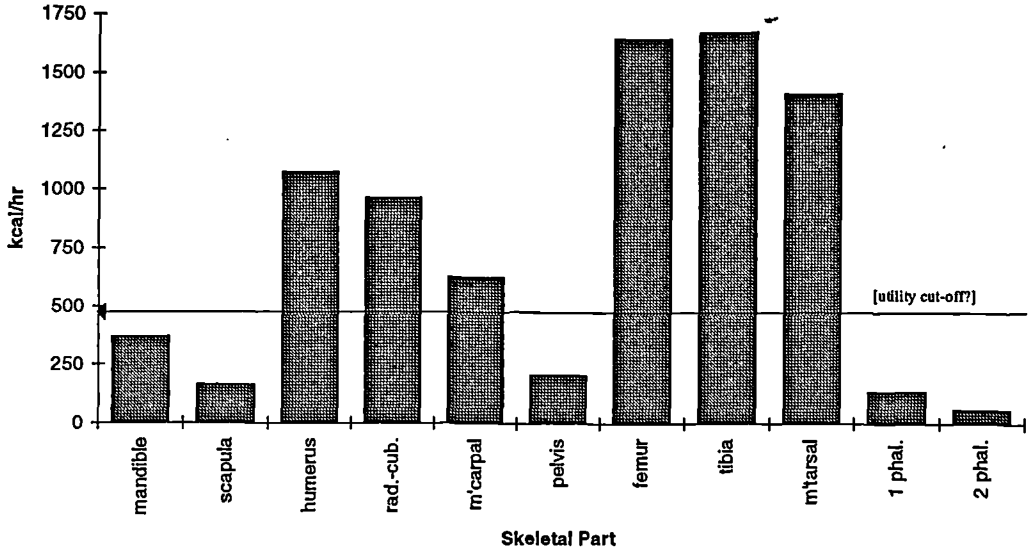


Figure 2.9 - A graph to show the value of marrow extracted from caribou skeletal parts expressed in Kilo-Calories per Hour (values from Jones and Metcalfe 1988, table 3)

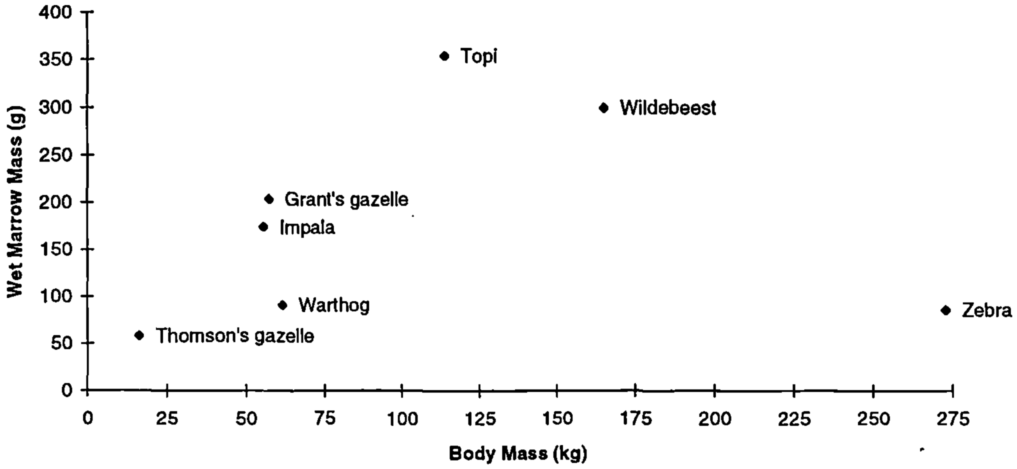


Figure 2.10 - A graph to compare the total mass of different animal species with their total yield of extractable marrow, in terms of wet weight (values from Blumenschine and Madrigal 1993, table 1)

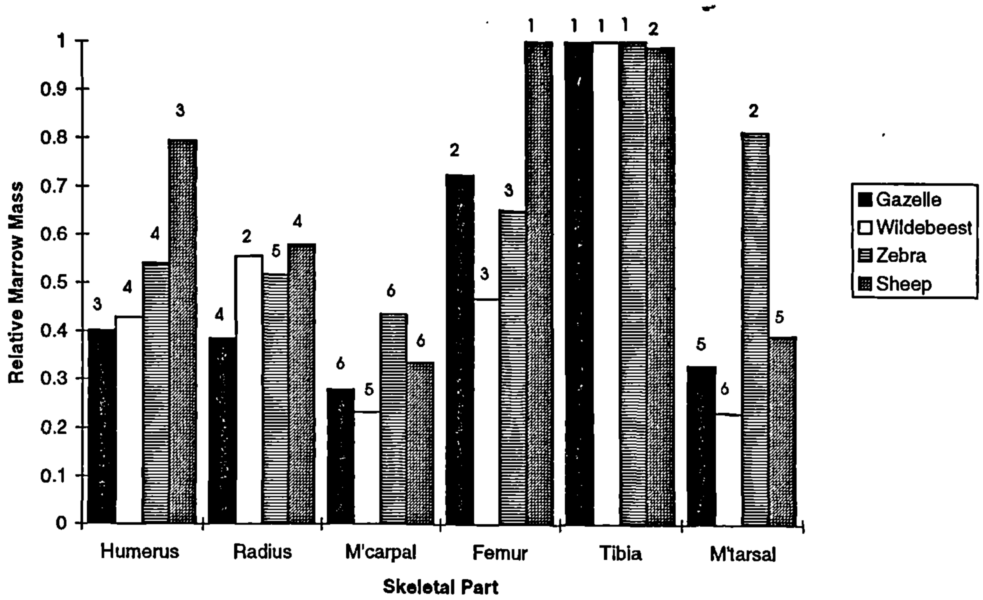


Figure 2.11 - A graph to compare the relative marrow yields from the long bones of four ungulate species (values from Blumenschine and Madrigal 1993, table 2)

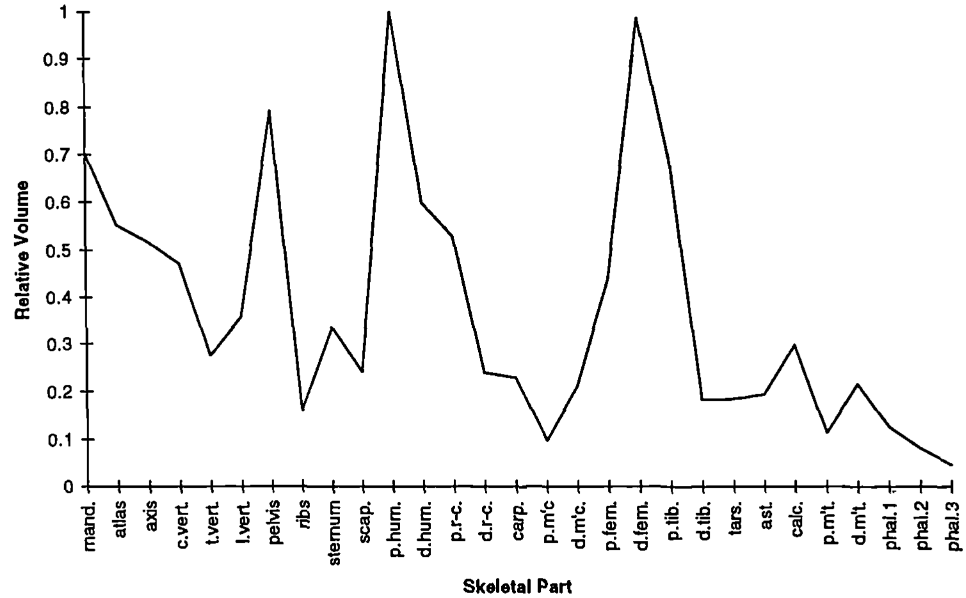


Figure 2.12 - A graph to show the relative volumes of caribou skeletal parts (values derived from Binford 1978, table 1.11)

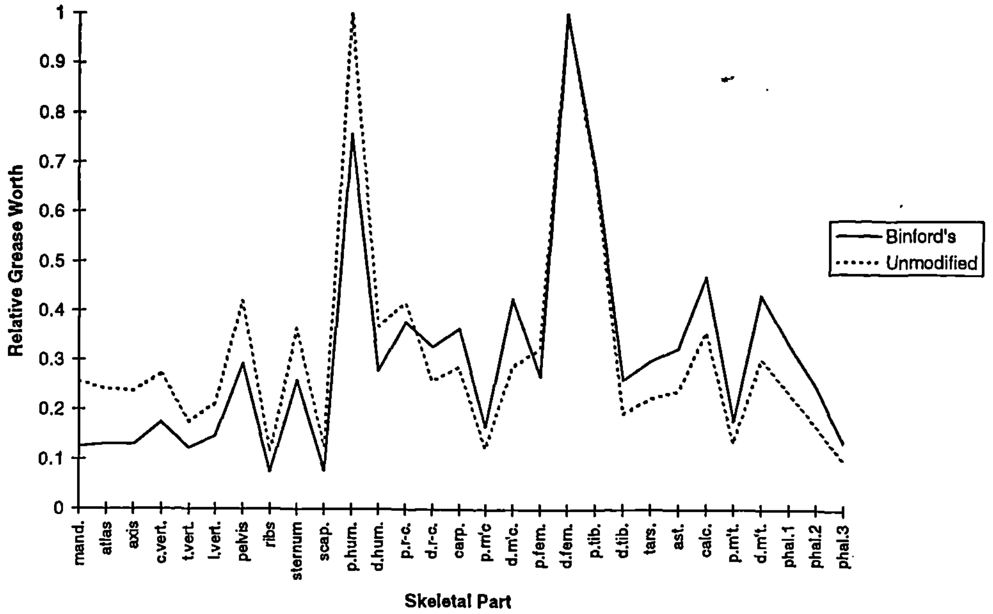


Figure 2.13 - A graph to compare Binford's bone grease index (WGI) for caribou with an unmodified form (values derived from Binford 1978, table 1.11)

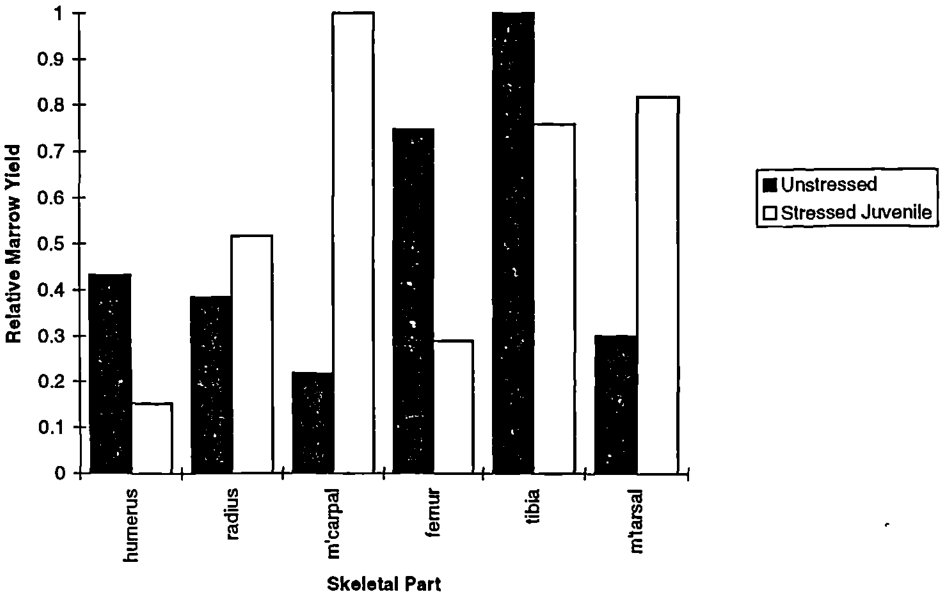


Figure 2.14 - A graph to compare the relative calorific yields from the limb bones of stressed and unstressed Grant's gazelle (values derived from Blumenschine and Madrigal 1993, table 5)

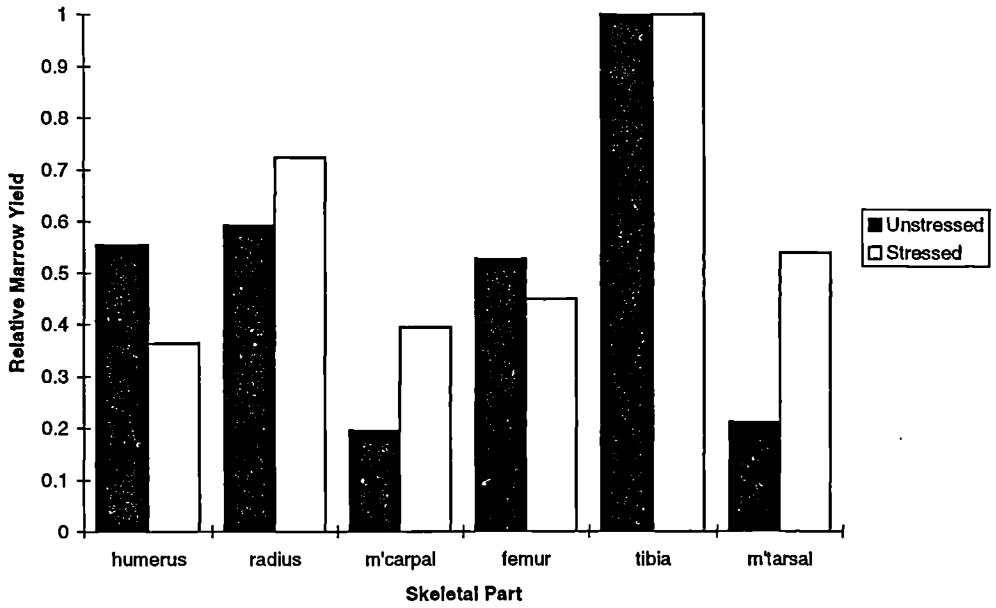


Figure 2.15 - A graph to compare relative calorific yields from the limb bones of stressed and unstressed wildebeest (values derived from Blumenschine and Madrigal 1993, table 5)

2.3 Application of Indices to the Archaeological Record

2.3.1 In consideration of Element Transport

Binford (1978, chapt 2), having constructed his utility indices for caribou, developed a methodology for comparing actual frequencies of bones on archaeological sites with the index. His method was simply to plot a scattergraph of elements' frequency against the utility index values for the elements. A best fit line is then drawn on the graph and it is interpreted according to a series of models.

Figure 2.16 shows the models for the bone assemblage of a camp site (i.e. the elements the hunters chose to transport home from the kill site). If the hunters had decided to transport elements purely according to their utility then the scattergraph would create a straight line emanating from the origin. Metcalfe and Jones (1988) refer to this as being an "unbiased" strategy but this is a little misleading as the strategy is not random, it is biased towards utility. Here it will be referred to as the "utility model" (see fig. 2.16). The "bulk" model (Binford, ibid.) refers to a model where more elements have been transported than their absolute utility suggests. The hunters in such a situation are aiming to gain as much as possible from a kill (in terms of marginal value theorem, the environment intake line is shallow and the cut-off is therefore late, see chapt. 2.1.2). Only the lowest value elements will be poorly represented on the campsite (see fig. 2.16). The opposite model to this is the "gourmet model" (ibid.) where the hunter has decided to bring only the best elements back to the camp (in marginal value theorem the environment intake is very steep and cut-off therefore early, or the groups total need has been reached, see chapt 2.1.2) (see fig 2.16).

Figure 2.17 shows the same models as designed for application to a kill site. The models are simply inverted. The "inverse bulk model" shows what would be left at a kill site if a bulk model had been practised. There would be only elements of very low utility (see fig. 2.17). The "inverse gourmet model" shows what would be left at a kill site if a gourmet model had been practised. There would be most elements present, with only those of highest utility missing (see fig. 2.17).

This method of addressing levels of element transport is now the standard methodology used by zooarchaeologists. However, Outram (in press, b) levels several criticisms at this methodology and suggests that a new method might be employed. It is often difficult to see exactly where a best fit line should go on such a scattergraph and it is very easy to allow one's eyes to be drawn to see a curve that is not there. Metcalfe and Jones (1988, p491) try to escape this problem by attempting statistical correlations. In order to carry out a linear correlation, they take a reciprocal of the element frequency data on the basis that "this transformation tends to straighten hyperbolic curves." The problem with this is that there is no particular reason why the curve should be hyperbolic.

Another problem with the scattergraph method is that it is difficult to tell what the relationship between particular element abundances and their utility is (Outram ibid.). By far the greatest drawback of the current method is that there is no particular indication of where the hunters' perceived cut-off point was, with regard to transportation (ibid.).

The new method Outram (ibid.) suggests is that a graph should be constructed which shows the difference between abundance of elements and their utility. This method has many complexities and is only outlined here. A histogram should be constructed where the elements are arranged in decreasing order of utility along the x-axis. The y-axis should represent the difference between standardised element abundance (%MAU) and the food utility index ((S)FUI, after Metcalfe and Jones 1988) (i.e. %MAU-(S)FUI).

Figure 2.18 represents the utility, gourmet and bulk models at a camp site using this method (N.B. the curves in these diagrams indicate the shape that would be created by the ends of the histogram bars). In a utility model, there will be no difference between abundance and utility. In a gourmet model elements will be under-represented at the camp site. They will be over-represented in a bulk model. The apex of the curve created by the ends of the histogram bars will represent the cut-off point in the transport strategy (see fig. 2.18). If a kill site is being considered the FUI values need to be inverted (ibid.) and the x-axis organised in increasing order of inverse (S)FUI. The y-axis will now be calculated thus: %MAU-Inv(S)FUI. This graph needs to be compared against another set of similar model diagrams.

The principal advantage of this method is that the hunters' perceived optimal cut-off point is shown. This makes for easier application of optimal foraging theory. Furthermore, the relationship between individual elements' abundance and utility can be clearly seen from the individual histogram bars. Anomalies in the pattern also show up clearly (ibid.).

2.3.2 Diet Breadth

The application of bone marrow and grease utility indices to a consideration of diet breadth and processing choices is straight forward. The indices will form the basis for the ranking of the elements in the diet breadth model (see chapt. 2.1.3). It is, of course, also necessary to consider the necessary processing time for each element. Binford (1978) did make some consideration of extraction efficiencies. It is clear that the extraction of marrow is a far more energy efficient activity than grease extraction, from ethnographic accounts (see chapt. 1), and this needs to be taken into consideration in any diet breadth ranking.

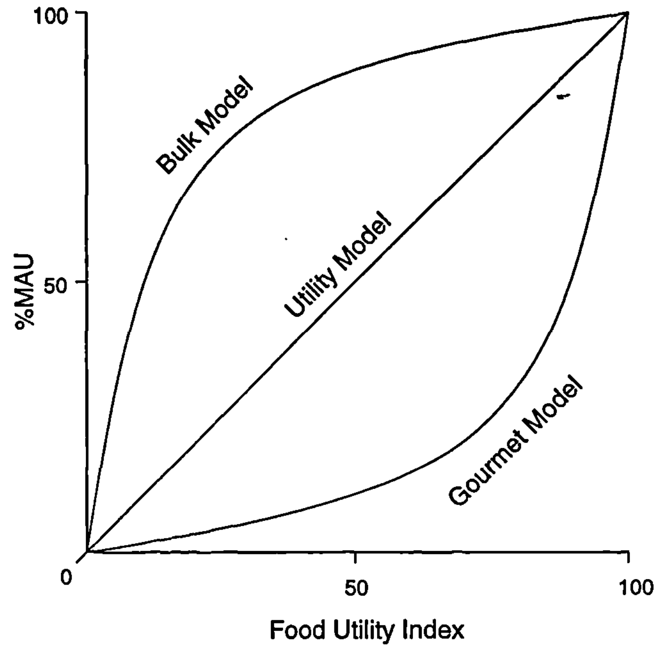


Figure 2.16 - Models, showing the relationship between element abundance and element utility, for three different transport strategies, as represented at a transport destination (camp site)(after Binford 1978, fig. 2.18)

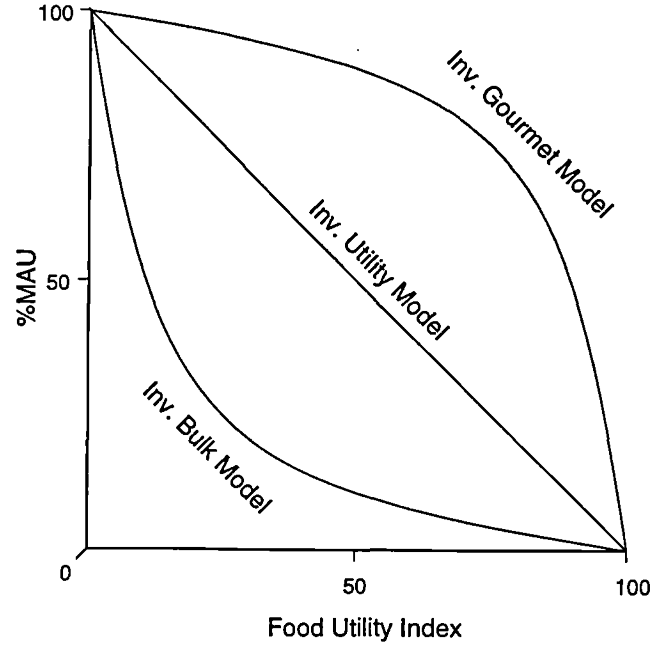
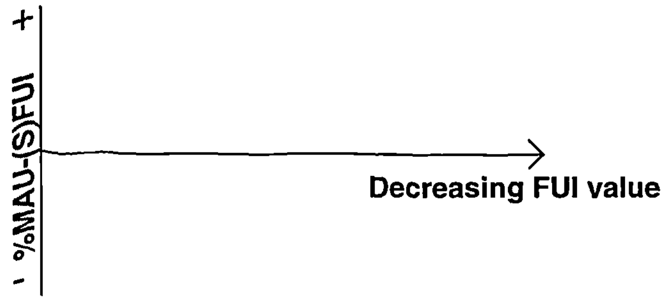
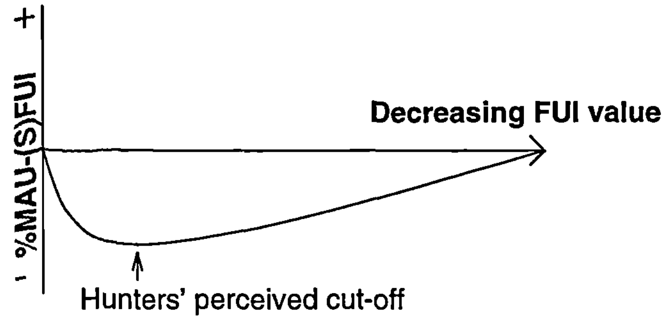


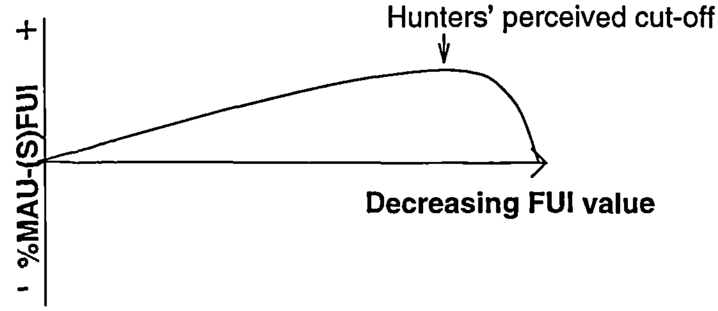
Figure 2.17 - Models, showing the relationship between element abundance and element utility, for three different transport strategies, as represented at a transport source (kill site)(after Binford 1978, fig. 2.18)



Utility Model



Gourmet Model



Bulk Model

Figure 2.18 - Models, showing the difference between element abundance and element utility, for three different transport strategies, as represented at a transport destination (camp site) (after Outram forthcoming)

2.4 The Chemistry and Nutritional Value of Animal Fats

2.4.1 Lipid Chemistry

The bulk of bone marrow and grease consists of lipids. Lipids can be split into two basic classes on the basis of melting point. Fats are lipids that are solid at room temperature whilst oils are liquid at room temperature (Nawar 1985, Erasmus 1986).

In chemical terms, lipids are quite a wide range of substances that usually have poor solubility in water but greater solubility in organic solvents (Nawar 1985, Mead *et al* 1986). They are also defined as being "...actually or potentially compounds of fatty acids" (Mead *et al* 1986, p5). In living things the vast majority (c. 99%) of lipids are esters created by a reaction between glycerol and fatty acids (Nawar 1985, 140).

Esters are created when alcohols react with organic acids. In this instance the alcohol is glycerol and the organic acids are fatty acids, which have long carbon chains. Glycerol, which has three alcohol (OH) groups can be seen structurally displayed in figure 2.19. Fatty acids, which are characterized as having a carbon chain ending in a double bonded (terminal) oxygen atom and an OH group (together, known as a carboxyl group), come in two basic forms: saturated and unsaturated. In saturated fatty acids the carbon chain consists only of single bonded carbon atoms; all other bonds being to hydrogen atoms. The chain is saturated with hydrogen. An example of a saturated fatty acid is stearic acid, common in animal fats, which has a carbon chain of 18 atoms (see fig. 2.20). Linoleic acid, also found in animal fats, has 18 carbon atoms as well, but two pairs of these are double bonded to each other (see fig. 2.21). The carbon chain is, therefore, not saturated with hydrogen. More hydrogen could be added at the expense of the double bonds (hydrogenation). Unsaturated fatty acids are monounsaturated if they have only one double bond or polyunsaturated if, like linoleic acid, they have more than one.

The carboxyl group of the fatty acid reacts with the alcohol group of glycerol to create the ester, resulting in the exclusion of a water molecule in the process. An example of a glyceryl ester can be seen in figure 2.22. This is a triglyceride, as all the alcohol groups have reacted, but sometimes only two react (diglycerides) or only one (monoglycerides).

2.4.2 The Composition of Bone Marrow and Grease

Triglycerides make up around 95% of all fats we eat (Erasmus 1986, p45) and the fats in bone marrow are also dominated by these. In a study of the composition of marrow fat from femurs and bone grease from ribs of several domestic animals (Abd-El-Aal & Mohamed, 1989), it was shown that triglycerides accounted for between 68.5% and 97.3% of bone fats. The bone fats of ribs tended to contain fewer triglycerides than femur marrow. In cows, rib fats contained 68.5% triglycerides whilst the femur marrow was 95.5%. These proportions were, respectively, 89.9% and 97.3% in goats, 90.0% and 96.6% in sheep and 71.4% and 93.1% in pigs. The rest of the lipid content was made up, in various proportions, by diglycerides, cholesterol, free fatty acids and polar lipids (ibid.).

The characteristics of a glyceryl ester are determined by which fatty acids reacted to create them. In animal fats the fatty acids usually have a chain length of 16 or 18 carbon atoms (Nawar 1985, p147). In the above analysis of femur marrow (Abd-El-Aal & Mohamed 1989), it was found that, in cattle, pigs, sheep and goats, oleic, palmitic and stearic acids were dominant. Stearic acid has a saturated chain of 18 carbon atoms (denoted by the notation 18:0, the 0 representing the number of double bonds in the chain). Palmitic acid has a saturated, 16 long carbon chain (16:0). Oleic acid is a monounsaturate (18:1). Linoleic acid (18:2), a polyunsaturate, myristic acid (14:0) and acids denoted by 14:1 and 16:1 are present in small quantities. This composition can be seen in graphic form in figure 2.23. Rib fat, in general, had a similar composition but slightly larger proportions of saturated acids (ibid.) (see fig. 2.24).

Binford (1978, p24), as mentioned above (chapt. 2.2.2), shows that the fatty acid composition of bone marrow changes for different bones down the leg. The percentage of oleic acid (18:1) increases from 40% in the proximal humerus to 79% in the second phalanges, on the front leg, and from 44% in the proximal femur to 77% in the second phalanges, on the rear leg of a six month old sheep. Very similar results were obtained from a mature caribou (ibid.) (see fig. 2.5). This is a common feature in most mammals (West and Shaw 1975; Turner 1979). The difference in appearance and consistency of marrow as a result of this can be seen in figures 2.25 and 2.26, which show cattle femur marrow and metatarsal marrow respectively. From viewing these pictures it is clear that the consistency varies considerably and this could easily affect the way marrow from different parts of the body is perceived and utilised.

One of the clearest physical characteristics of lipids to be altered by fatty acid composition is the melting point. As a rule of thumb, the longer the chain length of constituent fatty acids the higher the melting point will be (Erasmus 1986, 20; Mead *et al* 1986) and the more unsaturated the fatty acids, the lower it will be (Erasmus 1986, 30). Therefore, for instance, the marrow fat of lower limbs, containing a greater proportion of unsaturates, will have a lower melting point than the upper limb's marrow.

It has been suggested that the higher proportion of unsaturated fat in distal limbs is a useful adaptation to cold climates because the low melting point unsaturated fats will remain mobile even though they are in cold extremities of the body (West and Shaw 1975, p599; Turner 1979, p599). This may just be fortuitous, however, since many tropical animals display a similar pattern (Turner ibid.). Some mammals, though, have adapted their fat chemistry to the environment. The desert bighorn sheep lives in an extreme climate where it is very cold in winter but approaches 38°C in summer. It has a normal fatty acid distribution in winter, with more unsaturated fat in the lower limbs, but in summer the saturation level in the distal limbs vastly increases. This is likely to act as an insulator to prevent the heat conducting from the ground and raising the animal's temperature (Turner ibid.).

The possible combinations of fatty acids in glycerides are very numerous and so marrow is made up from a mixture of fats and oils with very variable melting points. Some potential combinations have melting points below the freezing point of water. Perhaps the highest likely melting point would be that of the triglyceride of stearic acid (glycerol trioctadecanoate) at 73.5°C. Certainly, bone marrow and grease will be totally molten before the temperature of boiling water. Most likely combinations have melting points between 20°C and 70°C (data from Buckingham (ed.) 1982).

In some cases, the diet of an animal can affect the fatty-acid composition of its lipids. For instance Hilditch and Williams (1964 table 41) present data from a study of pig depot fats of pigs under different dietary regimes. Animals fed on a diet of brewers' rice, tankage and grass or a diet of maize, skimmed milk and grass had a fair proportion of monounsaturates but little polyunstaturate. However, pigs fed exclusively on ground nuts or soya beans had high proportions of polyunstaurated linoleic acid in their fat. Ruminant animals (sheep, cattle etc.) tend to always have a very high proportion of saturated fats, irrespective of their diet. This is because the bacteria in their rumen hydrogenates most unsaturates present, hence, saturating them (Hilditch and Williams 1964, p112; Mead *et al* 1986, p76).

2.4.3 The Nutritional Value of Fats

Fats, above all else, are a provider of energy, giving approximately 9kcal/g. This is more than double the energy that can be gained from eating protein or carbohydrates, which both yield around 4kcal/g (Erasmus 1986, p185; Mead *et al* 1986, p459). Fats also help to supply several fat soluble vitamins. These are vitamins A, D, E and K (Mead *et al* 1986, p459). There are also two fatty acids which are essential to the proper functioning of the body. These are linoleic acid (18:2) and linolenic acid (18:3) which are both polyunsaturates (Erasmus 1986, Mead *et al* 1986). Fats also help to make food more palatable and provide the consumer with a feeling of satiety (Mead et al 1986, p459).

On the downside, long chain, saturated fatty acids, contained in animal fats, are thrombogenic and lead to coronary heart disease (ibid. p468). This is caused because of a tendency for these fatty acids to aggregate together and form deposits in organs and arteries (Erasmus 1986, p21). The essential fatty acids, however, help to combat this action (Mead *et al* 1986, p468).

A further problem with high concentrations of saturated and monounsaturated fatty acids is that they compete with the essential acids for the enzymes that metabolise them (Erasmus 1986, p215). Hence, if a fat has a low proportion of essential acids the value of those that do exist is reduced still further by competition with other acids for enzymes.

Referring back to figures 2.23 and 2.24, it can be seen that the fats in bone marrow and grease in most domestic animals are dominated by monounsaturates (oleic acid) and saturates (stearic and palmitic acids), with only small amounts of essential fatty acids being present. Of the animals shown, the pig is the only one with significant quantities of linoleic acid and is, therefore, the healthiest fat of those represented.

Figure 2.27 shows the results of analysis of fats from pasture fed cattle, pasture fed horse and chicken. In this graph the composition is displayed in nutritional terms. It can be clearly seen that whilst cattle have a very poor level of essential acids, horses have plenty. Cow fat is so essential acid impoverished that the net effect of consuming this fat, taking enzyme competition into account, is worse than having gained no essential acids at all from that source. There are sufficient saturates and monounsaturates to inhibit essential acid metabolism from other food sources. Beef fat could be thought of as "...an essential fatty acid robber" (Erasmus 1986, p215). Horse fat, on the other hand, is relatively rich in both linoleic acid (5%) and linolenic acid (17%) (Mead *et al* 1986, p75). The horse gains its high proportion of linolenic acid from grass, which itself has a linolenic acid representation of 46% (ibid. p71). Ruminant animals do not receive the same benefit from this source because, as mentioned above, rumen bacteria hydrogenate this acid (ibid. p76), saturating it. It is interesting to note that the fat from horses is apparently as healthy as that from chicken (see fig. 2.27).

It is also of particular interest to note that modern domestic animals have a different fatty acid composition from their wild counterparts. In both pigs and cattle, wild specimens have far more essential acids (and their useful derivatives) and also slightly less saturated fatty acids (Erasmus 1986, p214). This stark contrast can be seen in graphic form in figure 2.28 (NB. Erasmus ibid. does not give the source of his data and the author has been unable to find similar studies to confirm or contradict it). It would be interesting to know what this effect is due to. It would also be useful to know the composition of fats from a wider range of wild food species, but this author has yet to encounter such data.

2.4.4 The Relative Value of Bone Marrow and Grease to Other Fat Sources

The marrow cavity of bones is one of the major stores of fat in an animal's body and a very obvious fat source to anyone who requires it. The level to which a person is likely to require extra dietary fat is bound to be linked to the amount of fat already consumed within meat that has been eaten. Indeed Inuit marrow consumption has been witnessed to be related to how fatty the meat stew being eaten already is (Binford 1978).

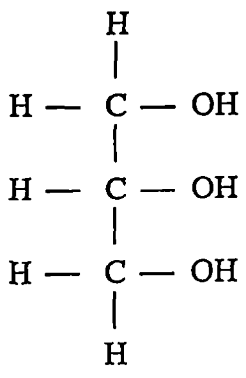
It is, therefore, important to note that modern domestic stock have a much higher proportion of fat in their meat than wild animals. Beef is usually between 24% and 45% fat, mutton between 20% and 40% and pork between 35% and 60%. On the other hand, wild moose and venison meat is usually about 2% to 3% fat. Wild reindeer meat is only 3% fat whilst domesticated reindeer has nearly 20% fat in its meat. Even rabbit meat increased from 5% fat to 8% fat when it became domesticated (Erasmus 1986, p213).

A conclusion that might be drawn from this is that bone marrow and bone grease may have been of considerably greater importance to those hunting wild animals, since the meat of such animals is relatively fat impoverished.

As noted earlier (chapt. 2.2.2) within-bone nutrients are also likely to be of greater importance when animals are themselves nutritionally stressed. The marrow cavities are one of the last fat deposits to be mobilised when an animal is stressed and distal limb bones, in particular, can still contain much fat even when the animal is excessively fat depleted (Peterson, Allen & Dietz 1982, p550).

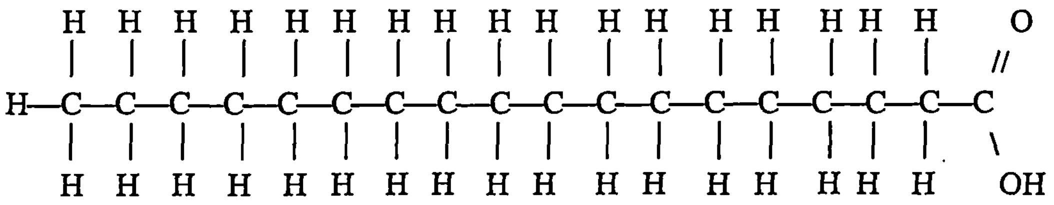
2.4.5 Discussion

It is clear, from the above, that absolute quantities of fat are not the only consideration when studying animal fat exploitation. Differences in fat chemistry in different parts of an animal's body or in different species may lead to different patterns of exploitation. Fats with different consistencies, appearances and melting points may be put to different uses. It is also important to be mindful of animals different physiologies. Changes in type, distribution and quantities of fat can be affected by particular climatic adaptations, seasonal changes, levels of malnutrition and composition of diet. The consumption of different types of fats can also have a major effect on health, whether or not the peoples under study were aware of this or not.



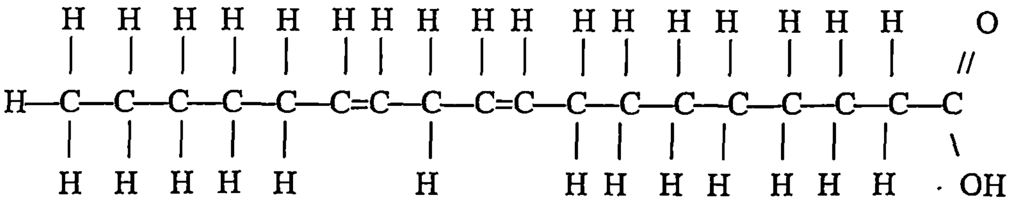
$CH_2(OH)-CH(OH)-CH_2(OH)$

Figure 2.19 - The displayed chemical structure of Glycerol



$CH_3(CH_2)_{16}COOH$

Figure 2.20 - The displayed chemical structure of Stearic Acid (Octadecanoic Acid)



$CH_3(CH_2)_4CH=CHCH_2CH=CH(CH_2)_7COOH$

Figure 2.21 - The displayed chemical structure of Linoleic Acid (6,9 Octadecadienoic Acid)

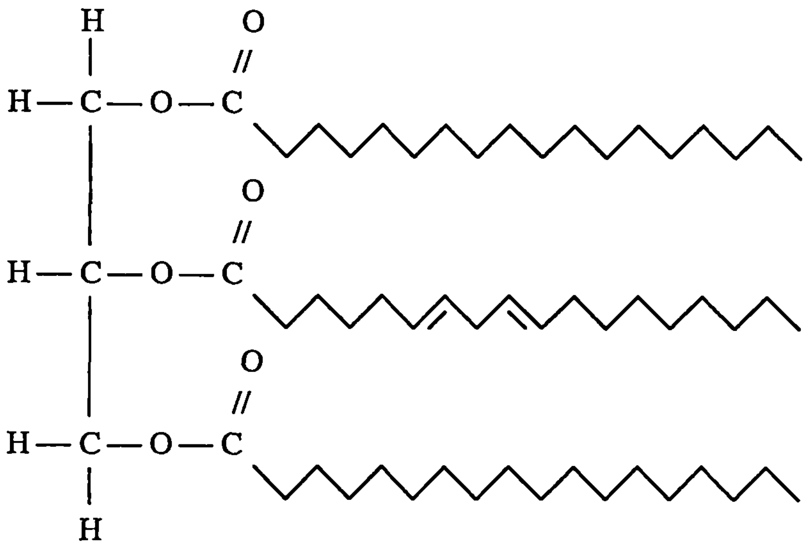


Figure 2.22 - The displayed chemical structure of a Triglyceride of Stearic and Linoleic Acids (Glycerol 1,3 - dioctadecanoate 2 - 6,9 octadecadienoate)

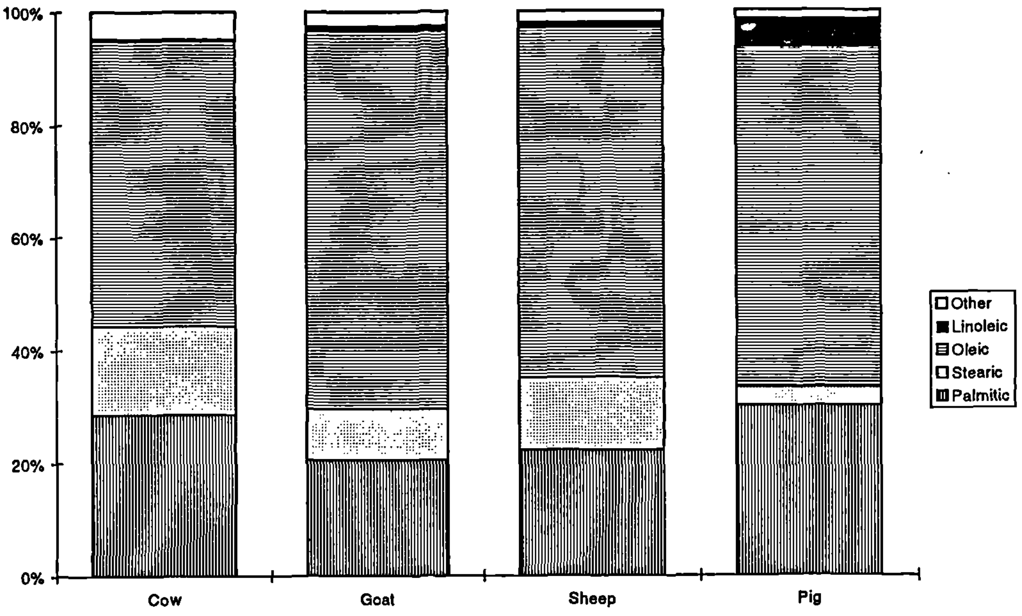


Figure 2.23 - A graph to show the fatty-acid composition of femur marrow from four different species (data derived from Abd-El-Aal and Mohamed 1989, table 3)

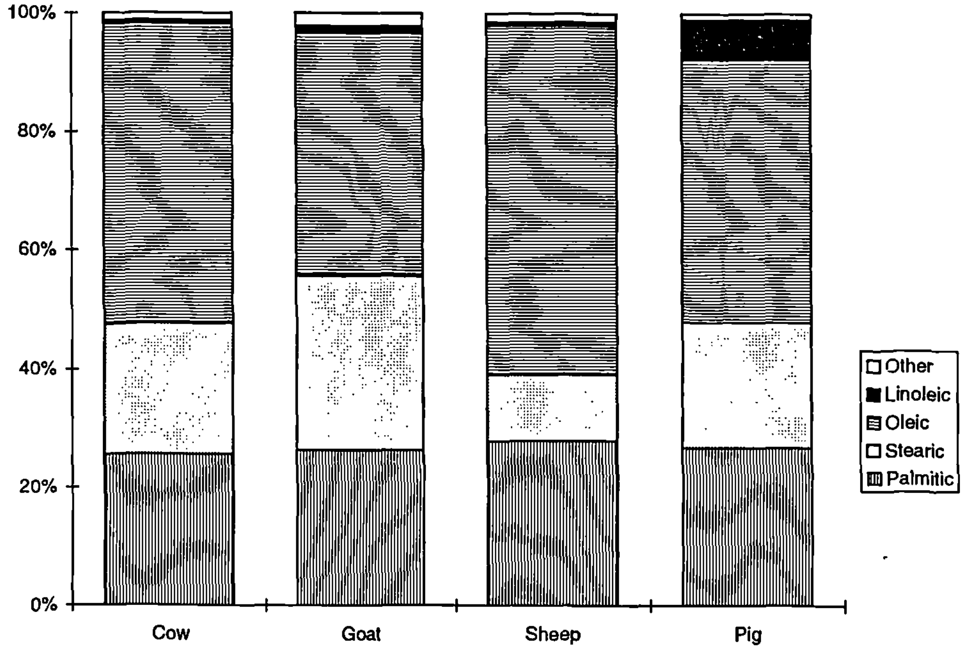


Figure 2.24 - A graph to show the fatty-acid composition of rib fat from four different species (data derived from Abd-El-Aal and Mohamed 1989, table 3)

Figure 2.25 - Marrow from a bovine femur

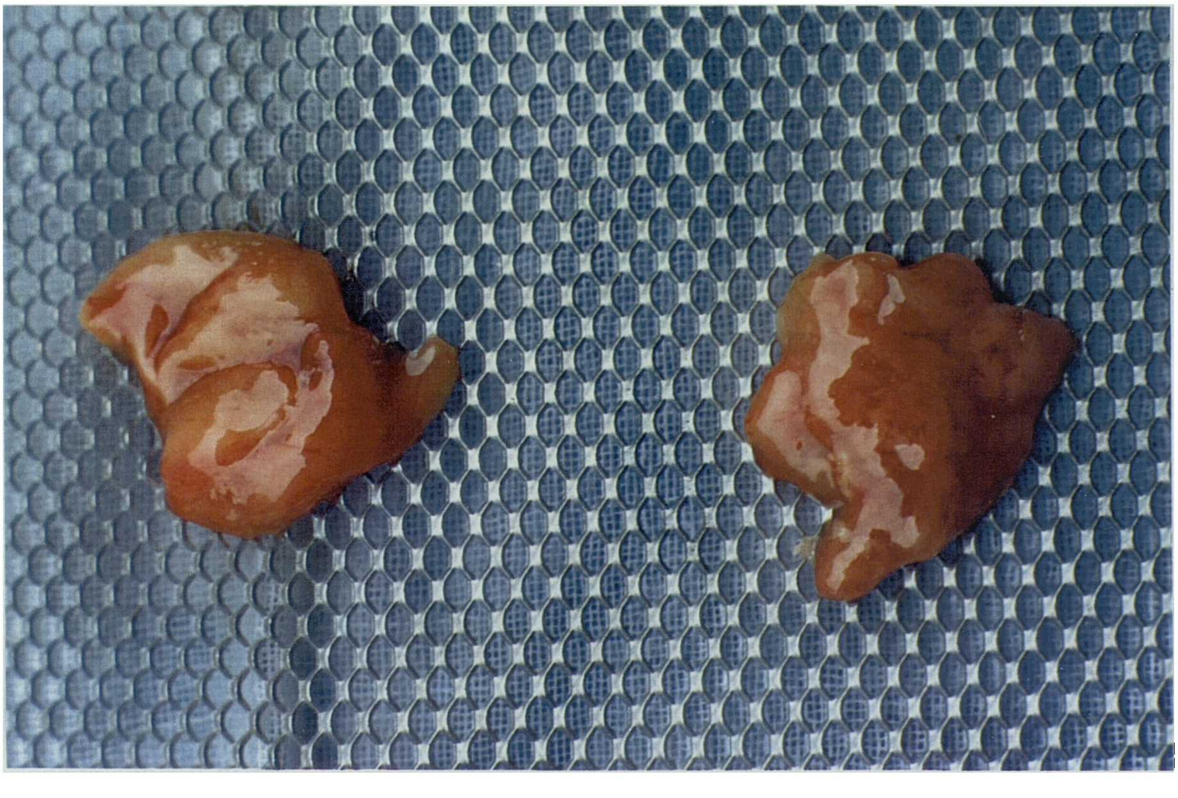


Figure 2.26 - Marrow from a bovine metatarsal

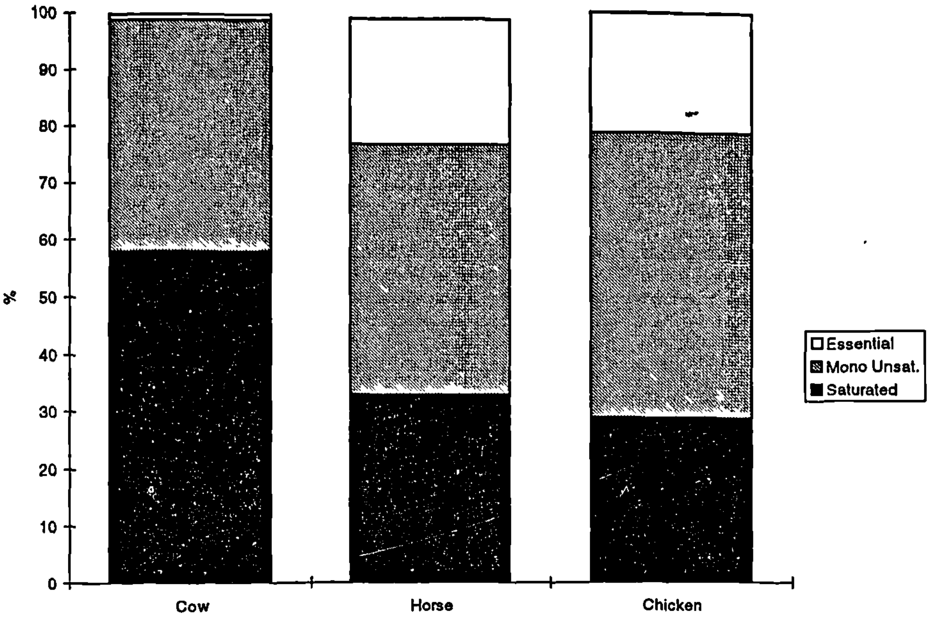


Figure 2.27 - A graph to show the fatty-acid composition of three species of animal in terms of degree of saturation (data derived from Mead *et al* 1986, tables 5.5 and 5.6)

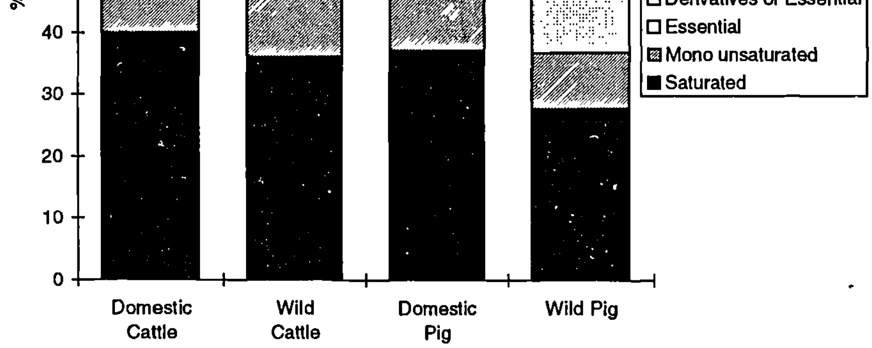


Figure 2.28 - A graph to show the fatty-acid composition of two species of animal, comparing the levels of fat saturation in wild and domestic specimens (data derived from Erasmus 1986, table D2)

CHAPTER THREE

THE FOOD UTILITY AND BONE FATS OF HORSE (EQUUS): A CASE STUDY

3.1 Introduction

The following is a study of the economic anatomy of horses and the nature of their bone fats. Most of the information which follows came from the experimental butchery of three horses by the present author in conjunction with Peter Rowley-Conwy (Outram and Rowley-Conwy 1998). This study was carried out because there were no published studies available and yet horse was a major quarry in the late Pleistocene in Europe. It is also a very good example of why it is essential to have the correct data for the species one is dealing with. Although both meat and marrow were studied in detail (ibid.), the discussion below will concentrate on marrow with some reference to general food utility.

All of the three horses butchered were mature animals in excess of 15 years of age. Horse 1 was female with a withers height of c. 149 cm; horse 2 was female with a withers height of c. 143 cm; and horse 3 was male with a withers height of c. 160 cm (withers heights were calculated using Kiesewalter's factors as listed by Boessneck 1970 table 1). All three were riding horses at the end of their useful working lives, and were in good condition; horse 3 in particular had been kept as a pet and not ridden for some time, and was particularly fat.

The horses were made available for study after they had been gutted, skinned and bled. Carcass weights in this state were horse 1: 193.25 kg; horse 2: 169.75 kg; and horse 3: 267.75 kg. Internal organs, viscera etc. were not weighed.

3.2 Marrow Measurement Methods

Both the mass of wet marrow and marrow cavity volume were measured for the marrow bearing elements from one side of each horse, namely the half-mandible, humerus, radius, metacarpal, femur, tibia, metatarsal and 1st phalanx. Marrow cavities in the scapula, astragalus, calcaneum and 2nd and 3rd phalanges were non-existent or negligible. To extract the marrow, the long bones were sawn in two at the mid-point of their diaphyses. The mandibular marrow cavity was accessed by sawing off the rear portion of the jaw just behind the 3rd molar. The metacarpal and phalanges of horse 1 were mislaid before marrow could be recorded, all means for these elements are therefore derived from horses 2 and 3 only.

The marrow was extracted using a variety of long metal implements. Complete marrow removal was very difficult, particularly from the femur and humerus, due to the large amount of trabecular bone present in the marrow cavity. This was also noted by Blumenschine and Madrigal (1993) in their work on a zebra marrow index. Animals of the horse family appear to have particularly dense cancellous bone in their long bone diaphyses. The present study followed Blumenschine and Madrigal (ibid.) in removing as much marrow as possible whilst attempting to exclude trabecular bone. The effects of this problem will be discussed more fully later. Wet marrow weight was ascertained by weighing the bones before and after marrow extraction and taking the difference. The electronic scales used were accurate to 0.1g.

The marrow cavity volume was measured after the bones had been boiled for over one hour to remove the remaining fat from the marrow cavities, including that which could not be removed from cancellous bone by mechanical means. This was in order to assess the effects of extraction difficulties caused by trabecular bone. The volume was measured by filling the marrow cavity with water from a graduated delivery pipette. The volume was recorded to the nearest 0.5ml. This measurement could not be carried out satisfactorily on the mandible, which tended to leak and disperse water into non-marrow cavities.

3.3 The Marrow Indices

Table 3.1 gives the wet marrow weights for each horse. There is a considerable degree of variation in each element in the different horses. This is not merely a function of gross animal size, since, if this factor is standardised in the same way as for meat, the variation remains substantial (table 3.1). This variation in standardised marrow weight yields is particularly striking if viewed graphically (fig. 3.1). The measurements of meat weights did not show this level of variation (Outram and Rowley-Conwy 1998).

The variations between animals are probably due to varying amounts of trabecular bone within the marrow cavities. Excessive trabecular bone growth has not been encountered in studies of marrow indices of animals outside the horse family. Blumenschine and Madrigal (1993) noted that trabecular bone depressed overall marrow yields in zebra, but not that there was variation between animals. This is, however, the case for horse. Table 3.1 shows that the rank order of element marrow utility varies between the horses. Femur has the highest marrow value in all three, but the order thereafter is not consistent. The rank order in horse 1 is femur, humerus, tibia, radius and lastly the metapodials. In horse 2, however, the tibia is up in second place, but in horse 3 it is down in fifth place, with the humerus, mandible and radius ranked above it.

The marrow cavity volume was measured in an attempt to counter the effects of the trabecular bone on the wet weight index. Table 3.2 lists the results of the volume measurements and converts them to standardised form. When displayed on a graph (fig. 3.2), there is still much variation between the different horses, but it is not of quite the same level of magnitude since the basic rank order of the elements is at least consistent. The femur ranks at the top, followed by humerus, tibia, radius and finally the metapodials. It is reassuring to note that this is the same order as that of the average figures for both marrow weight (table 3.1) and volume (table 3.2). The variability in the marrow volume figures must be due to differing volumes of trabecular bone growth.

Study of meat utility of horses showed a very great bias to upper limb, when compared, for instance to Binford's (1978) index for caribou (Outram and Rowley-Conwy ibid.). This is also the case with marrow. The marrow index values for the distal limb bones are relatively depressed in horse (fig. 3.3) by comparison to other species.. Furthermore, in caribou the tibia is ranked above the femur, which is not the case in horse. Caribou has a distinct bias towards the rear limb, with all the main elements ranking above those of the forelimb. This is very different from horse, where the descending ranking alternates between the fore and hind limb: femur, humerus, tibia, radius, metatarsal, metacarpal. Surprisingly, zebra, though closely related to the horse, has a pattern which closely resembles caribou marrow cavity volume, with high rear limb and a very high tibia value (Blumenschine and Madrigal 1993). Figure 3.3 plots the standardised zebra wet marrow index because Blumenschine and Madrigal do not give cavity volumes, but the figures should give a broadly correct outline. Why zebra should differ from horse is hard to understand, but this serves as a warning that assumptions cannot be made about the anatomical distribution of utility in different species.

A particularly important aspect is how low the absolute marrow yields are in horse. The horse is a very large animal with large bones and yet its marrow yields are relatively low. Figure 3.4 plots marrow cavity volumes relative to animal size. The horse relative marrow yield is only a small fraction of that of caribou. The trabecular bone in the upper limb bones is obviously the cause of their low yield. Figure 3.5 shows a horse humerus marrow cavity compared with one from a cow. The way the trabecular bone growth reduces cavity volume is plain to see. In the distal bones thick bone walls decrease the size of interior cavity. This can be seen in figure 3.6, where a horse metatarsal is compared to that of a cow. Study of zebra wet marrow weights by Blumenschine and Madrigal (1993) revealed the same extremely depressed values for the same reasons.

3.4 General Food Utility

It is worth considering the general food utility of horses here because general food utility will affect transport decisions which, in turn, dictate which elements will be available on a given site for processing for their within-bone nutrients. The GUI (general utility index) for horse is calculated from the addition of meat and marrow weights (table 3.3). This method of calculating GUI follows Metcalfe and Jones (1988) rather than Binford's (1978) over-complex method. To create an index suitable for studying transport decisions, however, the GUI is often modified to take into account "riders". Riders are bones of lesser utility which are transported more often than their utility suggests because they are attached to bones of higher utility (Binford 1978, p74). This is accounted for in a complicated averaging process of adjacent bone's values (see Metcalfe and Jones 1988). Binford (ibid.) called the resulting index the MGUI (modified general utility index) whilst Metcalfe and Jones (ibid.) refer to their simplified MGUI as the FUI (food utility index).

The FUI and standardised FUI ((S)FUI) are shown, with notes on their derivation, in table 3.4. The (S)FUIs for caribou (after Metcalfe and Jones ibid.) and horse (Outram and Rowley-Conwy ibid.) are compared in figure 3.7. A relative depression in the value of horse distal limb elements can be seen. This effect can be seen even more clearly if a graph of percentage difference between caribou and horse (S)FUIs is plotted (see fig. 3.8).

3.5 The Nature of Horse Bone Fats

As referred to in chapter 2.4, the fat of horses is fairly high in unsaturates and has a particularly high level of essential polyunsaturates. This has the result of significantly reducing the melting point of the fat. The effect of this was particularly noticeable in the marrow fats encountered by the author in the above study. None of the marrow fat was particularly solid. Whilst the femur fat of cattle is hard, like lard, the femur fat of horse was very soft. It more closely resembled the consistency of the marrow from the distal limbs of cattle. The marrow from the distal limbs of horse is a yellow, translucent liquid at room temperature. The grease resultant from the boiling of cattle bones will settle out on the surface of the water, when it cools, as a hard white lump, but the grease from horse remains semi-liquid.

Fats with high levels of polyunsaturates are, as mentioned earlier, far more healthy, but they do have their drawbacks. Unsaturated fats are more chemically reactive and are, as a result, more susceptible to becoming rancid (Nawar 1985). This point could be very relevant to hunter-gatherers who store food. It was certainly very noticeable, to the present author, that horse fat became rancid much quicker than fat from cattle. As evidence the following is verging on the anecdotal, but the author, over months of processing bone fat from cattle, never received a complaint about the smell, but received serious complaints when processing horse fat, which did appear to go "off" remarkably quickly!

The fatty-acid content of horse fat is affected by the horse's diet. Data given by Hilditch and Williams (1964, table 34) shows that horses fed on grass have a high proportion of linolenic acid (18:3), which is a fatty-acid abundant in grass. Horses which are stall fed on oats, however, have a greater abundance of linoleic acid (18:2) (ibid.). This can be seen in graphical form in figure 3.9.

3.6 Discussion

The above case study has proved, once again, how important it is to be in possession of the correct data with regard to particular animal species. It is clear that transportation of horse elements is likely to vary from other species, because the food value is distributed differently with regard to its anatomy. This may lead to different availability of marrow bones at camp site for horse in comparison with other species.

Furthermore, the relative value of bone marrow as a food resource on horse is very different from other animals, and the anatomical distribution of the marrow is also different. One must, however, consider qualitative as well as quantitative aspects of marrow use. Horse fat is of a very different nature to many other animals, particularly ruminants, and may therefore be put to different uses. It may be more highly or less highly prized as a result of its chemical composition. Its low melting point may make it particularly sort after or problematic to process. The problem of rancidity may be a problem for some hunting communities but not others. It is likely to depend on climate and storage customs.

The general conclusion is that it is necessary to be fully aware of a whole range of data with regard to a particular hunted species before it is possible to make any detailed conclusions about people's past utilisation of that animal as a food resource. This particularly applies to the study of within-bone nutrient exploitation. This point plays an important part in two of the case studies later in this volume. The species under consideration is not horse, it is seal, but knowledge of that species' specific anatomy and physiology plays an important rôle in the interpretation of those sites.

	Horse 1	**Horse 2**	**Horse 3**	**Mean**
Element	Marrow Weight (g)(standardised marrow weight index)	Marrow Weight (g)(standardised marrow weight index)	Marrow Weight (g)(standardised marrow weight index)	Marrow Weight (g)(standardised marrow weight index)
Mandible	**39.2 (*41.5*)**	**23.0 (*36.4*)**	**45.2 (*78.3*)**	**35.8 (*49.9*)**
Humerus	**45.5 (*48.1*)**	**24.3 (*38.4*)**	**52.1 (*90.3*)**	**40.6 (*56.5*)**
proximal	6.9	8.7	10.0	
distal	38.6	15.6	42.1	
Radius	**30.7 (*32.5*)**	**15.6 (*24.7*)**	**26.2 (*45.4*)**	**24.2 (*33.7*)**
proximal	19.8	10.6	20.5	
distal	10.9	5.0	5.7	
Metacarpal	N/A	**10.5 (*16.6*)**	**12.2 (*21.1*)**	**11.3 (*15.7*)**
proximal		6.9	9.6	
distal		3.6	2.9	
Femur	**94.5 (*100.0*)**	**63.2 (*100.0*)**	**57.7 (*100.0*)**	**71.8 (*100.0*)**
proximal	51.5	38.5	29.3	
distal	43.0	24.7	28.4	
Tibia	**43.2 (*45.7*)**	**30.6 (*48.4*)**	**25.9 (*44.9*)**	**33.2 (*46.2*)**
proximal	33.0	22.4	17.4	
distal	10.2	8.2	8.5	
Metatarsal	**6.0 (*6.3*)**	**8.2 (*13.0*)**	**13.9 (*24.1*)**	**9.4 (*13.1*)**
proximal	4.0	5.0	9.7	
distal	2.0	3.2	4.2	
1st Phalanx	N/A	**1.4 (*2.2*)**	**0.6 (*1.0*)**	**1.0 (*1.4*)**

Table 3.1 - Wet marrow weight and standardised marrow weight index (in parentheses) for the three horses studied. The metacarpal and phalanges of horse one were not available for measurement.

	Horse 1	**Horse 2**	**Horse 3**	**Mean**
Element	Marrow Cavity Volume (ml) (standardised marrow volume index)	Marrow Cavity Volume (ml) (standardised marrow volume index)	Marrow Cavity Volume (ml) (standardised marrow volume index)	Marrow Cavity Volume (ml) (standardised marrow volume index)
Mandible	N/A	N/A	N/A	N/A
Humerus proximal distal	**95.5 (*61.0*)** 39.5 56.0	**70.5 (*77.0*)** 40.0 30.5	**93.0 (*98.9*)** 30.0 63.0	**86.3 (*75.7*)**
Radius proximal distal	**63.5 (*40.6*)** 45.0 18.5	**36.0 (*39.3*)** 26.0 10.0	**52.0 (*55.3*)** 35.0 17.0	**50.5 (*44.3*)**
Metacarpal proximal distal	N/A	**15.0 (*16.4*)** 9.5 5.5	**17.0 (*18.1*)** 13.0 4.0	**16.0 (*14.0*)**
Femur proximal distal	**156.5 (*100.0*)** 88.0 68.5	**91.5 (*100.0*)** 58.5 33.0	**94.0 (*100.0*)** 44.0 50.0	**114.0 (*100.0*)**
Tibia proximal distal	**71.5 (*45.7*)** 54.0 17.5	**45.5 (*49.7*)** 34.5 11.0	**62.0 (*66.0*)** 42.0 20.0	**59.7 (*52.4*)**
Metatarsal proximal distal	**13.5 (*8.6*)** 9.5 4.0	**15.5 (*16.9*)** 10.0 5.5	**21.5 (*22.9*)** 14.5 7.0	**16.8 (*14.7*)**
1st Phalanx	N/A	**2.5 (*2.7*)**	**3.5 (*3.7*)**	**3.0 (*2.6*)**

Table 3.2 - Marrow cavity volume and standardised marrow volume index (in parentheses) for the three horses studied. The metacarpal and phalanges of horse one were not available for measurement and the measurement of volume in the mandible was impracticable.

Unit	Mean Meat Weight (kg)	Mean Marrow Weight (kg)	GUI Meat + Marrow (kg)
skull, brains	8.0	0.0	8.0
mandible, tongue	3.25	0.036	3.286
atlas/axis	3.5	0.0	3.5
cervicals 3-7	20.25	0.0	20.25
thorax	44.75	0.0	44.75
lumbar	10.0	0.0	10.0
scapula	6.75	0.0	6.75
humerus	5.75	0.041	5.791
radius/ulna	1.5	0.024	1.524
metacarpal	0.0	0.011	0.011
pelvis	23.75	0.0	23.75
femur	20.25	0.072	20.322
tibia	2.25	0.033	2.283
metatarsal	0.0	0.009	0.009
phalanges	0.0	0.001	0.001

Table 3.3 - General Utility Index for horse, based on summing the mean meat weight and mean marrow weight for each anatomical unit. Marrow weight is rounded to the nearest gram.

Unit	FUI	derivation	(S)FUI
skull	8.0	unmodified GUI	17.9
mandible	3.3	unmodified GUI	7.4
atlas/axis	3.5	unmodified GUI	7.8
cervicals 3-7	20.2	unmodified GUI	45.2
thorax	44.7	unmodified GUI	100.0
lumbar	10.0	unmodified GUI	22.4
scapula	6.7	unmodified GUI	15.0
prox. humerus	6.7	rounded up to scapula GUI	15.0
dist. humerus	6.3	mean of p.hum FUI and hum GUI	14.1
prox. radius/ulna	3.9	mean of d.hum FUI and rad GUI	8.7
dist. radius	2.7	mean of p.rad FUI and rad GUI	6.0
carpals	1.4	mean of rad FUI and m'c GUI	3.1
prox. metacarpal	0.7	mean of carp FUI and m'c GUI	1.6
dist. metacarpal	0.3	mean of p.m'c FUI and m'c GUI	0.7
pelvis	23.7	unmodified GUI	53.0
prox. femur	20.3	unmodified GUI	45.4
dist. femur	20.3	unmodified GUI	45.4
prox. tibia	11.3	mean of d.fem FUI and tib GUI	25.3
dist. tibia	6.8	mean of p.tib FUI and tib GUI	15.2
astragalus	3.4	mean of d.tib FUI and m't GUI	7.6
calcaneum	3.4	mean of d.tib FUI and m't GUI	7.6
tarsals	3.4	mean of d.tib FUI and m't GUI	7.6
prox. metatarsal	1.7	mean of tars FUI and m't GUI	3.8
dist. metatarsal	0.8	mean of p.m't FUI and m't GUI	1.8
phalanx 1	0.4	mean of d.m't FUI and phal GUI	0.9
phalanx 2	0.4	mean of d.m't FUI and phal GUI	0.9
phalanx 3	0.4	mean of d.m't FUI and phal GUI	0.9

Table 3.4 - Food Utility Index (FUI) values for each element of the horse skeleton, calculated from General Utility Index given in table 3.3 and rounded to the nearest 0.1. The method of derivation is listed (see text and Metcalfe and Jones 1988, note three for discussion). Standardised Food Utility Index ((S)FUI) is each FUI value expressed as a percentage of that of the largest value, given to the nearest 0.1%.

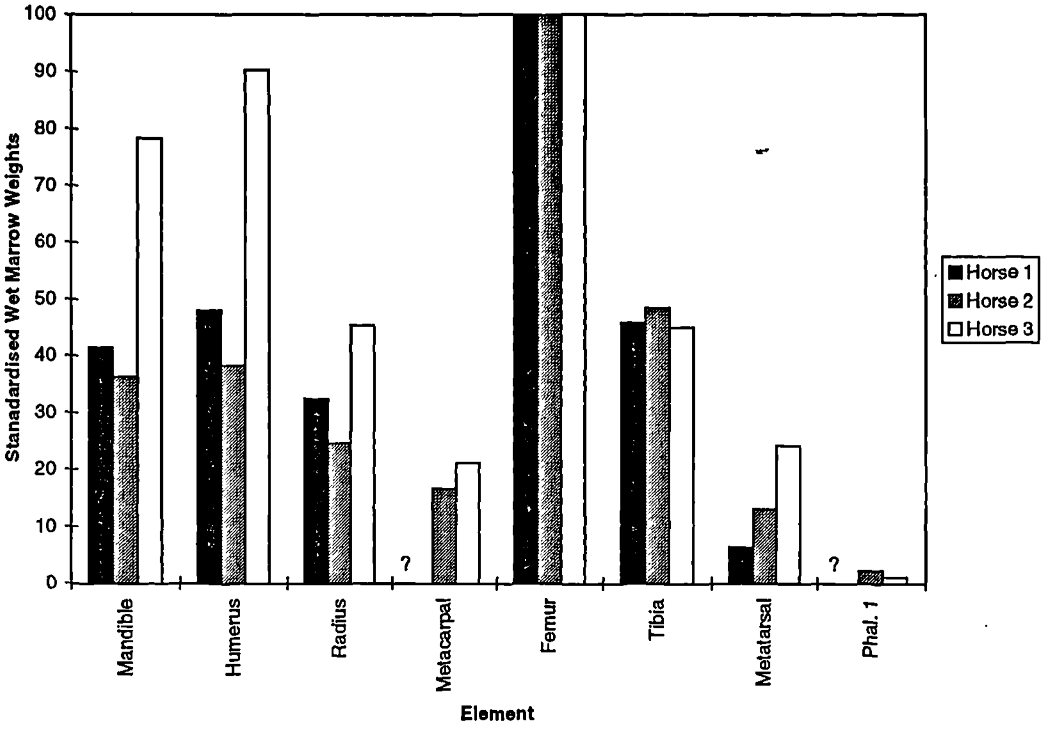


Figure 3.1 - A graph to show standardised wet marrow weights of three horses (values given in table 3.1)

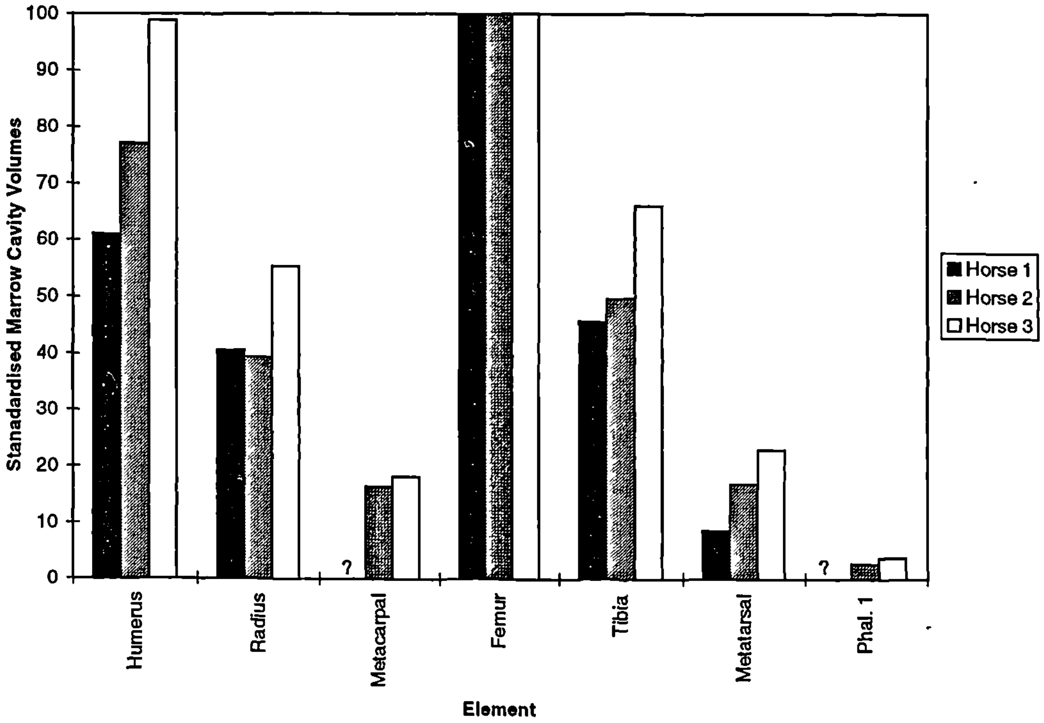


Figure 3.2 - A graph to show standardised marrow cavity volumes of three horses (values given in table 3.2)

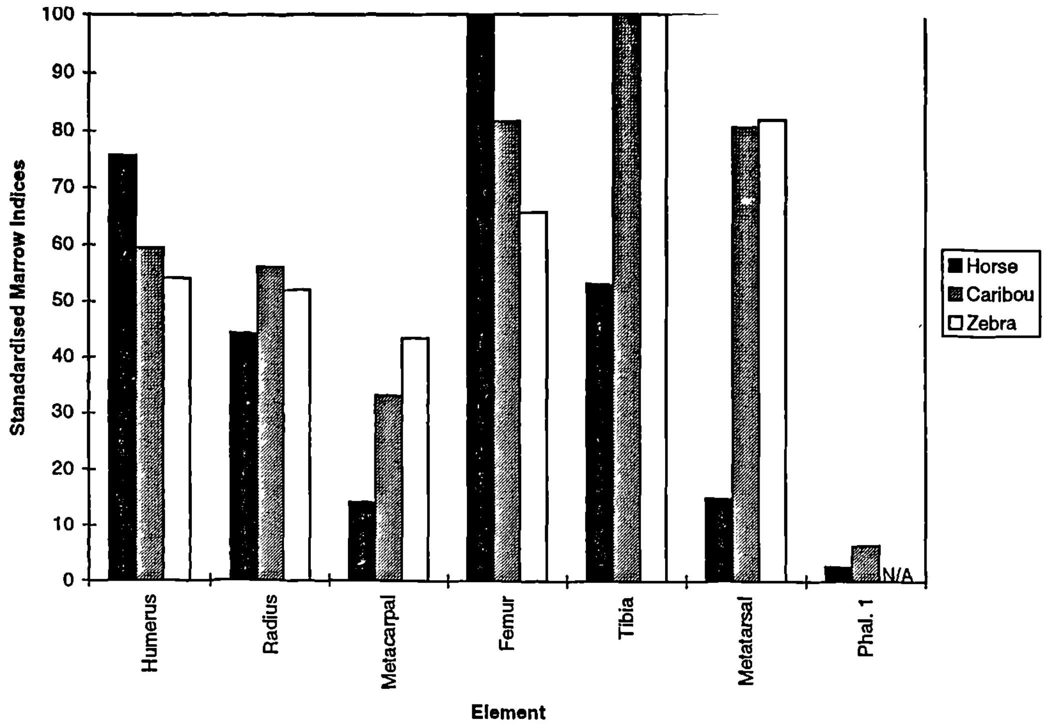


Figure 3.3 - A graph to compare standardised marrow cavity volumes for horse and caribou, and standardised wet marrow weight for zebra. The mean values for horse are listed in table 3.2. Caribou data are derived from Binford (1978, table 1.7) and the zebra data are derived from Blumenschine and Madrigal (1993, table 2).

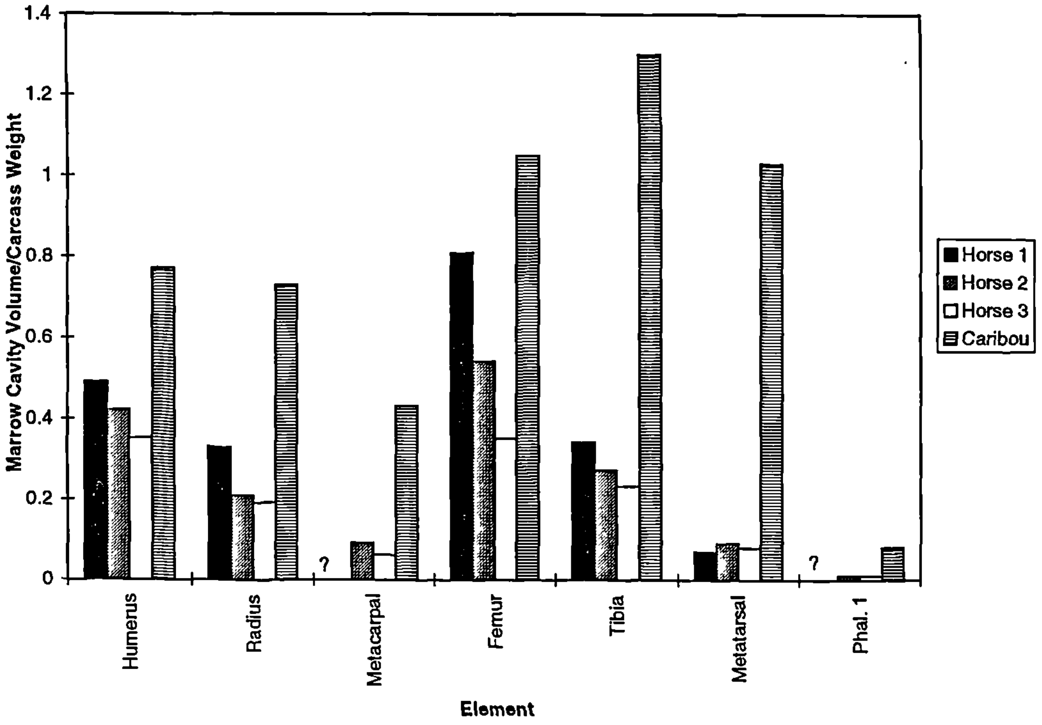


Figure 3.4 - A graph to show marrow cavity volumes for the three horses and for caribou, relative to body size: the marrow cavity volume in ml (table 3.2) for each element is divided by the wieght in kg of the carcass less internal organs, blood and skin. Weights of the three horses in this state are 193.25kg, 169.75kg and 267.75kg respectively. Caribou weight is 49.37kg, calculated by Binford (1978, table 1.3) and marrow cavity volumes are listed by Binford (ibid., table 1.7).

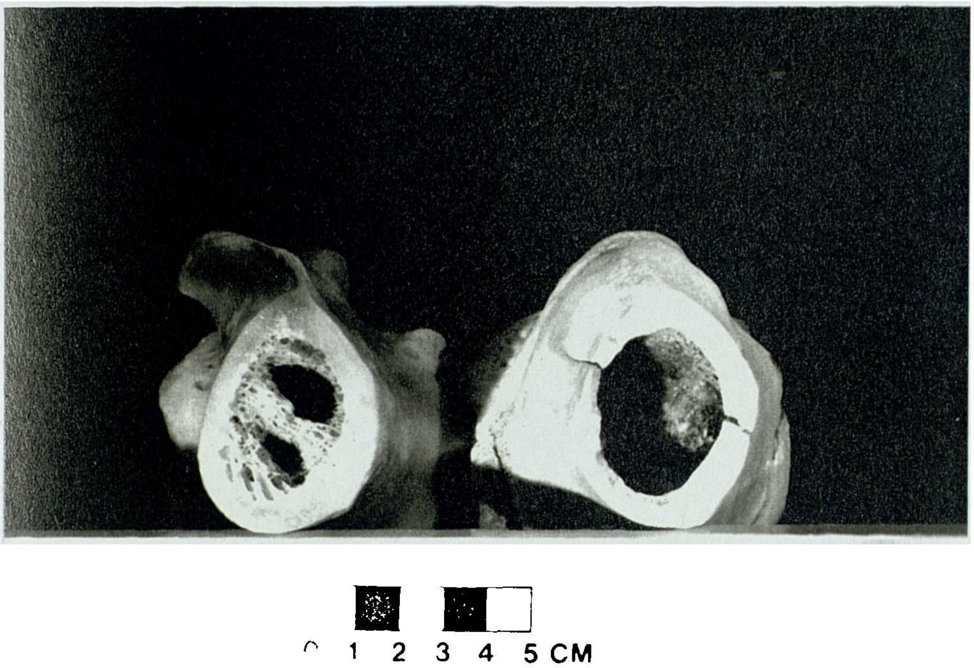


Figure 3.5 - Humerus marrow cavities of horse (left) and cow (right), showing how trabecular bone growth reduces marrow cavity volume in horse

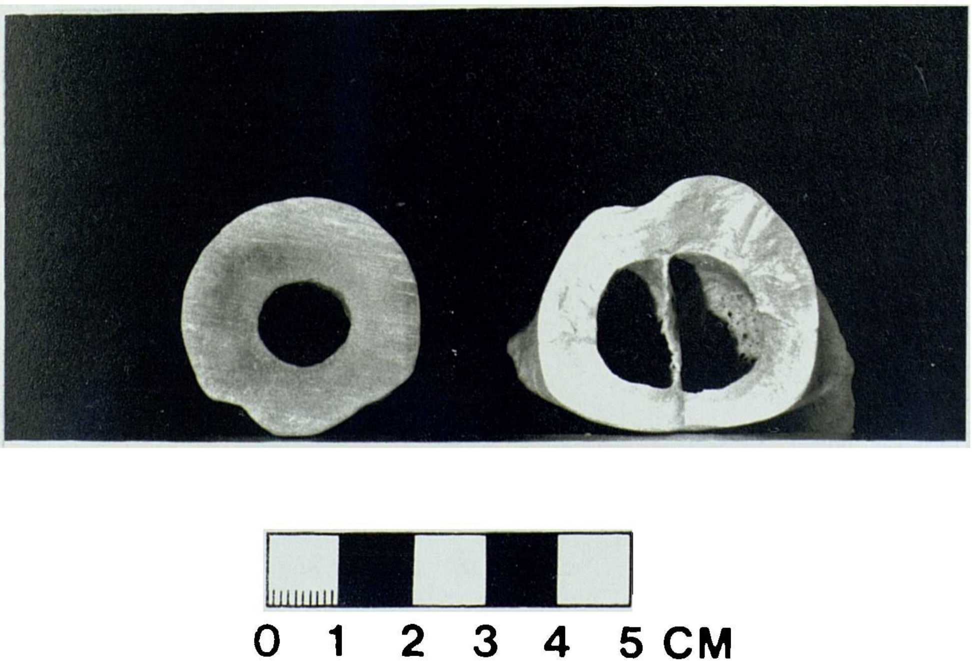


Figure 3.6 - Metatarsal marrow cavities of horse (left) and cow (right), showing how the thickness of the bone wall reduces cavity volume in horse

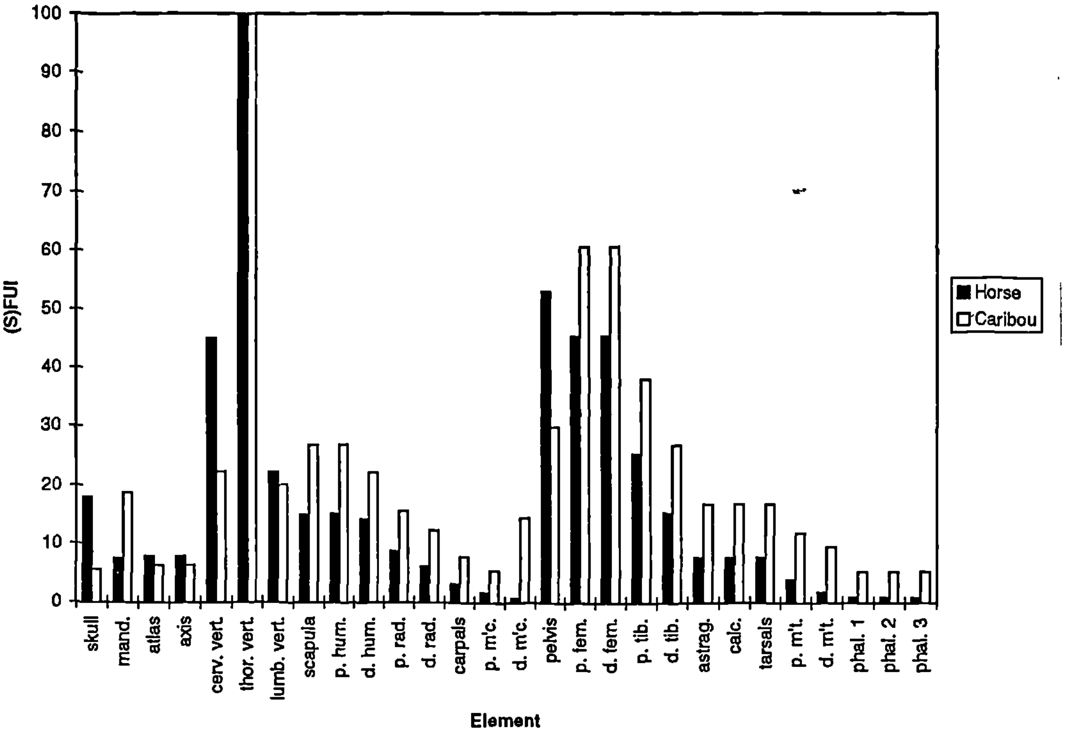


Figure 3.7 - A graph to compare standardised Food Utility Indices (FUI) for horse and caribou. The values for horse are given in table 3.4. Caribou data are based on Metcalfe and Jones' (1988, table 2) FUI. For comparison to the horses the values for thoracic vertebrae, ribs and sternum are summed as "thorax", and the index recalculated.

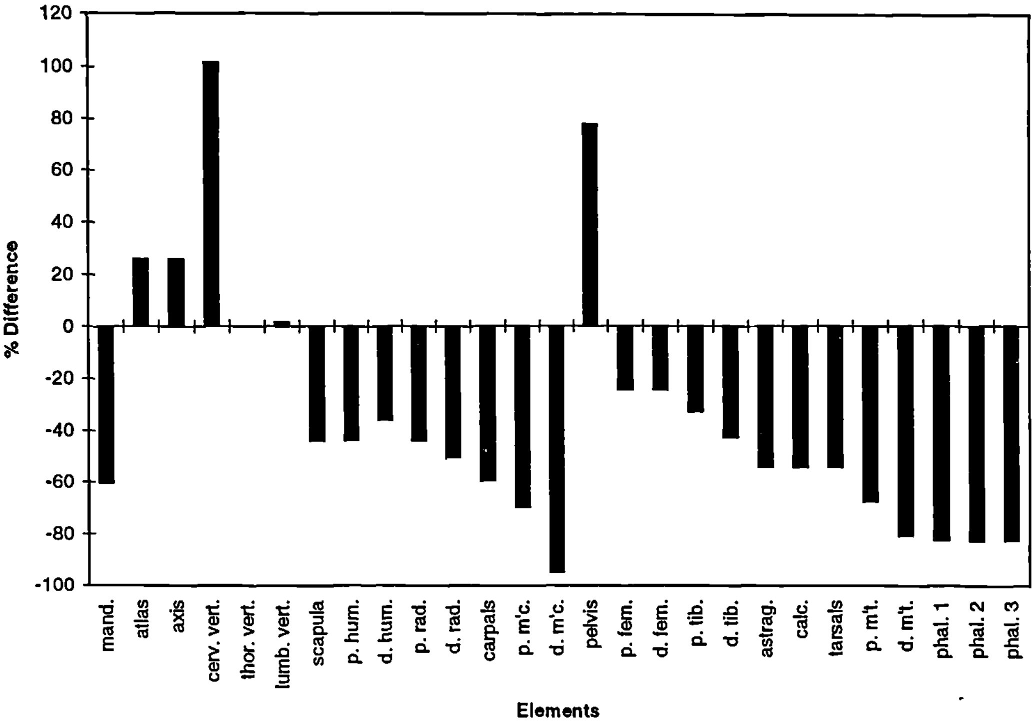


Figure 3.8 - A graph to show standardised Food Utility Index (FUI) for horse expressed as the percentage by which it differs from that of caribou. Caribou data are based on Metcalfe and Jones' (1988, table 2) FUI. For comparison to the horses the values for thoracic vertebrae, ribs and sternum are summed as "thorax", and the index recalculated.

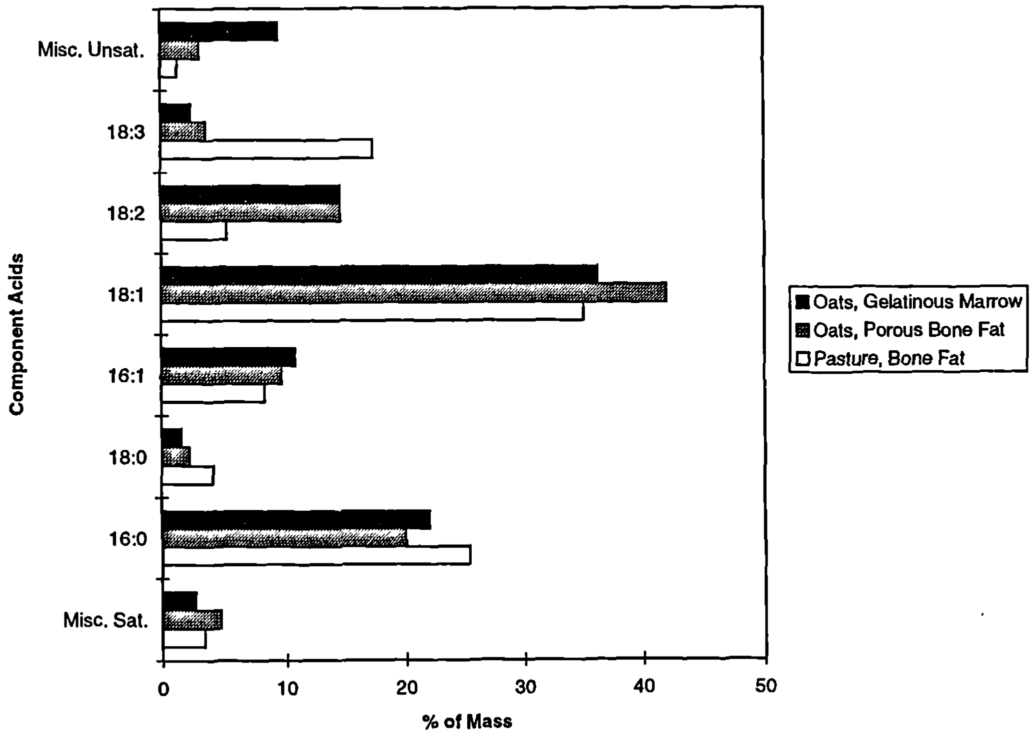


Figure 3.9 - A graph to compare the fatty-acid composition of bone fats and marrow of horses fed on different diets. The proportion of fatty-acids by percentage of weight is given for horses pasture-fed in New Zealand and stall-fed in Sweden (data from Hilditch and Williams 1964, table 34).

CHAPTER FOUR

STUDYING BONE FRACTURE

4.1 The Nature of Bone Fracture Types

4.1.1 Introduction

Having scrutinised the nature and exploitation of bone marrow and grease, attention will now be turned to the identification of bone fat extracting activities in the archaeological record. The study of bone fracture type is of great importance to the study and interpretation of bone modification, fragmentation and general taphonomy in archaeological assemblages. Through current knowledge in bone mechanics, and the application of uniformitarian principles, it should be possible to establish certain facts about the conditions under which bone fracture occurred on archaeological sites. It may not always be possible to identify a single causation for fracture at a given site from a study of fracture type, given the ever present problem of equifinality. It should, however, be possible, in conjunction with other lines of evidence, to move towards a greater understanding of past bone resource exploitation.

The vast majority of existing work in the field of bone fracture has been associated with palaeoanthropological assemblages. The main reason for such research has been aimed at the identification of hominid bone modification, as opposed to naturally created alteration of bones (e.g. Myers *et al* 1980; Johnson 1985, 1989;

Morlan 1984; Haynes 1983 and many more). Such work is part of the long running tool versus pseudo-tool argument. Much less work has been done on understanding the nature of fracture types on sites of known human occupation with a view to extrapolating something of the bone resource exploitation activities of the incumbent population. Too many assumptions have been made in the past regarding the identification of bone marrow and grease extraction. The integration of a thorough methodology for fracture type study, within assemblage analysis, is essential if the identification of levels of bone marrow and grease use is to be attempted.

4.1.2 Identifying Fracture Type

Johnson (1985, p175) complains of a general lack of understanding of bone mechanics shown by many analysts in their consideration of fracture type. For instance, Myers *et al* (1980) classes all diagonal breaks in bones as spiral fractures (as do Shipman *et al* 1981 and others) when Johnson (ibid.) demonstrates that the spiral fracture is something to be far more tightly defined. The result of Myers' (ibid.) study was to conclude that spiral (fresh bone) fractures are very common in the wild. The loose definitions used in this paper make it difficult to fully utilise its conclusions. Such errors could be very misleading but loose definitions are commonplace in the literature and occur in more recent papers (e.g. Gifford-Gonzalez 1989).

It is the belief of the present writer that the criteria given by Morlan (1984) and Johnson (1985) are the best and most soundly based for the identification of fracture type that are currently available in zooarchaeological literature. These two studies, which included good empirical research, agree on all major points of fracture type identification criteria. As such, it is worth giving, below, a combined summary of these criteria. Morlan (ibid.) and Johnson (ibid.) discuss fracture patterns seen in three categories of bone: fresh, dry, mineralized/fossilized (with the understanding that a complete continuum exists between these categories) (see table 4.1).

Generally speaking, fresh bone tends to fail along a spiral, or helical, path and leave a fracture surface that is smooth and at an acute or obtuse angle to the bone's cortical surface (ibid.). The fracture surface is likely to be the same colour as the rest of the bone, since there has been no time period for either surface to have become differentially discoloured. A schematic drawing of a helical fracture outline can be seen in figure 4.1a and an actual example of a fresh, helical fracture on an archaeological specimen can be seen in figure 4.2. Because fresh fractures leave an obtuse or acute angle to the cortical surface (see fig. 4.3), they tend to have sharp corners. Figure 4.4 shows a close-up of a fresh fracture surface generated in a laboratory experiment. It is very smooth and resembles, in some ways, broken plastic. This smooth surface may be interrupted by "hackle" marks (waves or ridges on the fracture surface) which are stress relief features on dynamically broken bone (ibid.). Such hackle marks are easily distinguishable from the surface appearance of unfresh fractures (see below).

When a fresh bone is dynamically fractured (i.e. it is impacted with such as a hammerstone) the bone around the dynamic loading point usually detaches as a separate flake with fresh fractures on all edges, creating a "bone cone" (Johnson ibid.). The helical lines of failure then radiate outwards from the loading point (ibid.). This can be seen clearly in figure 4.5 which shows a dynamically impacted cattle humerus. Lines can be seen radiating out from a hole created by the detachment of the "bone cone". On a bone fragment, the part of the fragment that was next to the loading point, where the flake detached, will be clearly visible. The bone cone or flake tends to fracture away at a steeper angle than the rest of the fracture leaving a sharper edge. This creates an impact scar on the fragment, as seen in figure 4.6.

The above pattern of fracture is interrupted in unfresh bones by the presence of split lines, caused by micro-cracks which develop as a result of stresses while the bone is drying out. Unfresh bone tends to fracture in straight lines. This may lead to diagonal (fig. 4.1d; fig. 4.7), transverse (fig. 4.1b; fig. 4.8) or longitudinal (fig. 4.1c; fig 4.9) fracture outlines. It is important to stress the difference between a diagonal fracture line, which is straight and a helical, curved fracture line. Unfresh outlines are also likely to be interrupted by split lines. When a line of failure meets a split line it will tend to follow it for a distance (ibid.) and create a step in the profile (see fig. 4.1e). If many split lines are present the outline will have many steps and this produces a columnar effect (see fig. 4.1f). Steps caused by split lines can be seen on an archaeological bone specimen in figure 4.10. In the case of mineralised bone, which has lost all its organic content, there tends to be very little ability to absorb stress and the bone breaks along the shortest fracture path. This tends to be perpendicular to the shaft axis (Morlan ibid.; Johnson ibid.).

Unfresh bone also tends to fracture with the fracture surface at right-angles to the bone's cortical surface (ibid.) (see fig. 4.3). The surface of the fracture tends to be rougher as a result of micro-cracks. In the case of mineralised bone, the fracture surface tends to look very granular, like broken coarse earthenware or biscuit (see fig. 4.11). It is likely that there will have been discolouration of the bone surface before breakage, so an unfresh break may contrast in colour to the rest of the bone (ibid.).

4.1.3 Bone Condition Before Fracture

As suggested above, the nature of fracture is strongly dictated by the condition of the bone prior to fracture, in particular its degree of moisture loss. It is worth examining the stages of the drying process in more detail. The drying process effectively starts in the first few hours after the death of the animal (Johnson 1985, p188). The bones will go through a transitional phase where drying and micro-cracking has started, but will not lead to split line interference or loss of helical nature of fracture. Moving further towards dry bone, there will be a stage where split lines will be a feature but the marrow is fresh and there is sufficient moisture to allow the appearance of loading points (i.e. there are dynamic impact scars). Fracture is liable to be a combination of helical (acute and obtuse angles) and horizontal tension failure (right angles). When the marrow has reached a rotten state fracture will follow the horizontal tension failure pattern without the appearance of dynamic loading points (ibid.). The length of time taken to reach each of the above stages depends on the environment. Bone may remain effectively fresh for hours or days, whilst marrow may remain unsoured for up to a year (ibid.). It should be noted that freezing is a drying process which will have different degrees of effect dependent on temperature and time (ibid.). Table 4.2 (below) summarizes Johnson's (1985 table 5.1) drying stages.

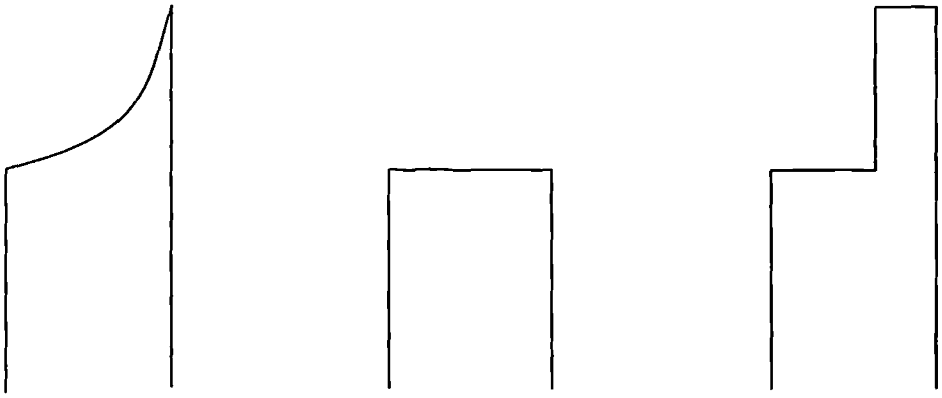
Gifford-Gonzalez (1989), in studying the bones left by the Dassanetch people of East Africa, found many "transverse" breaks from bone fractured in food processing and as a result calls into question Johnson's characterization of fracturing (Gifford-Gonzalez 1989, p198). Gifford-Gonzalez (ibid.) did not use the same system of classification as Johnson, which probably leads to an overestimation of the problem. Furthermore, only late on in criticism of Johnson does Gifford-Gonzalez (ibid. 200) note that many of the transversely broken bones had been notched with a blade prior to fracturing. This is a clear reason for transverse fracturing that is not relevant to discussion of Johnson (although it is worth noting for the research in hand). Gifford-Gonzalez (ibid. p199) also argues that transverse fracturing can easily be obtained from fresh bone by quoting Bonfield and Li (1966). If one examines Bonfield and Li (1966), one finds that they were carrying out controlled tests upon rectangular, quite thin sections of bone not whole bones. The fracture dynamics are unlikely to be comparable, therefore. Gifford-Gonzalez (ibid.) also notes the possible effect of cooking on bone fracture. This is a very useful contribution since cooking is very likely to have an effect on fracture and could be an important feature in discussion of bone marrow and grease processing. The fact that Johnson (1985) did not directly consider cooking is irrelevant. She made it quite clear that anything that changed the moisture content or micro-structure of the bone would have an effect on fracture.

Attribute	**Fresh**	**Dry**	**Mineralized**
Loading Points	present	present or absent	absent
Fracture Surface	smooth	more inclined to be rough	rough
Angle with Cortical Surface	usually acute or obtuse	more inclined to be perpendicular	perpendicular
Termination of Fracture	prior to epiphyses	may cross-cut epiphyses	may cross-cut epiphyses
Colour of Fracture	same as cortical surface	may be different to bone surface	contrasts with bone surface
Presence of Split Lines	absent	fracture perturbed by split lines	fracture perturbed by split lines
Outline Shape of Fracture	usually radial pattern circling diaphysis, helical	many possible outline shapes	usually straight or transverse to shaft axis

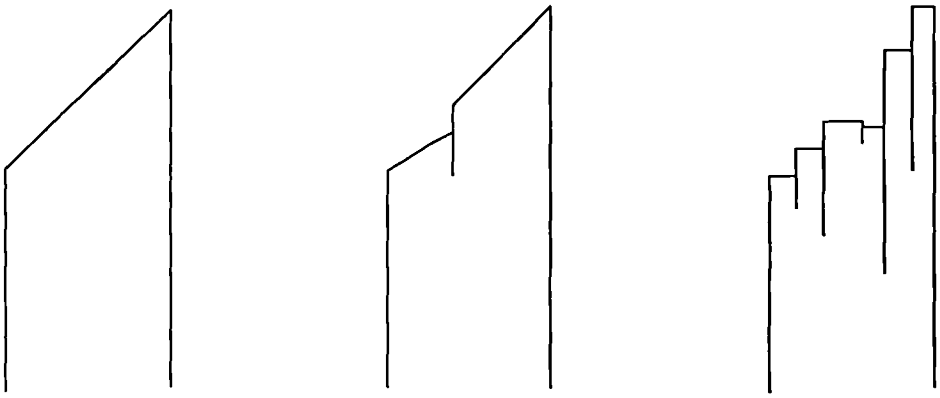
Table 4.1 - A Summary of criteria for the identification of fracture type taken from Morlan (1984) and Johnson (1985)

Fresh (0)	**Dry (1)**	**Dry (2)**	**Dry (3)**	**Dry (4)**	**Dry (5)**	**Mineralized**
high level moisture	initial moisture loss	low level moisture	low to advanced loss	advanced moisture loss	advanced moisture loss	
no desiccation features	split lines, no interference	split lines cause some interference	split line interference	split line interference	split line interference	
fresh marrow	edible marrow	edible marrow	soured marrow	decayed marrow	no marrow	
impact point	impact point	impact point	probably no impact point	no impact point	no impact point	
helical fracture	helical fracture	combined helical and horizontal fracture	mainly horizontal tension failure	horizontal tension failure	horizontal tension failure	

Table 4.2 - Moisture loss and its effect on fracture (from Johnson 1985, table 5.1)



a: Helical b: Transverse c: Longitudinal and Transverse



d: Diagonal e: Diagonal with Step f: Columnar

Figure 4.1 - Diagrams to show various different types of bone fracture outline: a) helical, b) transverse, c) longitudinal and transverse, d) diagonal, e) diagonal with step, e) columnar

Figure 4.2 - An archaeological example of a spiral (helical) fracture

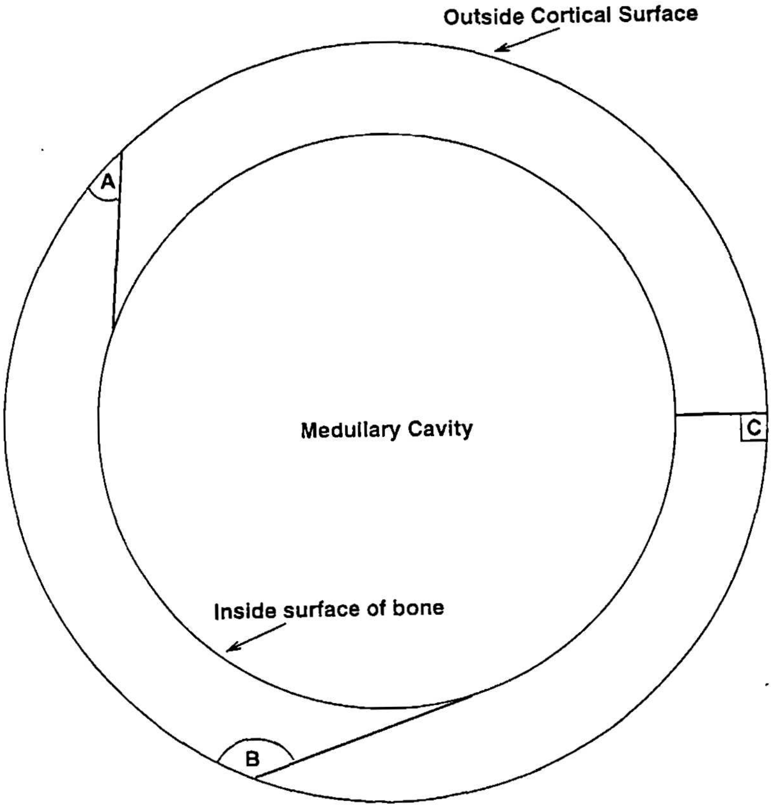


Figure 4.3 - A diagram showing a transverse section through a long bone shaft with various types of fracture angle indicated: a) acute, b) obtuse, c) perpendicular to cortical surface

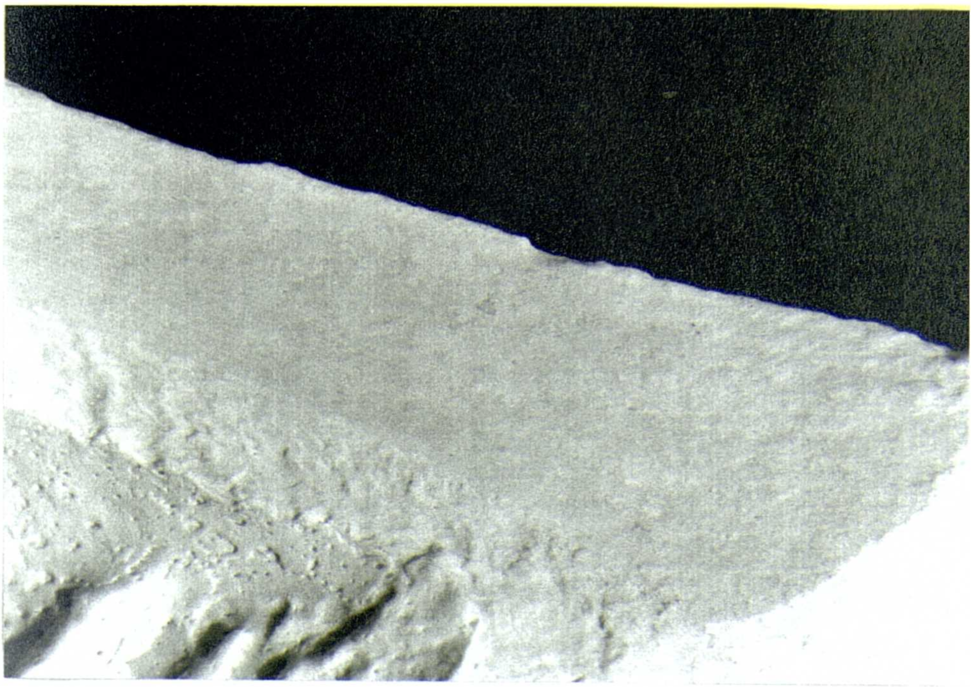


Figure 4.4 - A close-up photograph of an experimentally generated fresh fracture showing the smooth nature of the fracture surface

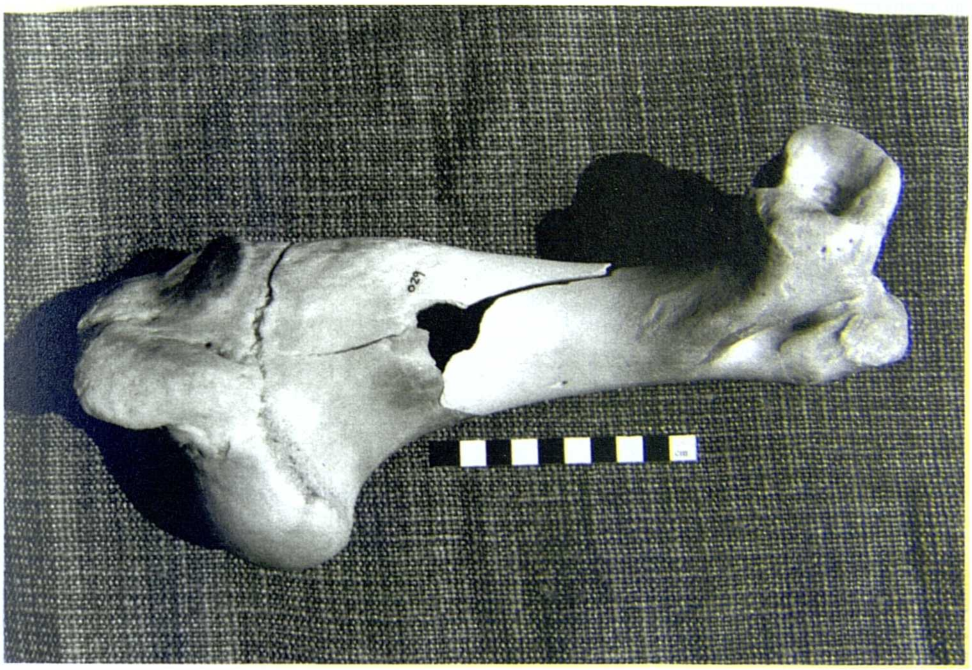


Figure 4.5 - An experimentally fresh-fractured cow humerus showing fracture lines radiating out from a central impact point

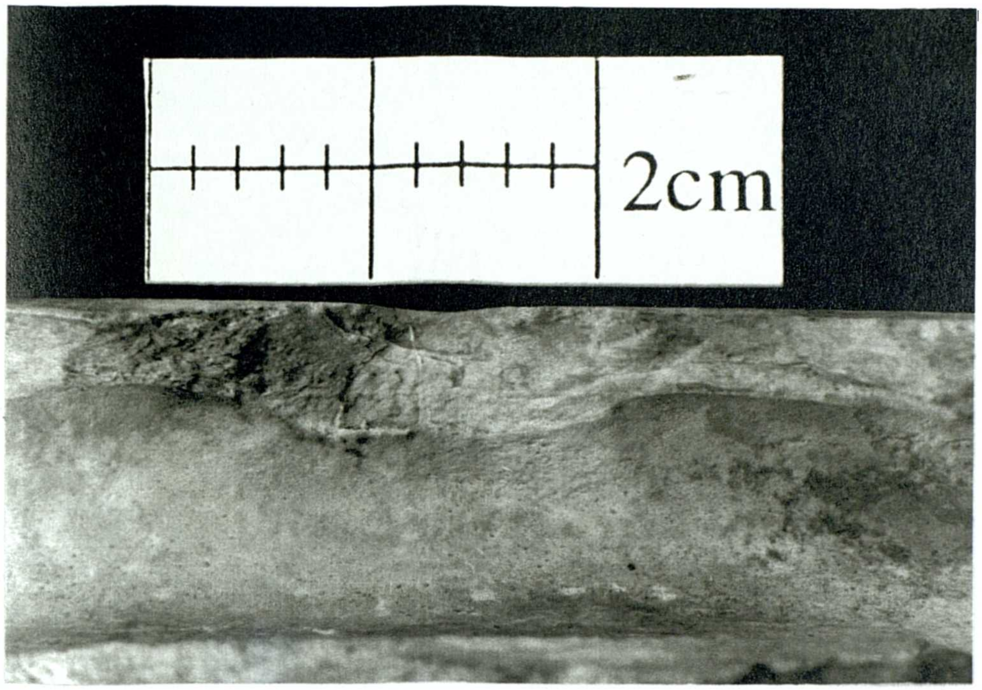


Figure 4.6 - A close-up photograph of an impact scar on an archaeological bone specimen

Figure 4.7 - An archaeological example of a diagonal fracture outline

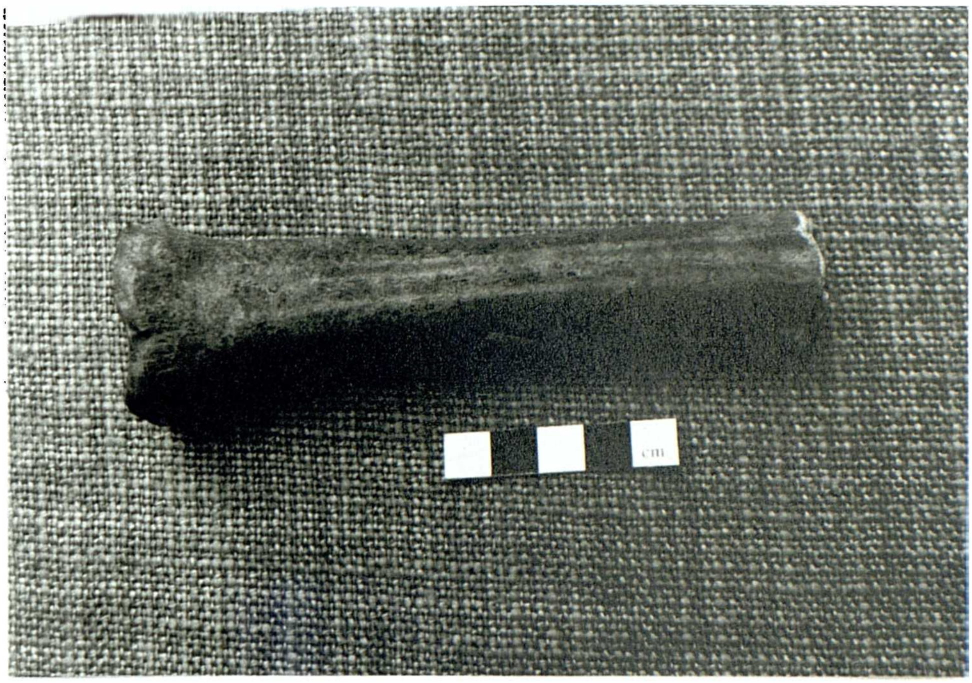


Figure 4.8 - An archaeological example of a transverse fracture outline

Figure 4.9 - An archaeological example of a longitudinal fracture outline

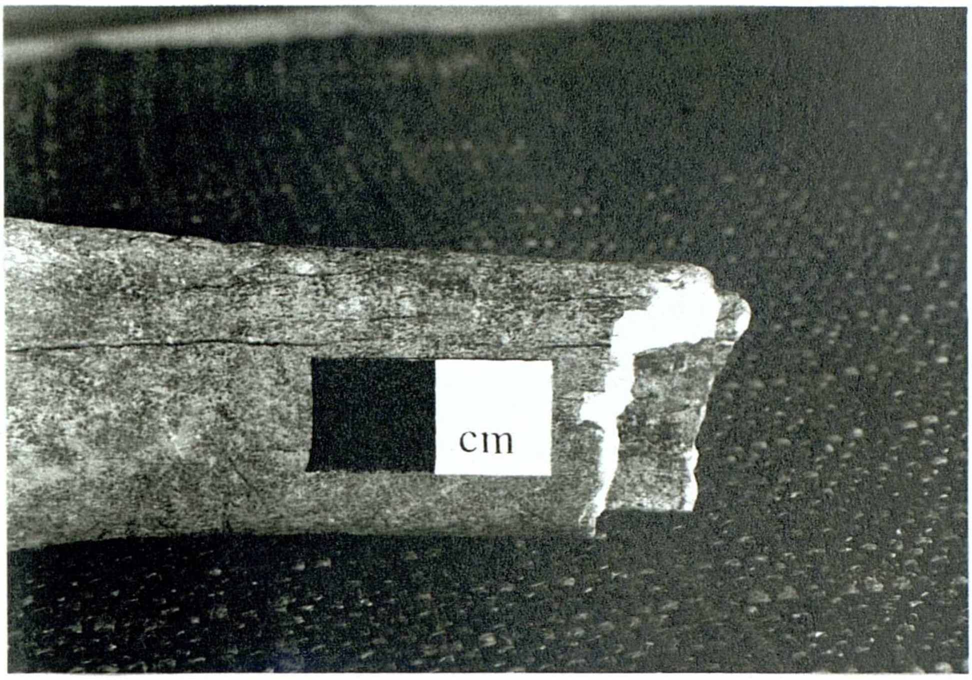


Figure 4.10 - An archaeological example of stepping and columns on a fracture outline

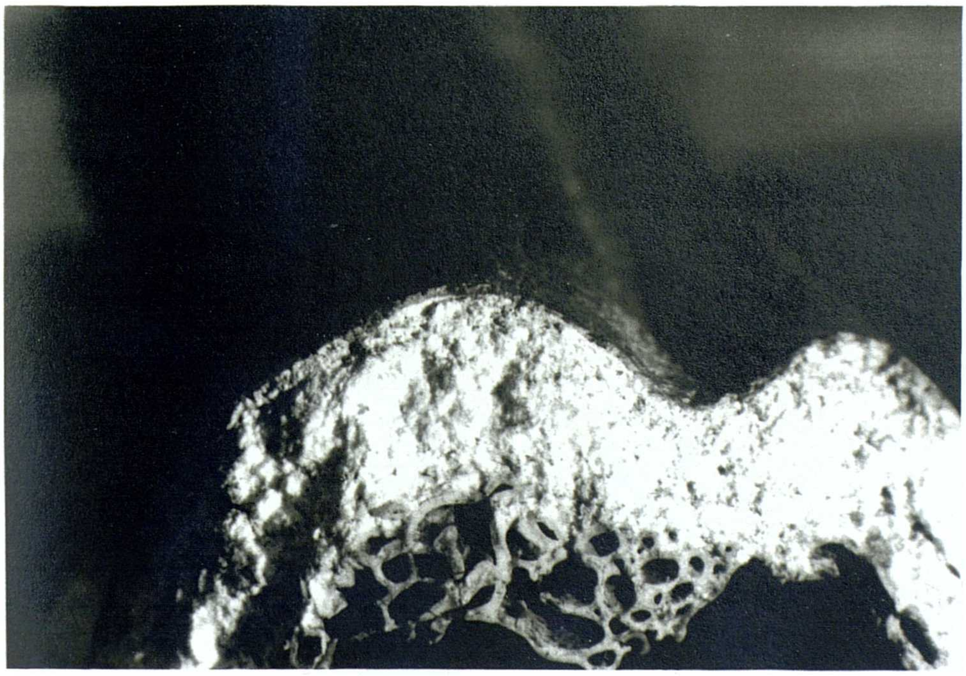


Figure 4.11 - A close-up photograph of an archaeological example of a mineralised fracture surface, showing how rough and granular it is

4.2 Fracture Type and Assemblage Analysis

Having, above, discussed the nature of fracture type, it is necessary to address the problem of how to go about recording fractures in the context of assemblage analysis.

Johnson (1989) has applied the criteria of fracture she developed (Johnson 1985) to palaeoindian sites in North America. This study is highly informative in understanding the sites in question. The discussion in this study, however, revolves around scrutiny and interpretation of individual bones in great detail. The assemblages are small and from a very remote period and maximum information needs to be gained. Whilst the very detailed study is needed on some sites, it will be entirely impractical on others. Some assemblages are just two large for individual fragments to receive individual interpretations. In many cases there just will not be the time and money available to carry out such a study. Excavators frequently have little enough funding to pay for the basic specialist environmental reports they need. If studies of fracture type are to be regularly incorporated into the analysis of faunal assemblages, then there needs to be a methodology for quickly classifying fracture types, in a sample of bones, so that the nature of fracture on the site can be accurately summarised. Systematic studies of fracture type in archaeological assemblages have very rarely been attempted. Below is a discussion of some past approaches.

Noe-Nygaard (1977) sets out to examine marrow fracturing in several major Mesolithic assemblages from NW Europe, but appears to go about it in entirely the wrong way. She commences with the assumption that the bones have been subjected to marrow exploitation and then characterizes the nature of this marrow breakage.

This is effectively working from the unknown (or at the least the uncertain) to the known. It is the fracture that is governed by uniformitarian principles, and it is from the fracture that testable theories of conditions of breakage can be formulated. Having established that the fracture patterns are consistent with possible marrow extraction methods, one can then go on to propose an interpretation of the bone marrow and grease processing activities at the site in question.

Shipman, Bosler and Davis (1981) do examine fracture type as part of their analysis of Acheulian sites. They examine mainly the fracture outline but also consider fracture surface. They express the results of their study as a series of χ^2 tests looking at contrasts between the occurrence of different fracture types in different assemblages. They do not, however, display all their data on fracture occurrence nor are their criteria too well defined. This is understandable given the lack of published studies regarding bone mechanics within archaeology at the time. They do, however, come to some useful conclusions in their study. What is needed is a methodology, similar to the above, but containing a fuller set of well-defined criteria that are well founded on good research into bone mechanics.

One such study has, indeed, been carried out. Villa and Mahieu (1991), in their comparison of a potential cannibal site with other human bone deposits, applied a detailed study of fracture and fragmentation. Their study uses criteria defined by Johnson (1985) as well as other criteria. They examined fracture angle (angle of fracture with the cortical surface), fracture outline (morphology of the fracture) and the fracture edge (whether it was smooth or not). Rather than being very descriptive, with regard to these criteria, they simply assessed whether features were present or not (i.e. was the fracture angle acute/obtuse, was it perpendicular or was it mixed). The assemblage could, hence, be assessed quickly. All the above criteria were ones given by Johnson (ibid.). In this study the results were expressed as a series of histograms displaying observations for each criteria and comparing different contexts/sites. They go on to look at issues of fragmentation such as the proportion of shaft circumference surviving. They examine shaft fragment length in terms of approximate proportion of original shaft length. They plot these two measurements against each other on a three dimensional histogram. All the fragments are measured and breadth/length ratios of fragments are calculated. All these criteria clearly indicated that the possible cannibal site was substantially different in its prevailing fracture type. The only exception was the study of fracture edge texture which showed only a slight difference (Villa and Mahieu 1991, p45). This general form of assemblage analysis seems exceptionally promising for the study of many questions regarding bone fracture and fragmentation. Further criteria from Johnson (1985) could be employed such as fracture colour (in contrast to the rest of the bone) or the existence of steps caused by split line interference. The criteria used would, perhaps, depend upon the question being asked.

It is worth discussing a detailed method for the recording of fracture outline developed by Biddick and Tomenchuck (1975). They devised a system whereby the co-ordinates of the fracture edge could be accurately plotted as a graph representing the 360° of the shaft circumference (at 20° intervals). Several objections can be raised to such a methodology. Firstly, the outline is only one criterion, of many, in identifying fracture type and such a study would require the expenditure of much time to assess just one criterion. Secondly, the method does not provide an interpretation. It merely records. At some stage an interpretation will need to be made with regard to what that fracture outline means. This may as well be when the bone is actually in the analysts hands! Thirdly, each fragment, according to Biddick and Tomenchuck (1975, p243), takes 10 minutes to record. With assemblages having many thousands of fragments, this seems far from practical.

CHAPTER FIVE

BONE FRACTURE EXPERIMENTS AND THE CREATION OF A FRACTURE FRESHNESS INDEX

5.1 Introduction

Johnson (1985) and Morlan (1984) (see chapt. 4.1) have discussed the nature of bone fracture types in detail. They note many criteria of fracture type that alter as a bone becomes less fresh. Villa and Mahieu (1991) (see chapt. 4.2) have applied this information in detailed assemblage analysis comparing fracture type and fragmentation in some human bone collections. The aim of the present research is to assess the degree to which similar assemblage analysis would be of use in identifying levels of bone marrow and grease extraction in archaeological faunal assemblages. Examination of ethnographic examples of bone marrow and grease extraction (see chapt. 1) shows that, whilst bones are often broken in a fresh state, there are a number of treatments prior to fracture that can be employed. These often take the form of warming the bone in hot water or near a fire. In some climates bones may have been frozen for some time before marrow is extracted from them.

Clearly, if fracture analysis is to be used to indicate levels of deliberate breakage for the extraction of bone marrow and grease, the effect of pre-fracture treatments on fracture type needs to be assessed. Whilst the above mentioned authors have discussed the changes that occur in bone fracture as the bone gets less fresh, they do not give much indication of the specific nature or magnitude of effect caused by a given treatment of a bone prior to fracture. It is important to ascertain under what level of treatment a bone will cease to fracture as if it were fresh. It is also of importance to discover whether fracture patterns caused by pre-marrow extraction treatments are discernible from those created by harsher treatments, which might occur during cooking processes, which are unrelated to marrow extraction. Discovering which of the criteria used by Johnson (1985), Morlan (1984) and Villa and Mahieu (1991) are most useful in distinguishing different treatments is also of great value.

Below, a series of experiments designed to address these questions is outlined. This series of experiments is not intended to represent a definitive study of all possible treatments and their effect on fracture. There are far too many combinations of treatment to make this practicable. It is hoped, however, that the experiments will indicate the feasibility of analysing animal bone assemblages for levels of bone marrow and grease extraction. The experiments will also serve to create a set of reference specimens of fracture types which will assist in the study of fractures in archaeological material. Useful practical observations regarding the effects of pre-fracture treatments on marrow extraction and marrow condition can be made.

5.2 Experimental Methods and Materials

All the bones in the experiments outlined below were fractured using the same method. They were laid upon a stone anvil and impacted, mid-diaphysis, with a sharp blow from a water-rounded flint pebble. Further blows to the same spot were used, if necessary, to fracture the entire circumference of the bone so that it could be parted in two. Before fracturing took place, the bones were cleaned of meat, connective tissues and as much of the periosteum as possible. Figure 5.1 shows the anvil and stone used for fracture and the condition the bones were in at the time of fracture.

After fracturing, the marrow was extracted using a variety of long metal implements. As many of the fragments resulting from the fracture were collected as possible. For the purposes of preservation, the two halves of the bone and all accompanying fragments were boiled for two hours in a fine net bag and then any remaining soft tissue was removed. The specimens were then degreased by immersion for a short period of time in boiling sodium hydroxide solution, rinsed and allowed to dry.

All the bones used were cattle bones collected in a fresh state (no more than a day old). Many specimens were from fairly young animals with epiphyses not fully fused but with bones of adult size. The exact number of bones and the elements used for specific experiments was largely governed by the fresh supply available at the time of the experiment. This situation was not ideal, but was unavoidable.

5.3 The Experiments

Below the details of the individual experiments are outlined.

5.3.1 Fresh Specimens

The sample of fresh bones (no more than a day old) consisted of 7 specimens; 2 humeri, 1 radius, 1 metacarpal, 1 femur and 2 tibiae.

5.3.2 Frozen specimens

Four experiments were carried out on frozen bones. Six bones (1 humerus, 1 radius, 1 metacarpal, 1 femur, 1 tibia, 1 metatarsal) were frozen for two weeks at -20°C and then thawed before fracture. The freezer temperature was maintained by the regular checking of a thermometer and the required adjustment of the freezer controls.

Four bones (1 humerus, 1 radius, 1 femur, 1 tibia) were frozen at the same temperature for four weeks and then defrosted.

Six specimens (1 humerus, 1 radius, 1 metacarpal, 1 femur, 1 tibia, 1 metatarsal) were treated to a much longer period of freezing, 20 weeks, before thawing.

A fourth freezing experiment was carried out on only two bones (1 humerus, 1 radius) which were frozen at -20°C for 10 weeks but fractured in their frozen state.

5.3.3 Oven Heated Specimens

Three experiments were conducted where the specimens were heated in an incubation oven. Four bones (1 humerus, 1 radius, 1 femur, 1 tibia) were heated for one hour at between 80 and 100°C. The bones were then fractured fresh from the oven and the maximum temperature of the marrow measured with the use of a digital thermometer.

The second experiment followed the same procedures but the four specimens (1 humerus, 1 radius, 1 femur, 1 tibia) were heated for five hours.

The third experiment, intended to provoke more extreme results, involved heating three bones (1 humerus, 1 radius, 1 tibia) to between 100 and 120°C for at total of 43 hours. These specimens were also fractured fresh from the oven.

The oven temperatures are quoted as ranges because of the oven's slowness in regaining its intended temperature after insertion of the specimens. The temperature of the oven was monitored by the use of a probe attached to a digital thermometer outside the oven.

5.3.4 Boiled Specimens

Two boiling experiments were conducted. The first involved boiling three bones (1 tibia, 2 radii) for 10 minutes before fracturing them immediately after withdrawal from the water. The maximum temperature of the marrow was recorded with a digital thermometer after fracture.

Four bones (1 humerus, 1 radius, 1 femur, 1 tibia) were boiled for one hour and then treated as above.

5.3.5 Specimens Subjected to Radiant Heat

These experiments were designed to replicate the heating of bones placed immediately adjacent to a wood fire. This was achieved by recording the temperature reached by a mercury oven thermometer placed approximately 15cms from a domestic sized wood fire and reproducing the same effect, in the laboratory, with the use of a one kilowatt electric bar fire, positioned to make the thermometer read the same temperature. Obviously the temperature of fires will vary tremendously and different distances from the fire would also cause considerable variation. The purpose of these measurements, however, was simply to produce conditions which are in the correct general range of magnitude. The temperature reached by the thermometer was in the range between 200 and 250°C. This, however, cannot be taken to represent the temperature reached by bones in the experiments below, since the thermometer and the bone will have different levels of ability to absorb radiant heat. These figures must be taken as representing nothing more than an indication of the general order of magnitude in the heating.

The first experiment conducted with radiant heat was carried out on three specimens (1 tibia, 2 radii). These specimens were subjected to the above specified radiant heat for six minutes on one side of the bone only. The bones were fractured immediately after heating and the maximum temperature of the marrow was recorded after fracture using a digital thermometer.

The second experiment involved subjecting four bones (2 tibiae, 2 radii) to radiant heat for four minutes. In this case the heat was applied evenly round the bone shafts (the bones were slowly rotated). Fracture took place immediately after heating and the marrow temperature was once again taken.

5.3.6 Radiantly Heated Frozen Specimens

Four specimens (1 humerus, 1 radius, 1 femur, 1 tibia) were frozen for 10 weeks at -20°C and, whilst still frozen, were subjected to radiant heat (as above) for ten minutes on one side. The bones were fractured immediately after heating and the temperature of the marrow taken on both the heated and unheated sides of the shaft using a digital thermometer.

5.4 Analytical Methods

Each of the fractures created in the experiments was analysed for a series of criteria. These criteria largely follow those outlined by Morlan (1984), Johnson (1985) and Villa and Mahieu (1991), as discussed in chapter 4. The criteria, and the methods of recording them, are described below.

5.4.1 Fracture Outline

The fracture outline is a description of the fracture's basic shape as it travels in the bone wall. It is not a macro description of the fracture pattern on the whole bone. Different types of outline are described in chapter 4. A combination of outline types may co-exist in a single fracture. In this analysis the outline types to be found on both the proximal and distal ends of the fractured specimen were described. If no separate fragments have been broken away, the two ends will have the mirror image of each others' fractures, but when large fragments are dislodged their outlines can be very different. Recording of fracture outline was achieved with a verbal description of the outlines present.

5.4.2 Fracture Edge Texture

The broken surface of a fresh fracture is usually smooth in nature whilst on less fresh specimens it may be of rough appearance. In carrying out this aspect of the analysis it is important to disregard roughness or jaggedness on small areas caused by stress relief features, where the fracture line has rippled (see chapt. 4.1). Roughness resultant from lack of freshness is relatively easily discerned. Recording was, again, by verbal description.

5.4.3 Fracture Angle

On a fresh fracture the angle of the fracture surface to the bone's cortical surface is usually acute or obtuse. Right angles are more common on unfresh specimens (see chapt. 4.1). For this study, an estimate of the approximate percentage of fracture surface that was at right angles was made for both the proximal and distal ends of the bone.

5.4.4 Steps and Columns

On unfresh specimens the fracture outline can become interrupted by cracks already present in the bone. These cracks lead to steps or columns interrupting the line of fracture (see chapt. 4.1). The presence or absence of such features was noted.

5.4.5 Impact and Radial Fracture

On fresh fractures an impact point is often clearly distinguishable and the fracture fronts run out radially from this point. Fresh fractures tend to terminate before the articulation but on unfresh bones the fracture continues to cut across the articulation (Johnson 1985). Information regarding these points was noted.

5.4.6 Flakes and Fragments

The detached flakes and fragments, resulting from the fracture, were counted and their dimensions recorded to the nearest millimetre.

5.4.7 Comments

Any other interesting features regarding the fracture were noted.

5.5 Individual Experimental Results and Observations

Table 1 gives a summary of the results obtained from each experiment with regard to the three principle criteria used; outline, texture and angle. The original recording contained far more descriptive detail. Below, observations on each of the experiments are made.

5.5.1 The Fresh Experiment

All the fresh specimens fractured according to expectations. The outlines of the fractures were helical and the edges were smooth. The metacarpal, however, had a slight area of longitudinal fracture, but this was almost certainly a result of the line of failure following the natural division down the centre of the metapodials of artiodactyls. The fracture angle was rarely at right angles. Most of the specimens displayed clear impact points and some also showed rebound points. The point of rebound is like a second impact point on the under side of the bone where the bone rebounded off the anvil (Johnson 1985). The fracture of fresh bones required, on the whole, just a single sharp blow. Figure 5.2 shows one of the fresh humeri specimens. This example shows the helical lines of failure radiating out from a central impact point (an impact scar was left on both the proximal and distal halves). It should be noted that, in line with Johnson's (1985) criteria, the line of failure approaching the proximal epiphysis stops before cross-cutting the articulation.

5.5.2 Two Weeks Frozen (and Thawed)

Once again the fractures were largely smooth and helical with some longitudinal fracturing on the metapodials. Both the humerus and radius had a certain amount of right angle fracturing, however. Impact points were often present. The ease of fracture was the same as for fresh specimens. Just one sharp blow was required.

5.5.3 Four Weeks Frozen (and Thawed)

Fractures were again helical and largely smooth with very little fracture at right angles. Impact points were present in all but one specimen. One blow was normally required for fracture.

5.5.4 Twenty Weeks Frozen (and Thawed)

Fracture was still largely helical after twenty weeks frozen. However, there was some diagonal fracture on a femur and some longitudinal fracture on a tibia and the expected longitudinal fracture on metapodials. The outlines were slightly more jagged and less uniform than those found on the experiments described above. The fracture surfaces were generally smooth. Some right angle fracture was encountered on every specimen, although in small amounts. Impact points were generally still present and fracture was still achievable with a single sharp blow.

5.5.5 Ten Weeks Frozen (Not Thawed)

The two specimens broken whilst frozen created smooth, helical fractures with very small amounts of right angle fracture. Impact points were present and fracture was easily carried out. Figure 5.3 shows one of these specimens. The helical fracture outline is plain to see.

5.5.6 One Hour in the Oven (80 - 100°C)

Fracture of these specimens produced largely helical fractures. The femur produced some longitudinal ones, but the radius was the major exception creating a combination of diagonal, longitudinal and transverse fractures with very little helical ones present. Some roughness on edges was encountered on three of the four specimens. Some right angle fracture was present on all specimens. Impact points, as such, were generally absent. Instead, an area of crushing was often present. Some of the specimens were distinctly harder to break than fresh or frozen specimens. After breaking, it was observed that the marrow in the cavities was loose because a fair portion of it was molten. The temperature of the molten marrow was circa 45°C at the time of breaking.

5.5.7 Five Hours in Oven (80 - 100°C)

Some helical fractures were present but most fractures consisted of a mix of outline types. The radius was particularly jagged. This particular specimen is pictured in figure 5.4 and lack of helical fracture is clear to see. There was a degree of roughness on all fracture surfaces. Right angle fracture was present in significant quantities on the humerus and tibia and also present on the femur. The radius was free from any right angles due to its jaggedness. No impact points were present. These specimens were not difficult to break. Much of the marrow fat was liquid in the cavity. This fat was at circa 75°C at time of breaking.

5.5.8 Forty-Three Hours in the Oven (100 - 120°C)

No helical fracture was present. Instead there was a combination of other outline types. The edges were rough or largely rough. No impact points were present and the articulations were cross-cut on both the humerus and radius. Two of the three specimens had large proportions of right angle fracture. Upon impact the specimens shattered creating many small fragments. The marrow cavities were completely dried out.

5.5.9 Boiled in Water for Ten Minutes

The fractures on these specimens were largely helical and smooth. One radius, however, had some rough, transverse fracture. This specimen can be seen in figure 5.5. Rough, non-helical breaks can be seen on the anterior and posterior faces of the bone. However, linking these two fracture lines are two areas of helical fracture on the medial and lateral sides of the bone shaft. This specimen also had a large degree of right angle fracture. The other two specimens had little or no right angle fracture. Impact points were not present and the bones were more difficult to break than fresh ones. Upon fracture the marrow was partly molten and at a temperature ranging between 57 and 67°C for the different specimens.

5.5.10 Boiled in Water for One Hour

On the humerus and radius helical fracture was entirely absent and on the tibia there was a mixture of helical and longitudinal fracture. The femur was anomalous in having mainly smooth, helical fracture without right angles. The humerus and tibia featured much rough, right angle fracture. Because the radius was jagged and saw-tooth in its fracture outline it was impossible to assess proportions of right angle fracture. This extremely jagged specimen can be seen in figure 5.6. These bones were incredibly difficult to break and, upon fracture, the marrow cavities were almost entirely devoid of marrow. The marrow had presumably all melted and made its way out of the bone through the foramen.

5.5.11 Six Minutes Radiant Heat, One Side

This experiment resulted in a degree of helical fracture on all specimens, mixed with other fracture types. Similarly, there was mixture of rough and smooth fracture on each specimen. Right angle fractures were present in only small quantities. An impact point was present on one specimen. The heated side of the bone had not been browned or charred in any way as a result of its treatment. The marrow was, however, quite hot and molten on the heated side. The marrow temperature of the heated side ranged between 60 and 74°C on the different specimens. The specimens were slightly harder to break than fresh bones.

5.5.12 Four Minutes Radiant Heat, Even

Most of the fractures were largely helical and smooth. Right angle fractures were present on three of the four specimens, but in fairly low proportions. Impact points were present on two examples and one rebound point was present. The bones were not particularly difficult to break and the marrow was part molten round the edges with temperatures ranging from 31 to 52°C.

5.5.13 Ten Weeks Frozen, Ten Minutes Radiant Heat, One side

The humerus was the only specimen to produce a largely helical, smooth fracture. The femur and tibia produced a combination of helical and other fracture types and had a mixture of rough and smooth fracture surfaces. The radius produced mainly rough fractures with transverse, longitudinal and diagonal outlines. The radius also produced this series of experiments' only clear steps caused by cracks present prior to fracture. Two large, right angled steps were present on the heated side of the bone. Two cracks, probably resulting from differential expansion caused by sudden heating of the frozen bone (heat shock), had clearly interrupted the fracture path. All but the humerus had proportions of right angle fracture. The radius had very high proportions. An impact point was only present on the humerus. The bone had begun to char on the heated side as a result of the treatment. Upon examination of the marrow cavity, it was found that the marrow was molten on one side and still very cold on the other. At its most extreme, on the radius, the temperature of the marrow on the heated side was 70°C and on the unheated side was still below freezing point.

5.6 General Observations Regarding Experimental Results

Several general observations should be made at this point. Firstly, it seems that the experiments largely lived up to theoretical expectations. Fresh bones produced helical, smooth fractures with sharp angles and, on the whole, the harsher the treatment the bones were subjected to, the less this was the case. However, there were frequent exceptions. Some of these exceptions are probably due to the different level of effect various treatments had on different elements. They could also be due to variation in the author's fracturing technique. It certainly seems that the use of the criteria listed above will not guarantee a correct detailed diagnosis of degree of freshness at time of fracture for every individual specimen. In fact, some of the criteria can be at odds with each other. For instance, in the "Two Weeks Frozen" experiment, the humerus had entirely helical fractures but a sizable proportion, c.40%, of right angle fracture. Conversely, the radius in the "Five Hours in the Oven" experiment had no right angle fracture but no helical fracture either! There are other, similar, examples. It was evident, however, that it was *generally* possible to discern levels of fracture freshness.

Secondly, it was surprising to find that the heated bones, particularly the boiled ones, were, in general, far more difficult to fracture than fresh specimens. Bonfield and Li (1966) demonstrated that bones "...exhibit a pronounced maximum in strength at 0°C". Their experiments (ibid.) included elastic and plastic deformation as well as impact testing at a range of temperatures from -196 to 900°C. So why were the heated specimens in this set of experiments so difficult to fracture? One explanation might lie in the fact that Bonfield and Li (ibid.) carried out their experiments on thin, rectangular cut strips of bone not whole bones, as in this series of experiments. With a whole bone, a fracture line clearly has to travel round the whole circumference of the diaphysis before the marrow cavity can be properly accessed. The boiled and oven heated bones (apart from the 43 hour oven specimen which was incredibly brittle) seemed harder to break, not because they were not fracturing, but because the fractures were not meeting up to allow the shaft to break in two. When the shaft finally became broken fully around its circumference it was because many fractures, often travelling in different directions, had met. This accounts for the jaggedness of some specimens. Helical fracture, in fresh bone, travels around the circumference of the diaphysis naturally making access to the marrow cavity much easier.

Thirdly, some of the treatments used were clearly too harsh to ever be successfully employed before marrow extraction. Boiling for one hour resulted in marrow loss, whilst boiling for ten minutes resulted in melting the outside of the marrow, which might aid marrow extraction. Heating the bone for one hour in the oven melted some of the marrow, whilst heating it for five hours resulted in most of it being liquid. Heating for 43 hours resulted in drying the marrow out completely. The application of radiant heat for a short time melted some of the marrow which, again, might ease marrow extraction.

5.7 The Creation of a Fracture Freshness Index

Above, individual specimens have been discussed and it was found that, whilst there were exceptions, bones tended to break according to theoretical expectations. Below, the principle criteria for distinguishing fracture type, i.e. fracture angle, outline and texture, will be used to create a numerical index of fracture freshness based upon the experimental data. If archaeological bone assemblages are to be analysed for fracture type, such an index, constructed with reference to a series of known experiments, will be invaluable in providing a measuring stick against which archaeological results can be compared. The index will also serve as a further check on the validity of the various fracture criteria, in terms of their correctly categorising the experiments according to freshness and their degree of consistency with each other. Clearly, the index needs to be formulated in such a way that very large numbers of archaeological specimens can be assessed relatively quickly. In practice, this means that it should be possible to assess each criterion at little more than a glance.

5.7.1 A Scoring System for the Criteria

Each of the three criteria can be represented easily by three categories which are assigned a score value. For all the criteria, 0 will represent an assessment that the criteria indicates a fresh break, 1 will indicate that the fracture shows a combination of fresh and unfresh features and 2 will indicate a domination by unfresh fracture features. For the fracture angle, 0 means an absence of right angle fracture (0% at 90°), 1 means the presence of less right angle fracture than acute/obtuse fracture (0 - 50% at 90°) and 2 means a majority of right angle fracture (>50% at 90°). For fracture outline, 0 means the presence of only helical breaks, 1 means the presence of both helical outline and other outlines and 2 means the presence of no helical outline. For fracture texture, 0 means an absence of roughness, apart from stress relief features, 1 means some roughness but mainly smooth and 2 means largely rough. The index has been calculated from the summary of results given in table 5.1. Proximal and distal ends of bones in each experiment have been considered jointly. Hence, if the proximal has 50% at right angles but the distal only 40% the score will be 1. When their average percentage at right angles exceeds 50% the score is 2.

The criteria scores are added up for each bone in the experiment and then these average criteria scores are averaged to create the overall index score for that experiment. There is, therefore a minimum (completely fresh) score of 0 and a maximum (no fresh features) score of 6. The results of this exercise are expressed in

Table 5.2. In this table, and in the text below, the angle criterion is denoted as criterion A, outline is B and texture is C.

5.7.2 Categorising the Experiments According to the Index

Table 5.3 puts the fracture experiments in order of freshness of fracture according to the index calculated above. Each experiment is followed by its standardised index value. It can be seen that the order makes a considerable degree of sense and the experiments can be classified into three broad groups. The first consists of experiments which had little effect on fracture type (and all have average index values below 2). The second group contains those experiments which might reasonably be expected to have affected fracture type but not to the total loss of fresh characteristics (all have values between 2 and 3). The third group contains experiments that were more harsh in their treatments and provoked the loss of many features of fresh fracture (values over 3).

It should be noted that the strict order of the freshness of experiments was not attained. For instance two week frozen bones have a higher score than four and ten week frozen bones. However, this simply created index seems to have successfully separated pre-fracture treatments into groups in line with theoretical expectations. Those bones fractured fresh or frozen for short periods could be discerned from those receiving mild pre-marrow extraction treatments and these could be discerned from harsher treatments incompatible with marrow extraction. The index, therefore, appears to be valid and useful, but how well do the criteria agree with each other and can the index be strengthened?

5.7.3 A Statistical Consideration of the Criteria and Index

In order to answer the questions posed above, a series of Pearson's coefficients of correlation were calculated to see how well each of the three criteria agreed with each other and with the finished index. The coefficient of correlation between criteria B and C was very strongly positive (0.9450) and most definitely significant (P=0.000). The correlations between A and B and A and C, however, were not so strong. The coefficient for A and B was a positive one (0.5223) but not very strong and had a significance (P=0.067) allowing the 6.7% chance the correlation was a random one. The correlation between A and C was similar (0.5290, P=0.063). This suggests that criterion A, whilst having some agreement, does have quite a degree of variance with the other criteria which are in strong agreement with each other. Criterion A also had a relatively low coefficient of correlation with the total index (0.6663) although it had a reasonable degree of significance (P=0.013). B agreed strongly with the index (0.9706, P=0.000) as did C (0.9741, P=0.000).

This all suggests that criterion A (angle), in its current form, could be a weak link in the index. The way the criterion of fracture angle is scored may not be the best one for the identification of fresh fracture. If the scoring system were altered would this improve the criterion's agreement with the other criteria and, hence, make the index more accurate?

5.7.4 Optimising the Index

If one examines table 5.1 it can be seen that when the criteria of outline and texture are indicating completely fresh fracture there is occasionally a small amount of right angle fracture. Perhaps the setting of 0% at 90° for a score of 0 was in error. Bearing this in mind, A has been recalculated allowing for up to 10% at 90° for a score of 0 and this new score (A_2) is presented in table 5.4 along with the recalculated Index ($Index_2$) it causes. One finds that A_2 correlates much better with criteria B and C and with a high degree of confidence of significance, 0.7782 ($P=0.002$) and 0.6993 ($P=0.008$) respectively. A_2 also has a much better correlation with $Index_2$, 0.8514 ($P=0.000$), whilst B and C maintain there very high correlation with the new index, 0.9808 ($P=0.000$) and 0.9622 ($P=0.000$).

It appears that the new formula for calculating the score for fracture angle has statistically strengthened the index. Can it be improved still further? It was also noted (see table 5.1) that when outline and texture indicated a lack of fresh features the percentage of right angle fracture had not always reached 50%. This was therefore taken into account along with the changes made in A_2 and now 0 to 10% at 90° was scored as 0, 10 to 40% was scored as 1 and >40% was scored as 2. The result, A_3, is shown in table 5.4 along with the recalculated index ($Index_3$).

The result of this alteration was to strengthen the correlation a little more. A_3 has a coefficient of correlation of 0.8191 ($P=0.001$) with B and 0.7281 ($P=0.005$) with C. A_3's correlation with $Index_3$ is 0.8753 ($P=0.000$) and B and C's correlations with the new index are 0.9843 ($P=0.000$) and 0.9596 ($P=0.000$). So, perhaps the best way to calculate the index is using the A_3 formula for fracture angle.

5.7.5 Categorising the Experiments According to $Index_2$ and $Index_3$

The result of categorising the experiments according to the amended indices is given in table 5.5. The overall groupings remain the same with one exception. The "20 weeks frozen" experiment can now perhaps be classified with those treatments having little effect on fracture type. This seems in line with the author's own experience of fracturing these specimens. Freezing, of all the experiments, had the very least effect on fracture. One alteration to the order which appears worrying is the fact that the 10 wk frozen (not thawed) experiment has an index value indicating that it is fresher than the fresh specimens! This, however, is likely to be due to the very small sample size (2) used for this experiment. It should also be pointed out that, since these specimens were deliberately not thawed before fracture, they will have experienced less strain, and potential microcracks, than might result from the effect of differential heat expansion. This experiment, therefore, could reasonably show less effect on fracture type than other frozen and thawed specimens. Another change in the order, worthy of note, is the equal placing of the 4 minutes even radiant heat experiment and the 6 minutes on one side radiant heat experiment.

5.7.6 Which Indexing Method Should be Used?

The amended indices have clearly better internal agreement of criteria, over levels of freshness of fracture, and the groupings of the experiments for the new indices are sensible. It is therefore clear that either $Index_2$ or $Index_3$ should be used. The two indices produce an identical order for the experiments; there are just two minor differences in actual value. $Index_3$, however, has slightly better statistical correlation between its criteria and is, therefore, perhaps the best of the indices calculated here. It is, perhaps, not the best index to apply in the study of large assemblages, though. Above, it was argued that each criterion should be assessable quickly and with ease so that the methodology can be effectively applied to large assemblages. The estimation of a category representing between 10% and 40% at 90° is, however, not simple. Ignoring a small amount of right angle fracture (i.e. 10%) can be easily done, as can estimating whether a majority of fracture is at right angles (i.e. 50%). Since $Index_2$ and $Index_3$ are so very similar it might be more pragmatic to apply $Index_2$ to assemblage analysis.

5.8 The Dimensions of Bone Fragments

Villa and Mahieu (1991) found that studying the relationship between width and length of shaft fragments helped them distinguish between fresh and unfresh fractures on collections of human bone. They found that fragments resulting from fresh breaks were longer in relation to their width than those from unfresh breaks. Shaft fragments resulting from these experiments have been measured to see if this criterion is useful in distinguishing between the varying levels of severity of pre-fracture treatment employed. The length dimension was taken as being the longest dimension and the width was taken perpendicularly to it. Measurements were taken using vernier calipers and were recorded to the nearest millimeter. Only shaft fragments were measured. Those with a dimension over 60mm were discounted since, at that size, there began to be too much curvature on the fragment to make the measurement of width and length possible. Experiments with a sample size of under 10 fragments were ignored. The average value of length/width was calculated, as was the standard deviation.

The results of these measurements are given in table 5.6. It can be seen that there is little discernible pattern in the length/width ratios. On the frozen specimens the length/width ratio falls as the treatment is continued for longer, but then jumps back up for the 20 weeks frozen specimens. With the oven experiments, the lowest value is for the 1 hour experiment whilst the highest value is the 5 hour experiment and the 43 hour experiment is in between.

This criterion may work in distinguishing mineralized from unmineralized breaks, as Villa and Mahieu (1991) were probably doing, but it does not appear to work for the more subtle variations of fracture encountered in this series of experiments.

5.9 Summary and Conclusions:

This series of experiments has demonstrated that the criteria for distinguishing freshness of fracture devised by Johnson (1985) and Morlan (1984) appear to be valid. More importantly those same criteria can distinguish between fresh bones and those which have received mild pre-fracture treatment, and between mildly treated bones and those more harshly treated. It would also be possible to distinguish between all of these treatments and mineralized bone. This suggests that study of fracture patterns in archaeological assemblages can be of use in establishing degrees of marrow exploitation, even if pre-fracture treatments vary. It also seems that it may be possible to assess the level of fresh breakage with the use of a relatively simple and easily applied index. The measurement of shaft fragments, however, did not prove such a useful criterion but may be applicable to the identification of mineralised breakage levels.

Experiment	PROXIMAL			DISTAL		
Element	**% at 90°**	**Outline**	**Texture**	**% at 90°**	**Outline**	**Texture**
Fresh						
Humerus	15	H	S	15	H	S
Radius	0	H	S	0	H	S
M'carpal	10	HL	S	0	HL	S
Femur	0	H	S	0	H	S
Tibia	0	H	S	0	H	S
Humerus	0	H	S	0	H	S
Tibia	0	H	S	0	H	S
2 wk Frozen						
Humerus	40	H	SR	40	H	SR
Radius	30	H	SR	30	H	SR
M'carpal	10	HL	S	0	HL	S
Femur	0	H	S	0	H	S
Tibia	0	H	S	0	H	S
M'tarsal	40	HL	S	0	H	S
4 wk Frozen						
Humerus	0	H	S	0	H	S
Radius	10	H	SR	10	H	SR
Femur	0	H	S	0	H	S
Tibia	20	H	S	20	H	S
20 wk Frozen						
Humerus	10	H	S	10	H	S
Radius	20	H	S	20	H	S
M'carpal	30	H (bit jagged)	SR	20	H (bit jagged)	SR
Femur	10	HD	SR	20	HD	SR
Tibia	50	HL	SR	20	H	SR
M'tarsal	0	HL	S	20	H	S
10 wk Frozen *(not thawed)*						
Humerus	10	H	S	10	H	S
Radius	10	H	S	10	H	S
1 hr in Oven						
Humerus	30	H(mainly)	SR	30	H(mainly)	SR
Radius	20	TLD	SR	10	TLD	SR
Femur	10	HL	SR	0	H	SR
Tibia	20	H	S	20	H	S
5 hr in Oven						
Humerus	35	TH	RS	35	TH	RS

Radius	0	LD	R	0	LD	R
Femur	15	DLH	SR	15	DLH	SR
Tibia	30	DL	SR	30	DL	SR
43 hr in Oven						
Humerus	50	TD	R	40	TLD	R
Radius	50	LD	R	50	TLD	R
Tibia	0	TLD	RS	0	TLD	RS
10 min Boiled						
Tibia	10	HL	SR	10	HL	SR
Radius	50	HT	SR	50	HL	SR
Radius	0	H	SR	0	H	SR
1 hr Boiled						
Humerus	50	TLD	R	50	TLD	R
Radius	Too Jagged	LD	R	Too Jagged	LD	R
Femur	0	HD	SR	0	HD	SR
Tibia	60	HL	R	60	HL	R
Radiant Heat: 6 min, 1 side						
Tibia	0	H(mainly)	SR	0	H(mainly)	SR
Radius	10	HD	SR	10	HD	SR
Radius	15	LDTH	RS	0	LDTH	RS
Radiant Heat: 4 min, even						
Tibia	0	H	S	0	H	S
Tibia	20	HT	SR	20	HT	SR
Radius	0	H	S	20	HD	SR
Radius	30	HLD	SR	30	HLD	SR
Frozen 10 wk, Radiant Heat 10 min, 1 side						
Humerus	0	H	SR	0	H	SR
Radius	70	TLD	R	70	TLD	R
Femur	30	HT	SR	25	HT	SR
Tibia	25	HL	RS	10	H	S

Table 5.1 - A summary of the fracture experiment results (Key: H = Helical, L = Longitudinal, T = Transverse, D = Diagonal (Combinations of letters mean more than one outline type is present) R = Rough, S = Smooth, SR = more smooth than rough, RS = more rough than smooth)

EXPERIMENT	A Angle	B Outline	C Texture	Index
Fresh	0.29	0.14	0.00	0.43
2 Weeks Frozen	0.67	0.33	0.33	1.33
4 Weeks Frozen	0.50	0.00	0.25	0.75
20 Weeks Frozen	1.00	0.50	0.50	2.00
10 Weeks Frozen (not thawed)	1.00	0.00	0.00	1.00
1 Hour in Oven	1.00	0.75	0.75	2.50
5 Hours in Oven	0.75	1.50	1.50	3.75
43 Hours in Oven	1.00	2.00	2.00	5.00
10 Minutes Boiled	1.00	0.67	1.00	2.67
1 Hour Boiled	1.33	1.50	1.75	4.58
Radiant Heat (6 min, 1 side)	0.67	0.67	1.33	2.67
Radiant Heat (4 min, even)	0.75	0.75	0.75	2.25
10 wks Frozen, 10 mins Radiant Heat	1.00	1.00	1.25	3.25

Table 5.2 - Mean criteria scores and fracture freshness index by experiment.

Fresh (0.43)
4 Weeks Frozen (0.75)
10 Weeks Frozen (not thawed) (1.00)
2 Weeks Frozen (1.33)

Treatments having little effect upon fresh fracture type.

****

20 Weeks Frozen (2.00)
Radiant Heat, 4 min, even (2.25)
1 Hour in Oven (2.50)
Radiant Heat, 6 min, one side (2.67)
10 Minutes Boiled (2.67)

Treatments having some effect upon fracture, but still many fresh features.

****

10 wk Frozen, 10 min Radiant Heat, one side (3.25)
5 Hours in Oven (3.75)
1 Hour Boiled (4.58)
43 Hours in Oven (5.00)

Treatments having more severe effect, many features of fresh fracture absent.

Table 5.3 - Experiments in order of freshness of fracture according to fracture freshness index

EXPERIMENT	A_2	$Index_2$	A_3	$Index_3$
Fresh	0.14	0.28	0.14	0.28
2 Weeks Frozen	0.50	1.16	0.67	1.33
4 Weeks Frozen	0.25	0.50	0.25	0.50
20 Weeks Frozen	0.67	1.67	0.67	1.67
10 Weeks Frozen (not thawed)	0.00	0.00	0.00	0.00
1 Hour in Oven	0.75	2.25	0.75	2.25
5 Hours in Oven	0.75	3.75	0.75	3.75
43 Hours in Oven	1.00	5.00	1.33	5.33
10 Minutes Boiled	0.67	2.34	0.67	2.34
1 Hour Boiled	1.33	4.58	1.33	4.58
Radiant Heat (6 min, 1 side)	0.00	2.00	0.00	2.00
Radiant Heat (4 min, even)	0.50	2.00	0.50	2.00
10 wks Frozen, 10 mins Radiant Heat	1.00	3.25	1.00	3.25

Table 5.4 - Adjusted criteria (A_2 and A_3) mean scores and corresponding index values by experiment.

10 Weeks Frozen (not thawed) (0.00)
Fresh (0.28)
4 Weeks Frozen (0.50)
2 Weeks Frozen (1.16)(*1.33*)
20 Weeks Frozen (1.67)

Treatments having a limited effect upon fresh fracture type. Fresh features dominate.

* * *

Radiant Heat, 4 min, even (2.00)
Radiant Heat, 6 min, one side (2.00)
1 Hour in Oven (2.25)
10 Minutes Boiled (2.34)

Treatments having some effect on fracture type, but there is still a majority of fresh features.

* * *

10 wk Frozen, 10 min Radiant Heat, one side (3.25)
5 Hours in Oven (3.75)
1 Hour Boiled (4.58)
43 Hours in Oven (5.00)(*5.33*)

Treatments having more severe effect. There is a majority of unfresh features.

Table 5.5 - Experiments in order of freshness of fracture according to fracture freshness Index$_2$ and *Index*$_3$

Experiment	Mean Length/Width	Standard Deviation	Number of Flakes
Fresh	2.69	1.13	27
2 Weeks Frozen	2.43	1.06	31
4 Weeks Frozen	2.27	0.70	16
20 Weeks Frozen	2.71	0.99	17
1 Hour Boiled	2.23	0.62	38
1 Hour in Oven	1.96	0.62	37
5 Hours in Oven	2.95	1.24	25
43 Hours in Oven	2.39	0.92	65

Table 5.6 - Mean length/width ratios of flakes

Figure 5.1 - The hammerstone and anvil used during the fracture experiments, and a freshly fractured cow metapodial

Figure 5.2 - A cow humerus fractured whilst fresh producing a classic pattern of helical fracture lines radiating from the point of impact where a bone cone was displaced

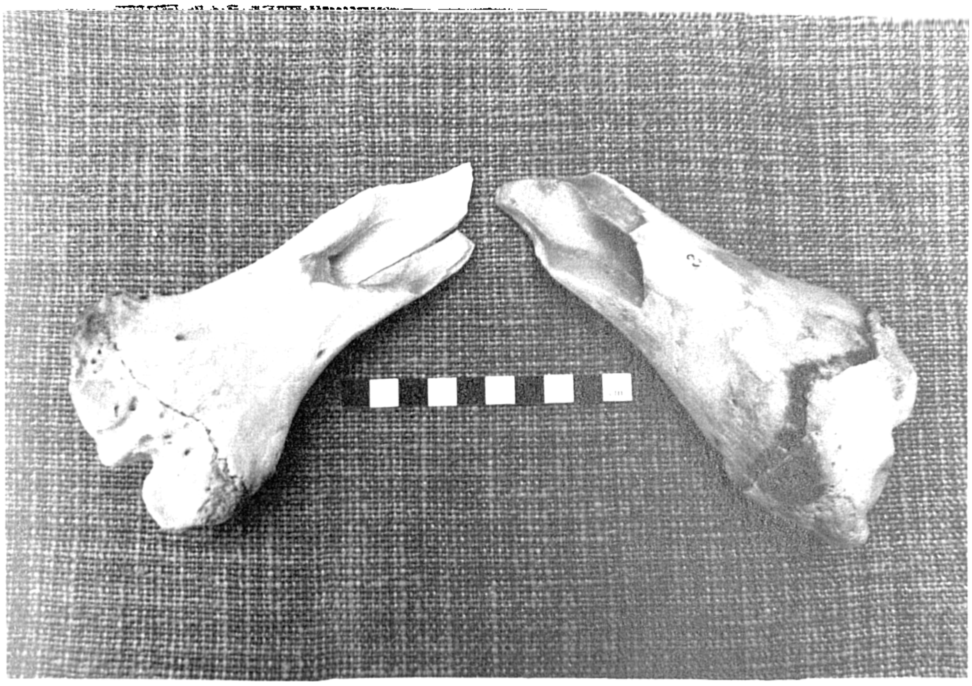


Figure 5.3 - A cow radius fractured after 10 weeks frozen, and not thawed before fracture

Figure 5.4 - A cow radius fractured after 5 hours in an oven at 80 - 100°C. Features of fresh fracture have been lost.

Figure 5.5 - A cow radius fractured after being boiled in water for 10 minutes. The anterior and posterior faces have lost features of fresh fracture but fresh, spiral fractures are still evident joining these two faces on both the medial and lateral sides.

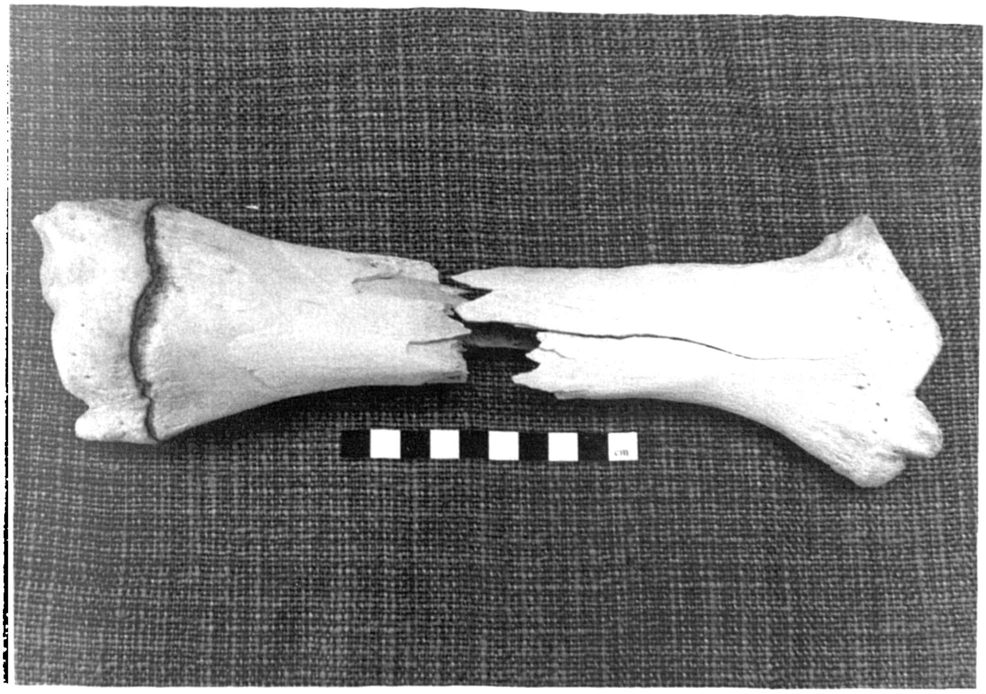


Figure 5.6 - A cow radius fractured after being boiled in water for 1 hour. The fracture is extremely jagged. The bone had to be hit many times to separate the bone into two.

CHAPTER SIX

ASSESSING AND MODELLING DEGREE OF FRAGMENTATION IN ARCHAEOLOGICAL BONE ASSEMBLAGES

6.1 Assessing Degree of Fragmentation

Having examined fracture patterns, attention must now be turned to the issue of fragmentation. For many years now, faunal analysts have been in need of sound methods of expressing the degree of fragmentation within the assemblages they are examining. All too often vague phrases (like *the fragmented appearance of the assemblage indicates....*) are used to sum up fragmentation in reports, without any substantiating data being presented. Degree of fragmentation is clearly of great importance in studying such areas as within-bone nutrient extraction, pre-depositional and post-depositional taphonomy and bone craft activities. There are many potential methods of gauging degree of fragmentation, some of greater use than others. Below is a long, but probably far from exhaustive, discussion of possible methods, some of which have been applied to assemblages and others that, as yet, remain theoretical. Many of these methods have been designed to sum up fragmentation with a single number, others are descriptive with regard to actual nature of the fragmentation (i.e. what is broken up and into what size pieces) and some have been designed to answer specific questions.

6.1.1 NISP:MNE Ratio

This method is probably the most used index of fragmentation because it is very easy to calculate in the normal course of an analysis, requiring little or no extra effort. It works on the basis that several identifiable fragments (as represented by the Number of Identifiable Specimens, NISP) will come from the same bone. In the normal course of analysis the minimum number of elements (MNE) is calculated that can account for all identified specimens. Clearly, the more fragmented the specimens, the more NISP there will be compared to MNE. If all bones were unbroken the NISP would equal the MNE (Lyman 1994, p336). The advantage of dealing only with identifiable specimens is that, if one so wishes, a separate index can be calculated for each element and species. The major drawback to the method is that many fragments will not be identifiable, and no matter how broken up or large the unidentified category is, the NISP:MNE ratio will not be affected. This limits the method's usefulness enormously. It is also possible that such a ratio may be more biased by individual analyst's confidence in their identification abilities, regarding small fragments, than by actual fragmentation. The ratio will also be affected by the method of deriving the MNE. Some analysts only identify certain "zones" of bones in order to calculate minimum numbers.

6.1.2 Total Frag: Total MNE Ratio

This potential method works in the same way as the above one, but includes all fragments whether identifiable or not. Since the indeterminate fragments are included, this ratio cannot be calculated for individual elements or species, but only for the assemblage as a whole. The total number of fragments is compared against the sum of the MNE counts. Although this is a far less specific index, it will more accurately reflect the degree of fragmentation in the assemblage, in comparison with the NISP:MNE ratio, whilst remaining easy to calculate.

6.1.3 Percent Identifiability

This method, applied by Gifford-Gonzalez (1989), works on the principle that the more fragmented an assemblage is, the more unidentifiable its fragments will be. Effectively this could be expressed as a Total Frag.: Total NISP ratio. The premise is clearly correct, in most cases, but the index will, of course, be seriously affected by the analyst's identification abilities and aims. There will be cases where such an index would be misleading. Identifiability is not always entirely governed by size of fragment. Small fragments from articulations of bones may, in fact, be easily identified. It is more difficult to identify shaft fragments, however. This indexing method could, therefore, be seriously affected by the type of bone which is most fragmented.

6.1.4 Percent Complete

This method simply compares the number of whole bones with the number of fragments (Todd and Rapson 1988). The validity of this method cannot be denied, but it is only really useful on sites where breakage is, in general, low. On many archaeological sites, however, few whole bones are found and one might be more interested in how broken the fragments are!

6.1.5 Percent Completeness

This method, after Morlan 1994, is quite closely related to the NISP:MNE ratio, but is more subtle and certainly requires more effort in its calculation. Identifiable portions are defined for each element individually. The number of "portions preserved" (PP) is counted on each fragment. This is then turned into the average number of portions preserved per specimen (PP/NISP). By dividing this value by the number of "portions defined" (PD) for each element and multiplying by 100 (100(PP/NISP)/PD) the Percent Completeness is calculated. Although this method, like the NISP/MNE ratio, only deals with identifiable specimens it is less flawed because it implicitly considers what has been destroyed by defining what should be there and ascertaining what actually is there. As such, its lack of consideration of unidentifiable fragments is partly redressed by an implied extrapolation of the portions that are missing. It still fails to assess degree of fragmentation amongst unidentifiable specimens but it provides a higher quality of information regarding the nature of fragmentation amongst identifiable specimens. Using this method requires more work in analysis and cannot be calculated *post hoc*; it must be integrated into the analysis from the start.

6.1.6 Total Frags:Volume Ratio

A completely different approach to the above methods, which were all based on zooarchaeological quantification methods, is one based on gauging the average size of fragments in absolute terms. This ignores identifiability, number of elements represented etc. that can lead to systematic bias or bias caused by variability in analysts ability or approach. There are several ways of achieving this and one of these is to examine volume. Volume of fragments can be assessed in a rough and ready fashion simply by seeing how many fragments will fit in a given size of box. Volume can be more accurately measured by displacement in a liquid. Whilst such a method eliminates many of the above discussed problems, it has some of its own. It fails to acknowledge that bones started off at different sizes. This problem can be partly side-stepped by separating small animal bones from large animal bones in advance. This is not too difficult to achieve, even on quite small fragments. Care must be taken in making inter-site comparisons with such a method, however, since there may be different species and element representation affecting starting size of bones.

A further problem related to volume, particularly when considering questions of within-bone nutrient use, is that when a bone was fresh it had contents. If volume were measured through liquid displacement the cancellous bone tissues of the articulations would fill with liquid and, hence, that volume would not be counted. When the bone was fresh the cancellous bone would be filled with fat and this full volume would be relevant. Under many circumstances of analysis this might not be a problem, but for some specific questions this could be a serious drawback. It could be avoided by using the more rough and ready box method.

6.1.7 Total Frags:Mass Ratio

As an alternative to volume, size of fragment could be assessed in terms of average mass. This is very much easier to calculate than volume, needing only some weighing scales. A specific bias that will be encountered in using mass as the index is that diaphysis bone is more dense and heavy than cancellous epiphysial bone. There would, therefore, be a systematic error in the index.

6.1.8 Actual Surviving Mass: Theoretical Mass Ratio

The actual mass of surviving fragments of given elements could be compared to mass that should be present if all the suggested bones were present and had survived. This index is derived by working out the MNE for a given bone of the skeleton and then weighing the requisite number of whole bones from a reference collection. This measurement represents the total amount of bone that should be present if recovery and survival had been total. This can then be compared, in ratio form, with the actual weight of the bone fragments that survive and were counted in arrival at the MNE figure (James Rackham *pers. com.*).

This is a very sophisticated method which gives a clear idea of how much bone has been lost for each of the elements. This could be related to recovery, fragmentation or differential deposition. There are two possible problems with the method. The first is that, as with many of the other methods, it can only deal with identifiable material. The second is that reference specimens are unlikely to be the same size as the animals on the site. If the same reference animal is used for all of the elements, this is however irrelevant. The size ratio of one element to another will remain fairly constant, so the absolute size and mass of the comparative is of no consequence. It still represents a point of fixed comparison.

6.1.9 Mean Fragment Size

Yet another similar method is calculating the average size of fragments by linear measurement. This could be achieved by taking the maximum dimension of each fragment. This may seem less accurate than volume or mass measurements, and clearly fragments can be long and thin (a large maximum dimension representing little bone) or as wide as they are long (the same maximum dimension representing a larger amount of bone). This is probably not as serious a problem as it sounds, however, because, in a large assemblage of variable fragment shapes, the error will largely average out, unlike the systematic errors caused by bias in the above two methods. As such, measurement is probably, in many respects, the better option. It is, however, very time consuming.

6.1.10 Percent Difference in Articular Ends

Todd and Rapson (1994 p309) note the potential importance of comparing the level of fragmentation between the proximal and distal articulations. They draw attention to the fact that proximal and distal epiphyses have very different abilities to survive mechanical attack in many skeletal elements. This is particularly true of the tibia and humerus (ibid. p311) where the proximal end is far less dense and far more vulnerable to attrition. Todd and Rapson (ibid. p312) postulate that sites open to natural causes of attrition, particularly carnivore attack, will reflect this natural difference in bone resistance. In other words, on a carnivore attacked bone assemblage the proximal articulations will have suffered far greater fragmentation (on tibia and humerus at least) than the distal end due to the animals' greater ability to get their teeth into the proximal end. On natural or human sites where carnivores had no access the effect will be less (ibid.). Todd and Rapson (ibid.), therefore, propose to index the difference in survivorship of proximal and distal ends as a proxy for understanding levels of fragmentation caused by density mediated attrition. The index is derived from calculating "Percent Complete" (see 6.1.4) for proximal and distal ends and then taking the difference between the two. Although the Percent Complete index is criticised above because often very few bones survive whole, applying this method to articulations is more valid because whole articulations do often survive. Furthermore fragments of articulation are more easily identified than shaft so the problem of having large numbers of indeterminate fragments is much reduced. Obviously, the human processing of articulations for grease will make it difficult to assess post-depositional, density-mediated attrition. Human processing could, itself, lead to interesting patterns in this index.

6.1.11 Shaft Length Ratio

This method (Todd and Rapson 1988, p314) is one designed to produce a standardised index of the length of shaft left attached to an articular end. Clearly a simple measurement of this length will not produce a useful index since bones vary in absolute size so much. Instead the ratio of the attached shaft length to the articulation width is taken (ibid.). This produces a set of relative and comparable data. Todd and Rapson are particularly interested in potential differences between carnivore and marrow extraction damage in the application of this method. This is an interesting proposal, but it should be acknowledged that marrow cracking methods would, themselves, create different lengths of attached shaft. Binford (1978) notes that, in some circumstances, the Nunamiut would break the bone mid-shaft, but at other times they would break it near to the articulation. The above proposed index may, therefore, be of little use in distinguishing marrow exploitation from carnivore damage but it would still be potentially informative with regard to marrow exploitation strategies.

6.1.12 Shaft Fragments

Todd and Rapson (ibid. p319) also note the need to compare the number of shaft fragments to the number of articulation fragments. This is certainly of great importance in studying the processing of bones for within-bone nutrients (discussed further below). The way they go about this is to directly compare numbers of shaft fragments to articular ones for different elements. There are two points with regard to this. Firstly, is a simple count of fragments the best way? Fragments vary greatly in size representing different absolute quantities of bone and, therefore, different quantities of bone grease. Secondly, since the method was being considered for different elements (ibid.) one must assume that only identifiable shaft specimens were considered. The failings of such an approach are discussed above. With adjustments to approach and methodology the study of the difference between shaft and articulation fragmentation could be of extreme importance. Shafts only need to be accessed to extract marrow, whereas articular ends must be fragmented to extract grease.

6.1.13 Frequencies of Distinct Portions

The last of Todd and Rapson's (ibid. p321) methods to be discussed here is one designed to look specifically at the proportions of different parts of a bone that survive. This is achieved by identifying certain portions of different elements that are positively identifiable (in this respect it is similar to Morlan's (1994) Percentage Completeness method). These identifiable zones were such as foramen, crests, muscle attachments, tuberosities and articulations. These portions are counted and then a graph of relative bone portion survival can be constructed. This is clearly a very good way of looking at which parts of bones are suffering the most attack. This method side-steps the problem of what to do with unidentifiable fragments in the same way as Morlan's method does.

6.1.14 Fragment Measurement

Rather than creating a single index related to fragmentation, the nature of the fragmentation can be described. One way of doing this is to plot a histogram of fragment size class (Lyman 1994, p334). This method provides a visual summary of degree of fragmentation in an objective fashion. This method could be applied to identified specimens if species/element comparison was necessary, but could equally be applied to the unidentified material as well, if the whole assemblage's fragmentation needs to be characterised. The major difficulty with this method is the length of time required to measure each fragment.

One way of reducing the amount of time required for such a study would be to use sieves. There are two problems with this, however. One is that sieves would probably damage the bones by abrading them. The second is that bones would not behave well in sieves in the way that stones do. Bone splinters are often much longer than they are wide. A large splinter might slip through the sieve end-on whilst a similar fragment might stick sideways.

A more practical method of speeding up the measuring process would be to decide upon the proposed size classes in advance. One could then, rather than carry out actual measurements, put each bone into its size class by sliding it over drawn size templates representing the size classes (perhaps drawn circles). This would be considerably quicker than measuring each fragment.

6.2 Models of Fragmentation in Archaeological Faunal Assemblages

Having discussed means of recording fragmentation in archaeological bone assemblages it is worth considering the fragmentation patterns one might hope to detect with such methods. Producing models for fragmentation is a far from simple task. Any practical model must consider a very large number of variables including which elements were transported to the site in question (i.e. the initial bias in the assemblage before any processing or post-depositional attrition), which ones were chosen, if any, for within-bone nutrient extraction, which ones were chosen for other forms of processing by humans (e.g. for craft activities) and which elements are most susceptible to post-depositional attrition. Post-depositional attrition can, itself, take many forms, and have a different effect. There will be fracture caused by trampling (either by human inhabitants or livestock) either close to the time of disposal or much later, carnivore damage and, of course, excavation damage! In some places there will be the effect of freeze-thaw action and in others there may be alluvial or colluvial movements which exert stresses. Plant roots can cause damage on bones and much fracture can be caused by agricultural activities.

6.2.1 Modelling for Within-Bone Nutrient Exploitation Patterns

Putting aside taphonomic problems, it is first important to suggest some fracture and fragmentation models for different regimes of bone marrow and grease exploitation. Let us initially consider the exploitation of bone marrow only. If the people of a site were exploiting bones for marrow alone, the only fracturing they would need to perform would be to access medullary cavities in those bones which have marrow. These bones are the appendicular skeleton and the mandible. This process should not result in any damage to axial skeleton. So, on a site with perfect preservation (and no other processes occurring) one would expect to find undamaged vertebrae, ribs and appendicular epiphyses. One would also expect to find many fragments from the broken diaphyses. These shaft fragments should show the signs of having been fractured fresh (or after a pre-fracture treatment, leaving many features of fresh fracture intact). The mandible may well also be fractured.

If bone grease were also being manufactured this pattern would be radically altered. Binford (1978) and others have stressed that different grease is obtained from appendicular elements in comparison to axial ones. Assuming that there was production of types of grease, we should expect to see the comminution of both the axial skeleton and appendicular epiphyses. If processing were total this would leave many tiny fragments of cancellous bone, most of which would have been rendered unidentifiable and unrecoverable on sites not employing sieving. The bulk of the larger fragments would be shaft splinters resulting from the original marrow extraction (bearing the characteristics of fresh fracture). These shaft fragments would be larger since they would not have been deliberately comminuted in the rendering process. In extreme cases the shaft fragments are rendered for fat (see Binford 1978, chapt. 2) and in such a case there would be little of the assemblage surviving to an identifiable size.

Clearly, if only one type of grease was being produced, then only the elements which produce that type of grease (appendicular or axial) would have suffered fragmentation.

6.2.2 Identifying Levels of Exploitation and Resource Stress

The above models apply if all of a particular resource were being exploited. In reality, the peoples at different sites will have had different total fat need and levels of resource stress. If a people did not require all of the bone fat available to them, how would this manifest itself in terms of fragmentation pattern? There are at least three possible ways.

If a people could afford to be choosy over their diet they could choose to process just those marrow and grease bearing elements that produced fat to their taste. For instance they might choose not to produce grease from axial elements on the basis that they considered the grease from limb bones to be superior.

On the other hand, another relatively unresource-stressed people might wish to produce grease and marrow of the full range of types, since they might have different uses for them. Their lack of resource stress, with regard to fats, would then manifest itself in the survival of some elements. The general fragmentation pattern would be the same. There would be much comminuted cancellous bone and fresh-fractured shaft splinters, but some epiphyses and vertebrae would survive unbroken.

A third way of looking at this problem is in blunt economic terms. Another group of people may not be interested in fat taste or different applications, but in pure efficiency. If this were the case, the elements chosen for processing would be those that produce the maximum amount fat and grease per unit effort expended in processing. This strategy would manifest itself by the survival on bones (from comminution) in inverse proportion to that suggested by economic utility indices (see chapt. 2.2).

6.2.3 The Effect of Initial Transportation Choices Upon Fragmentation Patterns

The above models assume that the full range of elements is available on the site before processing begins for bone marrow and grease. However, some choices may have been made away from the site. For example, a hunter, knowing that his people do not process vertebrae for grease, may not bother to transport the spine of his quarry back to the camp. Such a case could cause potential confusion in interpreting fragmentation and survival patterns. Does the absence of identifiable vertebrae fragments suggest that there were no vertebrae on the site or that vertebrae were being processed and totally destroyed. On a well-recovered, sieved site, if vertebrae were present but were heavily processed, it is going to be likely that some diagnostic features (such as spines, etc.) are going to indicate the original presence of those elements. There would be more of an interpretational problem on sites where recovery was poor or preservation of small cancellous fragments was poor. In such cases it would be difficult to ascertain whether absence was due to grease rendering or genuine absence from the site.

6.2.4 The Effect of Post-Depositional Damage on Fragmentation Models

The greater the level of post-depositional attrition on an assemblage and the more bone marrow and grease processing may become obscured. It is essential, when analysing an assemblage for levels of bone marrow and grease exploitation to assess the level and nature of post-depositional damage. If an assemblage has been subjected to carnivore damage this should be apparent for the existence of gnawing marks and the effects of digestion on small bone fragments. One would expect the attrition to be differential according to different elements abilities so survive carnivore attack. Brain (1981) produced a rank list of goat bones' survival in the face of dog gnawing, from experimental results.

Other damage will be caused by the trampling of humans and animals. In terms of which elements suffer most as a result of such attrition, it is often asserted that low density bones are most vulnerable. Several studies of bone density have been undertaken (see Lyman 1994) to provide a model which might allow the identification of density-mediated attrition. Trampling will also affect fracture type.

If trampling occurs soon after deposition then all fresh features will not have been lost but fracture patterns in a trampled assemblage will tend to show more and more features of "dry" fracture. If trampling occurs long after deposition "mineralised" fracture type will become more common.

6.2.5 The Effect of Context of Deposition Upon Fragmentation Models

The level to which bones will suffer post-depositional damage will be very much dependent on their place of disposal. It is clear that bones deposited in to a pit, which is then sealed, will be less open to damage from trampling and carnivores than material spread about the general area of occupation. Since bone marrow and grease processing patterns will be more identifiable if there is little other damage to the bones, then choice of contexts to be studied could be important. Clearer results are likely to come from the study of a protected context such as a waste pit than from a heavily trampled floor area. One should, however, be wary of only looking at one sort of context since different peoples may dispose of different waste in different places. Some people may always midden there fat processing waste whilst burying other bones. It is therefore worth sampling a full range of context types.

Middens and other deposits will protect their contents from attrition to differing extents depending on the nature of their formation. Quickly formed deposits are likely to be better preserved since there will be less time that the top bones are open to trampling and carnivore attack. Bones may be deposited straight onto a midden, but it is also possible that they may suffer damage on an occupation floor for a period of time before being cleared away onto a midden.

6.2.6 The Effect of Excavation Practices on Fragmentation

Excavation and post-excavation practices can also have a serious effect on fragmentation patterns. Excavation is a destructive process. One generally hopes that it is a process which will not cause too much damage to artifacts, but excavation conditions and competence do vary. On such as rescue sites that have been dug hurriedly with heavy tools, new bone fractures may result in quite large numbers. In some cases, fortunately less so now than in the past, bone has not been treated as being as important as other “finds”. Poor storage of bones can also lead to new fracture. All too often too many bones are packed into bags which are then tightly packed into boxes. Bones get crushed and further damaged when they are poured in and out of boxes and bags. It is therefore important to assess the level of modern damage to bone assemblages. This can be achieved by looking for clean (there will be no soil matrix on the fracture surface), new breaks.

Apart from causing damage, some excavation techniques can also cause bias in the recovery process. In some older excavations there was deliberate selection of which bones to retain, either during excavation or the immediate post-excavation sorting. Only bones considered to be “diagnostic” may have been kept. This would eliminate much material which is diagnostic from the point of view of interpreting bone marrow and grease exploitation. If bones are purely recovered by hand, much of importance will be missed. Sieving is of particular value when one wishes to study an issue like fragmentation.

Obviously, the best sites to study for fracture and fragmentation are ones which have been dug and recorded to high modern standards including extensive sieving. This does not preclude the study of other sites, but one must be aware of what might be missing from the assemblage as a result.

6.2.7 Other Features Associated with Bone Grease Production

Above is a discussion of considerations to be taken into account in modelling fragmentation and fracture patterns in faunal assemblages, but models should include other evidence that may indicate bone grease production. In order to make bone grease one must boil bone fragments. This implies three things: a source of water, a source of heat and a container to boil the bones in. On a site where bone grease is being produced there should be evidence of a hearth of some description. After the arrival of metal containers the process could be carried out easily simply by boiling the water in a cauldron over a fire. All that would remain of the process would be bone fragments, a hearth and fire output.

In ages before metal cauldrons there are limited technological options for carrying out boiling processes. The water must have been contained in a ceramic, wooden or leather container or perhaps a pit. These, however, cannot be heated directly over a fire. Probably the only viable way to heat the water is by the use of "pot boiling" stones (stones which have been heated in a fire and placed into the water to boil it; stones have a very high thermal capacity). On such a site one would expect to find evidence of fire, bone fragments and fire cracked rocks (see Binford 1978, chapt. 2).

Sites must also have a supply of reasonable quantities water. This is required not only for the boiling but for the cooling of the surface to solidify and extract the fat (see chapt. 1).

CHAPTER SEVEN

CHOOSING THE METHODOLOGICAL APPROACH TO BE USED IN THE CASE STUDIES

This chapter does not outline in detail the methodology to be used in the following chapters. It, instead, provides the rationale behind the choice of the general methodological approach used in the case studies, below. The details of methodology are given towards the beginning of the first case study, chapter eight. All the following case studies have discussion of the exact methodology employed for that study. In most cases there are only minor alterations to the methodology layed out here and in chapter eight.

7.1 Fragmentation

Chapter six summarised many methodologies for examining fragmentation levels in archaeological bone assemblages. Many of the single indices of fragmentation could be derived without extra analysis. Those single indices, however, are unlikely to provide the level of information required to identify patterns resulting from various within-bone nutrient extracting processes (see chapt. 6.2). What is needed is a more descriptive analysis of which types of bone have been fragmented, and to what extent. Of the methodologies presented above, the most likely to be useful is the categorisation of fragments by size class. Probably the most efficient way of carrying this out, as previously mentioned, is to have a series of templates, representing the size classes, against which the fragments can be quickly compared. The fragments will be classified by maximum length. This admittedly introduces a bias towards long slender bone splinters, in terms of actual bone present. However, any method which took into account actual quantity of bone present would require a complex and time consuming set of measurements or volume calculations for each fragment. This, plainly, would not be practical. Classification by maximum length is the best method which can be applied quickly.

The actual size classes used may be dependent upon the nature of the assemblage and level of detail required for the study. In any case, the size classes are going to be arbitrary. It is important that the classes cover the full range of variability in the assemblage in reasonable detail, without being so detailed as to make the analysis impossibly arduous. In most of the case studies, below, size classes are every ten millimetres for the smaller classes and every twenty millimetres for the larger classes.

There is, however, one major problem with this size class methodology. It does not take special account of bones which have not been broken at all! In interpretational terms, would it be right for a large fragment from a large broken epiphysis to be grouped in the same class as an entirely undamaged, smaller epiphysis? Almost certainly not, because the unbroken element is not a *fragment* and irrelevant of its size it should be noted that it survives undamaged. The large fragment of an epiphysis may come from an element which has seen some degree of processing, whereas the undamaged epiphysis has not been processed at all. There must be a distinction. As such, in addition to the size classes, there should be two further categories: one for complete bones and one for complete epiphyses. Complete bones have seen no processing at all, whilst complete epiphyses may have seen marrow exploitation from their attached diaphyses but have not been processed for grease.

Having effected the separation of fragments into size classes, it is necessary to consider how the contents of the classes should be quantified. Counting is the most obvious method but it is clearly very biased towards the smaller size categories. A large fragment can be broken up into a very large number of small fragments. A small number of very large fragments could actually represent quite a lot of bone fat resource by comparison to a large number of small fragments. However, if the size classes are quantified by number and plotted on a histogram, there may be a tendency that the significance of the larger fragments will be underplayed. Taking the mass of the size class will give a more accurate picture of the actual amount of bone present. This will, however, mean that it will be difficult to see the detail in the small size classes, since small fragments weigh so little. There is also a bias against light cancellous bone in comparison to dense diaphysis bone. Quantification by number will not suffer this bias. Perhaps the best compromise is to both count and weigh the size classes and have the benefits of both systems. Both methods have severe bias, but, since their biases are almost opposites, the use of both methods is likely to guard against misinterpretation.

As well as knowing fragment sizes it is important to know which types of bone have been fragmented (see chapt. 6.2). There must be a separation of bone type with each size class, therefore. This separation might be carried to various levels of detail, depending on the site in question and the aims of the study. There should at minimum be a separation between axial bone, appendicular diaphysis bone and appendicular epiphysis bone. Because of the aforementioned bias against cancellous bone that would result from weighing, it would probably be best to ascertain the proportion of each bone type in a size class by number. Furthermore, the weighing of all types in all classes would significantly slow down the analysis, making it a less practical research tool.

It will not be possible to identify bones to type in the very smallest size classes. The exact point where the separation would become possible would be dependent on the preservation state on the sites and the species being dealt with. It would also depend on level of detail required in the analysis and the amount of time available to the analyst. In the following case studies, different levels of detail were attempted. With the exception of the final case study, the level of detail attempted generally increased with each case study. This was because later case studies were more complex sites with more complex questions and it was considered worthwhile extracting a greater amount of detail from the analysis. Furthermore, the author gained in competence, with experience, and developed more confidence in making separations in smaller size classes. There is no simple rule by which one can work and many factors will affect the point at which one decides that fragments are too numerous or too small to effect a successful separation of bone types. This cut-off point is noted in the methodology for each case study.

7.2 Fracture Type:

The study of fracture type in assemblages could very easily follow the same methodology as that used in the evaluation fracture experiments (chapt. 5). Fragments of shaft could be studied for the three criteria of fracture outline, edge texture and edge angle to the cortical surface. Scoring should follow the system used for the calculation of Index_1 (see chapt. 5) (where there is a slight allowance, 10%, for right angle fracture for a "fresh" classification). The result would be an index for each specimen ranging from zero (most fresh) to six (no fresh features).

The major difference between the application of this index to experimental specimens and archaeological ones is that archaeological specimens have different breaks made at different times. On an experimental specimen, for instance, a score of three indicates that the specimen was broken when it maintained many fresh features but was no longer quite fresh at the time of fracture. On an archaeological specimen, a score of three could have resulted in the same way but it could equally have resulted from an initially fresh-fractured bone being broken again whilst dry (resulting in the same mixture of fresh and unfresh indicators). Despite this problem of equifinality, the index would still provide a good indicator of how much fracture was due to fresh and unfresh breakage.

One possible insight into the level of fracture caused by post-depositional attrition (attrition after the bone had been discarded by humans) would be to count obvious mineralised fractures. The fracture pattern of a bone when it has lost all its organic content is often very obvious. Its identification need not rely on an index based on a number of proxy indicators, but can be achieved through the experience of what they look like. As such the number of fragments bearing obvious mineralised fractures should also be recorded as an important taphonomic indicator. Equally the number of clear dynamic fracture scars (see chapt. 4) could be recorded as an indication of the level of deliberate fresh fracture.

Modern damage to fragments is also obvious. If bone have been broken during excavation, finds processing or storage, the fracture surface will be unweathered and unsoiled. The level of modern damage can and should, therefore, be recorded.

Fracture types will only be recordable on fragments of sufficient size to display a reasonable length of fracture surface. This will not be the case with the smallest fragment classes but the exact size where fracture type becomes diagnosable will be dependent on the preservation at a particular site, particularly the degree to which edges have been abraded. Deciding on a size cut-off point for fracture type studies is as complex as deciding on the cut-off for bone types. In the end, all one can do is makes one's decision and define the cut-off point used. This is done for each of the case studies.

7.3 Other Features

7.3.1 Burning

There are several reasons why levels of burning should be recorded during an analysis of fracture and fragmentation. Firstly, the burning of bones could contribute to the levels of fragmentation. Secondly, one might expect to see a certain level of burning if bone grease was being extracted. The process involves fire and the fragmentation of bones near fire. One might reasonably expect that a number of fragments would end up getting burnt. The indication of the presence of fire is one of the criteria for identifying the practice of grease exploitation (see chapt. 6.2). Thirdly, calcined bones (burnt until they have gone white and lost all organic content) will have lost up to 30% of their original size (Lyman 1994).

Burnt bones can simply be counted at the same time as the fragments were being counted in their size classes.

7.3.2 Animal Gnawing

As with all taphonomic studies, it is essential to assess the extent of damage done to bones by carnivores and rodents gnawing them. An assessment of gnawing levels should, therefore, be made. Not all fragments will be large enough to make this possible. A good strategy would be to record incidents of gnawing on those bones studied for fracture type.

7.3.3 Cut Marks and Working

It would also be worth recording evidence of butchery or craft activities on specimens studied for fracture type. It is of value, in taphonomic terms, to be aware of the damage done to bones by butchery and craft working.

7.4 Recording Method

It is worth considering the actual way the data are recorded. Studies of this nature are clearly going to generate very large quantities of data. Such large amounts of data are certainly best processed by computer on a spreadsheet or in a database. One could, in fact, enter the data directly into a portable computer whilst carrying out the analysis and save a considerable amount of time (given that such a computer is available). There is, of course, the potential problem that the data might be lost and a paper backup is desirable. The author opted to record the data on paper in a way which would make it easy to enter it into a computer.

In the case of the fragmentation study, the record form looked something like table A1 (in appendix A), except that it was hand written and there was also a column in each size class for mass. The recording of fracture freshness, post-depositional damage, animal gnawing, fracture scars and other modifications was done on a separate sheet. Squared paper was used and a column allocated to each criterion. The fracture freshness index score was entered into the first column and other features were usually noted as present or absent by the use of a 0 or a 1. The precise layout of record sheets obviously changed from site to site, since different levels of detail were recorded.

Now that methodology, and the rationale behind it, has been discussed, we are ready to move on to the case studies.

CHAPTER EIGHT

CASE STUDY ONE:
THE ASSEMBLAGE FROM THE PREHISTORIC ALPINE SITE OF MONDEVAL DE SORA, NORTHERN ITALY

8.1 Introduction

The prehistoric, rock-shelter site of Mondeval de Sora is situated high in the Italian Dolomites, on a terrace above the tree line at 2100m above sea level. Its earliest occupation dates to the Sauveterrian Mesolithic in the 7th millenium BP (Alciati *et al* 1992). The occupation continues through the Castelnovian Mesolithic period (6th millenium BP), which is followed by a hiatus in the use of the site before it is re-occupied in the Copper Age. There is also some Mediaeval use (ibid.).

The largest deposits of bone come from the Sauveterrian levels of the site, in the form of an occupation level above an apparent stone pavement (ibid.). The main feature of the Castelnovian occupation is an inhumation pit. The fill of the pit contained a certain amount of animal bone, as did a Castelnovian hearth pit. To the Copper Age levels are attributed a cooking pit and two hearth areas (ibid.), one of which is associated with occupation debris which may be in part derived from both the Copper Age and Castelnovian occupations (Fontana pers. com.).

The animal bone assemblage, which has yet to undergo full analysis, appears to consist largely of red deer and ibex (P. Rowley-Conwy, pers. com.). The principal feature of this assemblage is its extreme degree of fragmentation. Recovery on the site was excellent with all deposits having been wet sieved. Figures 8.1 and 8.2 show the average contents of two bags of bone, one Sauveterrian and one Copper Age. The immediate appearance of the assemblage is one of extremely broken up shaft fragments with few articulations surviving. One must ask what taphonomic mechanism led to this pattern of fragmentation. Was it post-depositional attrition or the result of human action? In order to answer this question the nature of the fragmentation and bone fracture patterns must be rigourously assessed.

If the bone assemblage has been deliberately fragmented to a pulp, then the most likely explanation would be the large-scale extraction of bone marrow and bone grease. Given that this site, situated as it is above the tree line in the mountains, can be considered to be in an area of marginal resource, it would not be unreasonable to expect such an industry. Bone fat could provide an essential dietary subsidy to a hunting party otherwise reliant upon lean meat.

The major problem in assessing the nature of fracture in this assemblage is that it is so fragmented that it is difficult to find enough bones with sufficient length of fracture profile to study. Complete shaft circumferences, which are most informative, are all but absent. However, fragments large enough to warrant study do exist in sufficient numbers to give some indication of the proportions of different fracture types in the deposits. Figure 8.3 shows some of the larger size components from the Sauveterrian levels. Some of these fragments appear to be splinters resulting from fresh fracture (fig. 8.4). Only the rigourous analysis of a large sample will determine whether this fresh fracture pattern predominates.

8.2 The Material Studied

8.2.1 Sampling

All the contexts containing large amounts of bone were studied, as were a few other selected contexts. Where a context was very large, a representative sub-sample was taken (see methodology of fracture study, below). Small contexts were studied in their entirety. When sub-sampling was undertaken, a stratified-random selection of bags was taken for study. Bags were selected randomly, but it was ensured that the selection comprised bags of different sizes and at least some bags from each box. This strategy was adopted in an attempt to overcome any sorting which may have been employed advertently or inadvertently by the excavators during packaging.

8.2.2 Sauveterrian Layers

By far the largest group of bones came from the occupation layer (Context 8) immediately overlying the Sauveterrian pavement area. Layer 8 was split into three arbitrary stratigraphic units (8I, 8II, 8III) by the excavators (F. Fontana pers. com). Arbitrary though these divisions were, layer 8 is sizeable enough to allow the divisions to remain in this study, hence, allowing for an internal comparison of variability within this large occupation layer. It was possible to study both 8I and 8II. 8III is too small. Just beyond the edge of the pavement is a further Sauveterrian deposit, context 31. Unlike the elements of layer 8, which were sampled, context 31 was sufficiently small to study it in entirety.

8.2.3 Castelnovian Layers

The most substantial group of bones from a Castelnovian feature comes from the fill of a burial pit (context 4). This layer was sub-sampled. It should, of course, be noted that such a pit, dug down into earlier layers, could well contain a substantial amount of re-worked Sauveterrian material. The other Castelnovian feature (context 20) to produce a fill worthy of study is a hearth or cooking pit. This sample was studied in its entirety.

8.2.4 Copper Age Layers

Two hearth areas interpreted as being Copper Age had bone samples worthy of study. Context 21 is a discrete hearth feature which did not need to be sub-sampled. Context 3 had a larger collection of bones, which were sub-sampled. This hearth context blends into a probable occupation level (context 7) (Alciati *et al* 1992). Context 7 has also been subsampled for study, although the excavators are not sure whether all of it belongs to the Copper Age or whether some of it is of Castelnovian date (Fontana pers. com.).

8.3 Methodology

8.3.1 Fragmentation Study

The fragmentation study follows the general methodology described in chapter 7. Ten size classes were used: <20mm, 20-30mm, 30-40mm, 40-50mm, 50-60mm, 60-80mm, 80-100mm, >100mm, bone part, whole bone. "Bone part" respresents undamaged articular ends and undamaged centra of vertebrae. "Whole bone" refers to entirely unbroken appendicular and axial elements. The reason for counting these classes separately is discussed above (chapt. 7). The "part" and "whole" classes were only applied to sizeable unbroken elements (i.e. representing a substantial resource of grease that had been ignored). Those classes were not applied to small whole bones like phalanges or small carpals in the 20-30mm class, for instance, since such bones do not represent a large piece of unprocessed cancellous bone in the same way as an entire distal femur would. Such small whole bones were just assigned to their size class.

Fragments were assigned to size class by their maximum dimension. The fragments were classified by running them over drawn rings denoting the various class dimensions. Once in classes, the fragments were quantified by both number and mass. Mass was recorded to the nearest 0.1g. Fragments were counted manually with the aid of a mechanical clocking device. For the very large samples, the number of the smallest size class, which could reach more than 25,000, was calculated by mass/number ratio. Individual counting of fragments in this size class would impracticably lengthen the time spent on the analysis for no real conceivable gain. In order to calculate the ratio, a sub-sample of that size class (a minimum of 1,500 fragments) was counted and weighed. An approximation of the total number could then be derived by extrapolation. Where this method was employed, the mass/number ratio was recalculated for the different samples. For the smaller samples, all of the smallest size class was counted. All other size classes were counted fully.

Within the size classes, the proportion of different types of bone was also noted. An attempt was made to discern between shaft fragments, cancellous, articular fragments and axial/cranial fragments. The classification of fragments into type was possible to different levels in the different size classes. It could not be reliably carried out for the smallest size class, and doing so would take an incalculable amount of time. For the classes 20-30mm to 40-50mm it was possible to reliably classify the fragments as being shaft fragments or cancellous fragments (whether from appendicular epiphyses or axial bones). A full division into the three classes was possible, in a reliable way, only in the 50-60mm class and above.

8.3.2 Fracture Type

The study of fracture type in the archaeological material from Mondeval follows the general methodology laid down in chapter 7. The score for each of the three criteria was recorded separately for each fragment. From these the general fracture-freshness index from 0 to 6 could be calculated. Both the average score for the sample and distribution of individual score values can, therefore, be examined.

Fracture type was only recorded on shaft fragments which were large enough to exhibit sufficient length of fracture surface. Ideally, one would wish to study fractures which extend all the way round the diaphysis. Much can be said about the cause of fracture and state of the bone at time of fracture when the whole circumference is present. The problem with the Mondeval assemblage is that hardly any such specimens survive, so fragmented are the bones. It was decided that bones in the 40-50mm size class and above exhibited sufficient fracture surface to be worthy of study.

For smaller contexts all shaft fragments in those size categories were studied. In the large contexts, bags of bone were sampled until a sufficient number of such fragments had been analysed to be representative. This means that the overall size of the sample taken from a given context was dictated by the need to record a sufficient number >40mm fragments. The sample was considered sufficient when the addition of further groups of fragments began to have a negligible effect upon the fracture index average. The cut-off point was typically after 250-300 fragments of sufficient size to warrant fracture type study had been encountered. This usually meant that tens of thousands of fragments in total had been analysed from each sample before the above number of diagnostic fragments had been reached. The extremely fragmented nature of the site was the original reason for inquiring about the nature of fracture type, but it is also an extreme hinderance in finding a sufficiently large sample of suitable fragments to analyse!

As suggested in chapter 7, the presence or absence of mineralised breaks was noted on those fragments examined for fracture type. Obvious modern breaks were also noted, although slight chips (trowel marks or abrasions from storage etc.) were ignored. Modern breaks, though themselves counted, were not considered in the creation of the fracture freshness index. Therefore, if an otherwise entirely fresh-fractured fragment had a modern break it still scored zero on the index, but the modern break was noted.

8.3.3 Other Features

Burnt fragments were counted during the study of fragmentation levels. This index of burning is expressed as a percentage of the total number of fragments in a size class that are burnt. All burnt fragments were counted, even those in the vast <20mm size class. In that class, however, the count was carried out at great speed by scanning fragments and tallying with a mechanical counter, but with enough accuracy for the purposes of this study.

Dogs, and other bone gnawing animals, are another taphonomic factor which must be taken into account. The incidence of apparent dog gnawing on fragments studied for fracture type was, therefore, recorded. This was recorded in two ways. Bone fragments possibly bearing traces of dog gnawing were recorded in one category, whilst, those obviously suffering much gnawing were recorded in another. It should be noted that on these small shaft fragments, which often had other surface damage from other, natural, forms of attrition, the identification of gnawing was not always easy. This provided the need for the two categories of identification (possible traces/obvious marks). A clear set of carnivore tooth marks can be seen on a radius from Context 8 (fig. 8.5).

Occurrences of dynamic impact scars were recorded on fragments studied for fracture type. The presence of an impact point was only recorded if it was a clear, unambiguous example.

Fragments studied for fracture type were also examined quickly for evidence of butchery marks or craft working, and any such occurrences were noted. It is unlikely that all cut marks were identified since fine ones often require magnification for sure identification. However, the vast majority of major cuts or modifications are likely to have been spotted. A clear cut mark can be seen on a radius shaft from Context 8 (fig. 8.6).

8.4 Results

Raw data relating to Mondeval is given in Appendix A.

8.4.1 Fragmentation

The contexts assigned to the Sauveterrian layers (8I, 8II, 31) display very much the same fragmentation patterns. Taken by both mass and number, there is a dramatic decline in the quantity of fragments as size class increases (see figs. 8.7a-c, 8.8a-c). The smallest size class is clearly dominant in both terms of number and mass. Of the circa 29,636 (4179g) assessed in the sample from 8I only 337 (1474.6g) were larger than 40mm; that is only 1.14% by number and 35.29% by mass. Hardly any bones survive whole, or with whole articulations. In the 8I sample there were only 7 specimens in the "part" or "whole" classes (0.02% by number, 3.28% by mass). The 8II and 31 samples can be seen to present very similar statistics (see tables 8.1 and 8.2).

The <20mm size class, in these contexts, itself, contained many very small fragments. This factor is best gauged by the number/weight ratio that was calculated to extrapolate the total number of fragments (see table 8.3). The number of fragments in each gram for context 8I averaged at 18.37, and for 8II and 31 it was 14.58 and 19.30 respectively.

The Castelnovian grave fill deposits (context 4) continue with extremely high fragmentation levels (see figs 8.7d and 8.8d, tables 8.1 and 8.2). Of its 10,358 fragments (2793g) only 147 (564.4g) were larger than 40mm. This is a similar proportion by number as the Sauveterrian deposits but less by mass (only 20.21%). This suggests that there are significantly fewer fragments in the larger of the upper size classes. This is borne out by the complete absence of specimens in the part/whole classes. There were, however, fewer tiny fragments in the <20mm class with only 6.69 fragments per gram (see table 3).

The other Castelnovian context (context 20), a hearth, not unexpectedly had even more severe levels of fragmentation. Very few fragments survived that were over 20mm (see figs. 8.7e and 8.8e). Of 3,371 (243.9g) fragments only 3 (17.6g) were above 40mm and none were parts/whole (see tables 8.1 and 8.2). The

<20mm class itself was highly fragmented with 16.10 fragments per gram (see table 8.3).

The Copper Age hearths are very similar to context 20. Context 21 is almost identical (see figs. 8.7f and 8.8f) with only 4 (5.7g) of the 4,667 (465.4g) being above 40mm (see tables 8.1 and 8.2) and 12.24 fragments per gram in the <20mm class (Table 3). The Copper Age hearth, context 3, however, is less severely fragmented than the other hearths but is still more fragmented than non-hearth contexts (see figs. 8.7g and 8.8g, tables 8.1 and 8.2) and the number of fragments per gram in the <20mm class is less, at 7.13 (table 8.3).

Context 7, an occupation layer associated with hearth context 3 (but may contain some Castelnovian deposit), is very similar in the nature of its fragmentation to context 4 (see figs. 8.7h and 8.8h, tables 8.1, 8.2 and 8.3).

8.4.2 Proportions of Bone Types

Figures 8.9a-f show the proportions of different bone fragment types (shaft, axial cancellous, appendicular cancellous and miscellaneous cancellous) in different size classes (above 20mm) in contexts 8I, 8II, 31, 4, 3 and 7 respectively. Contexts 20 and 21 have not been included because of the general absence of most of the larger size classes in those contexts. It can be seen in all of the graphs there is a general trend. Firstly, there is a predominance of shaft fragments and this predominance tends to increase from the 20-30mm class up to about the 60-80mm class. On some graphs this increase in predominance continues into still higher size classes (eg. context 4, fig. 8.9d), but in others it declines somewhat in very large size classes (eg. context 8I, fig. 8.9a). The part or whole categories, however, consist purely of axial or-articular bone, but it should be noted that this is as a result of the definition of these categories. Furthermore, the sample size for these categories is extremely small and, as such, little useful information can be gained from their study.

The problem of sample size also applies to the very large size classes (i.e. >100mm and 80-100mm) where often there are but a handful of fragments in the sample. If those size categories are disregarded and only the good sized sample used, one can see a clear pattern of increasing predominance of shaft fragments with fragment size. Figure 8.10 shows proportions of bone types for all contexts (including 20 and 21) and size classes (above 20mm). This underlines the dominance of shaft fragments and, taking into account that the fragments identified as axial or articular cancellous (rather than misc. cancellous) are the fragments above 50mm, this graph demonstrates how small the sample for the larger size classes are. The actual statistics for this graph are given in table 8.4.

8.4.3 Fracture Type

All but contexts 20 and 21, which had too few large enough fragments, have been studied for fracture type. Contexts 8I, 8II and 7 were able to produce samples of 250 specimens or more, whilst contexts 4 and 3 produced reasonable samples of 125 and 70 respectively and context 31 could only produce the small sample of 33 (see table 8.5). On the fracture freshness score scale of 0 - 6, the mean score value for all the samples was three or below (table 8.5) and in general around 2.5.

The highest average (3.00) came from context 31, with its small sample size, whilst the lowest score came from context 3 (2.31). This seems to indicate that most fragments have features of fresh fracture, and, furthermore, generally a greater number of fresh fracture features than non-fresh features.

Figures 8.11a-f show the fracture scores in more detail, showing the frequency of each score classification for each of the contexts. It can be seen that, in all contexts, the score classification of "3" dominates by far, indicating many fragments with a fairly even mixture of fresh and unfresh fracture features. It is also clear that the distribution of scores is not (with the exception of context 31) a normal one. Whilst there is usually a high representation of low scores, particularly "0" scores, scores of "5" and particularly "6" are often very poorly represented. Context 8II (fig. 8.11b), in particular, exemplifies this pattern. To summarise, there are many fragments demonstrating entirely fresh features, whilst there are very few demonstrating an entire lack of them.

Furthermore, the samples did not contain large numbers of fragments suffering from obvious mineralised fractures (see fig. 8.12). The highest levels of mineralised fracture were in context 7 where 26.8% of fragments displayed at least one mineralised break. The lowest level was in context 4 with only 12.8% showing mineralised fracture (table 8.6).

8.4.4 Modern Damage

Considering the damage that can occur to archaeological bones during excavation, sieving and packaging, the levels of modern breakage could be considered to be quite low. The highest proportion, by far, was in context 31 with 33% showing modern damage, but most contexts had much less damage (see fig. 8.13, table 8.6). Context 4 had only 9.6% damaged.

8.4.5 Evidence of Dynamic Impact

Evidence for dynamic impact, in the form of preserved impact points and scars, was present in all contexts studied for fracture type, with the exception of context 31 (probably due to its small sample size). Between 2% and 5.6% of specimens in the other contexts displayed marks of dynamic impact (see table 8.7).

8.4.6 Burning

All contexts showed some level of burning and in all cases burning was in general more frequent the smaller the size class (see fig. 8.14). The hearth contexts (3, 20 and 21), unsurprisingly, had far higher levels of burning; between 80 and 90% in the <20mm size class. Levels of burning remain high in these contexts up the 40-50mm class.

The samples from the Sauveterrian layers (contexts 8I, 8II and 31) all have much lower levels of burning. Around 20% of fragments are burnt in the <20mm class but very few indeed by the 30-40mm class. The non-hearth Castelnovian and

Copper Age levels (contexts 4 and 7), however, take a middle path. Burning levels in the smallest size class are about double those displayed by the Sauveterrian contexts. This higher burning level is maintained through the larger size classes, but at nowhere near the level of the hearth contexts.

8.4.7 Animal Gnawing

Levels of "probable traces" of animal gnawing ranged between 23.6% of assessed fragments, in context 8I, to 8.6% in context 3 (see fig. 8.15, table 8.7). Levels of certain, heavy gnawing were much lower, ranging between 3% (context 31) and 0.4% (context 7) (fig. 8.15, table 8.7). Almost all of this gnawing appeared to be the result of a carnivore but a certain amount of rodent gnawing was present.

8.4.8 Cut Marks

Cut marks were noted at a low level of frequency (highest 2.9% in context 3) in all contexts studied, apart from context 31 (see table 8.7).

8.5 The Creation of Indices of Post-Depositional Damage

In order to discern to what extent the fragmentation is due to deliberate pre-depositional human action, it is important to collectively assess the extent of all post-depositional attrition (i.e. taphonomic effects after the disposal of bones by humans). The post-depositional factors recorded in this study were animal gnawing, mineralised fractures and modern damage. A combined index of these factors is what is required.

One simple way of achieving this end is to average the percentages of the three factors together. The result of this exercise can be seen in figure 8.16. This approach allows for a quick comparison of relative amounts of post-depositional damage between contexts. One can see that context 31 appears most damaged, whilst context 3 seems least damaged. The problem with this method is that we do not know whether all the damage is occurring on a small number of fragments, or whether most fragments are affected by one or other of the forms of attrition.

Perhaps a more useful approach would be to examine how many forms of damage there are on each fragment. This index is created by recording the number of fragments which have suffered none of the post-depositional forms of damage, those which have suffered just one, those with two and those suffering from all three. Figures 8.17a-f are pie charts for each of the contexts showing these statistics. Figure 8.18 summarises this information.

It can be seen that a large proportion of fragments are unaffected by any of the three damage types. Between 35% (context 31) and 63% of fragments (context 3) fall into this category in the various contexts. The bulk of the rest of fragments appear to have suffered just one type of damage. A maximum of 12% (in context 31) suffered two and the highest proportion of those with all three damage types is 2% (context 7). It appears that these forms of post-deposition damage do not account for the majority of fragmentation.

8.6 Discussion and Interpretation

In ethnographic examples (see chapt. 1) it was shown that fat might be extracted from bones to different levels of totality depending upon needs. Chapter 6.2 models the various fracture patterns that might result from different levels of processing. If only marrow was being exploited, then only the shaft should have been broken. If grease was being exploited, some or all (depending on the total need for grease) of the cancellous bone would be comminuted for rendering. In extreme cases of bone grease exploitation, shaft bone is also processed (Binford 1978). This would result in nothing but very small pulverised fragments.

After due consideration of other possible taphonomic effects, the Mondeval pattern fits the model for marrow exploitation with the processing of axial and epiphysial cancellous bone for grease. The assemblage is extremely fragmented and hardly any whole bones or appendicular bone ends survive at all. The vast majority of larger bone fragments are shaft fragments. Precluding the unlikely scenario that axial and epiphysial bone was disposed of off-site, one must conclude that all cancellous bone has been broken up into the undifferentiatable <20mm class or has been so pulverized as to have escaped recovery. The shaft fragments have a fracture type score of 3 or under (mostly around 2.5) indicating many fresh features on the fractures, in line with expectations for marrow extraction.

Fragmentation and attrition unrelated to bone fat utilisation has certainly had an effect on the assemblage. There are significant amounts of mineralised bone fracture and modern damage and some carnivore gnawing. These other types of damage do not occur in sufficiently large frequencies or affect a large enough proportion of the assemblage to explain the very high level of fragmentation. They merely add to it. Despite the levels of mineralised breakage, the fracture type score remains below 3. This suggests that without the later post-deposition breakage the fracture score would have been even lower (even fresher).

The principal conclusion is that it can be asserted fairly firmly that the bulk of fragmentation occurred before or very soon after deposition. There are very few mechanisms that could create this pattern. The best explanation appears to lie with bone grease production and there is further circumstantial evidence in favour of this theory.

Burning could of course result in fragmentation. There are several severely fragmented hearth contexts on the site, but these display a very different pattern from the occupation/pit deposits. Their burning level is far higher and fragmentation is greater. The fragmentation in the other contexts is therefore unlikely to be caused by excessive burning.

There is, however, a certain level of burning within all contexts. Fires would, of course, have been used in the grease extraction process. They would be required to heat pot-boiling stones used to bring water to the boil in a wooden, leather or some other container (the use of metal cauldrons over a fire being precluded by the date of this site). A background level of burnt bone from the discharge of hearths would be unavoidable. If large quantities of bone were being fractured into small pieces with the proximity of a fire, it is inconceivable that some fragments would not have ended up in it.

The hearths demonstrate the presence of fire in the Castelnovian and Copper Age levels and quantities of charcoal and burnt bone demonstrate it in the Sauveterrian layers (Fontana pers. com.). Furthermore, the Sauveterrian occupation layers contain many heat cracked rocks (Fontana pers. com.) which may represent the necessary pot-boilers. It should be noted that the Sauveterrian pavement would be particularly useful to an activity like mass bone fragmentation, since it would form a firm platform for striking bones on.

It would, in fact, be very reasonable to find such an industry at a site like this one. A mountain camp-site above tree line can certainly be considered to be in an area of marginal food resource, where the procurement of fat would probably have made the vital difference in maintaining subsistence (see nutritional importance of fat, chapt. 2.4).

On a temporal scale, it seems that the same pattern in the bone assemblage is seen in all periods. However, the best evidence comes from the large occupational and midden deposits of the Sauveterrian. Such deposits are not present, on the same scale, in the later periods but all the samples studied lead to the same conclusion. The Castelnovian burial pit could represent re-working of earlier material and, hence, is not very good evidence for the continuation of the grease extraction practice into that period. The occupation layer, context 7, in part may represent both the Castelnovian and the Copper Age. It represents better evidence for the continuation of grease production.

8.7 Conclusion

The bone assemblage from Mondeval de Sora has a very distinctive pattern to its fragmentation. It appears that bone marrow and grease, both axial and epiphysial, was being extracted in large quantities during the Sauveterrian period. The same pattern is found in the later deposits from the Castelnovian and Copper Age, but limited suitable samples make it difficult to demonstrate the continuation of bone grease production into these periods with certainty. The extraction of fat from bones may well have been of great subsistence importance to those living at this mountain camp-site in an area of marginal resource.

Mondeval provides a clear pattern that fits the grease production model. It is difficult to appreciate just how extreme the pattern at Mondeval is, however, without something to compare it to. The next chapter provides an illustration of a site where grease processing probably did not take place. This acts as a form of experimental control.

Context	Total No. of Fragments	No. Frags. >40mm	% >40mm	No. Frags. >Part	% >Part
8I	29,636	337	1.14	7	0.02
8II	21,269	431	2.03	9	0.04
31	3,362	39	1.16	0	0
4	10,358	147	1.42	0	0
7	21,726	295	1.36	2	0.01
3	10,845	73	0.67	1	0.01
20	3,371	3	0.09	0	0
21	4,667	4	0.09	0	0

Table 8.1 - The proportions of numbers of fragments in various size groupings with respect to the total number of fragments in given contexts

Context	Total Mass of Fragments (g)	Mass Frags. (g) >40mm	% >40mm	Mass Frags. (g) >Part	% >Part
8I	4179.0	1474.6	35.29	137.2	3.28
8II	4712.4	2117.9	44.94	337.4	7.16
31	470.5	150.6	32.00	0	0
4	2793.0	564.4	20.21	0	0
7	4718.0	1360.7	28.84	98.3	2.08
3	2507.8	311.7	12.42	12.4	0.49
20	243.9	17.6	7.22	0	0
21	465.4	5.7	1.22	0	0

Table 8.2 - The proportions of masses of fragments in various size groupings with respect to the total mass of fragments in given contexts

Context	Number of Frags.	Mass of Frags.(g)	Frags. per Gram
8I	3353	182.5	18.37
8II	8103	555.6	14.58
31	3115	161.4	19.30
4	1780	266.0	6.69
7	2005	197.8	10.14
3	9971	1397.8	7.13
20	3331	206.9	16.10
21	4542	371.1	12.24

Table 8.3 - The ratio of number of fragments to mass in samples from the <20mm size class in given contexts

Context	Shaft Frags.	Axial/Artic.	Axial	Articular
8I	1281	386	25	16
8II	1400	449	26	20
31	175	70	1	1
4	907	204	5	2
7	1360	452	15	4
3	737	132	1	4
20	32	8	0	0
21	88	36	1	0

Table 8.4 - The number of fragments (>30mm) identified to different types of bone in given contexts

Context	Sample Size	Mean of Fracture Scores
8I	250	2.63
8II	300	2.52
31	33	3.00
4	125	2.38
3	70	2.31
7	250	2.65

Table 8.5 - Sample sizes and mean fracture freshness index scores by context

Context	% Mineralised Breaks	% Modern Breaks
8I	17.6	23.6
8II	18.7	15.7
31	21.2	33.0
4	12.8	9.6
3	17.1	10.0
7	26.8	11.6

Table 8.6 - Percentages of fragments in samples displaying mineralised and modern breaks by context

Context	% Dynamic Impact Marks	% Cut Marks	% Probable Traces of Gnawing	% Heavy Animal Gnawing
8I	2.4	0.4	23.6	0.8
8II	2.0	0.7	22.0	1.3
31	0	0	18.2	3.0
4	5.6	1.6	21.6	1.6
3	4.3	2.9	8.6	2.9
7	3.2	1.2	16.8	0.4

Table 8.7 - Percentages of fragments in samples displaying impact marks, cut Marks and animal gnawing

Figure 8.1 - The average contents of a bag of bone fragments from the Sauveterrian layers of Mondeval (context 8II) (10cm scale)

Figure 8.2 - The average contents of a bag of bone fragments from a Copper Age hearth at Mondeval (context 21) (10cm scale)

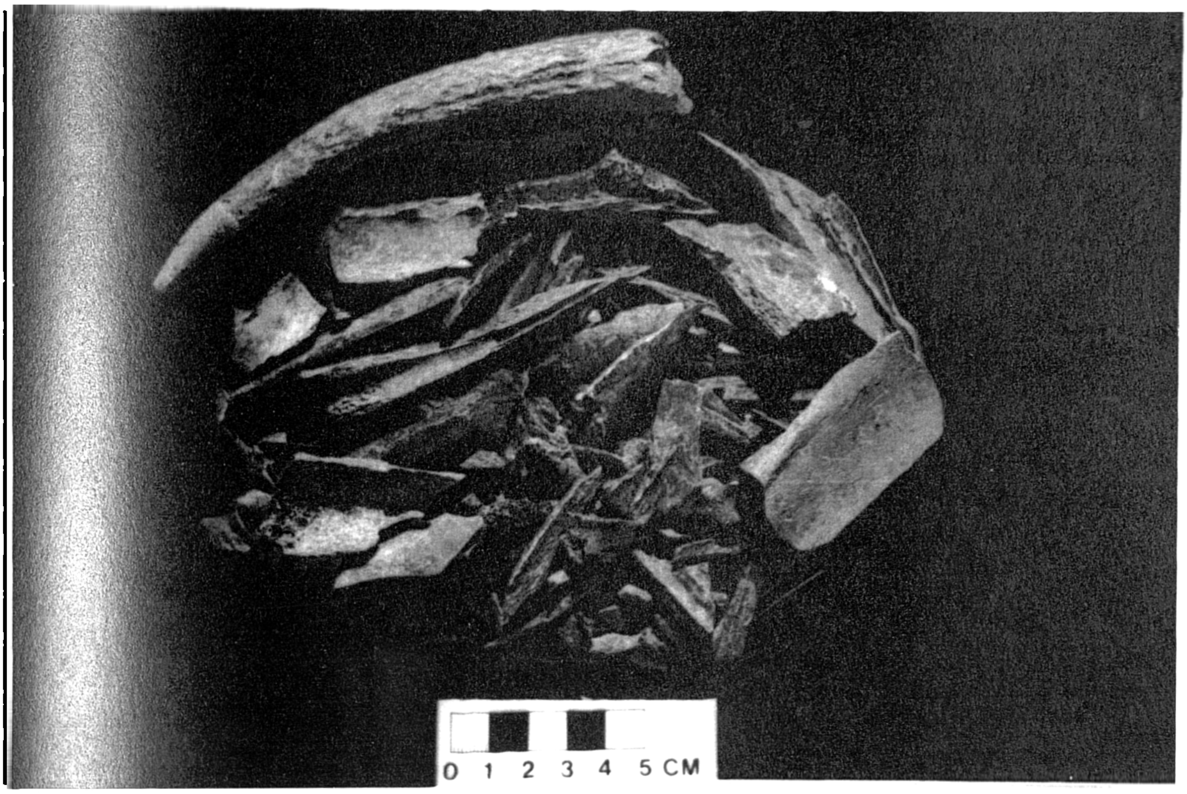


Figure 8.3 - An example of a relative unfragmented bag of fragments from the Sauveterrian layers of Mondeval (5cm scale)

Figure 8.4 - Some fresh-fractured splinters of bone from the Sauveterrian layers of Mondeval (10cm scale)

Figure 8.5 - Carnivore tooth marks on the shaft of a red deer radius from context 8 at Mondeval

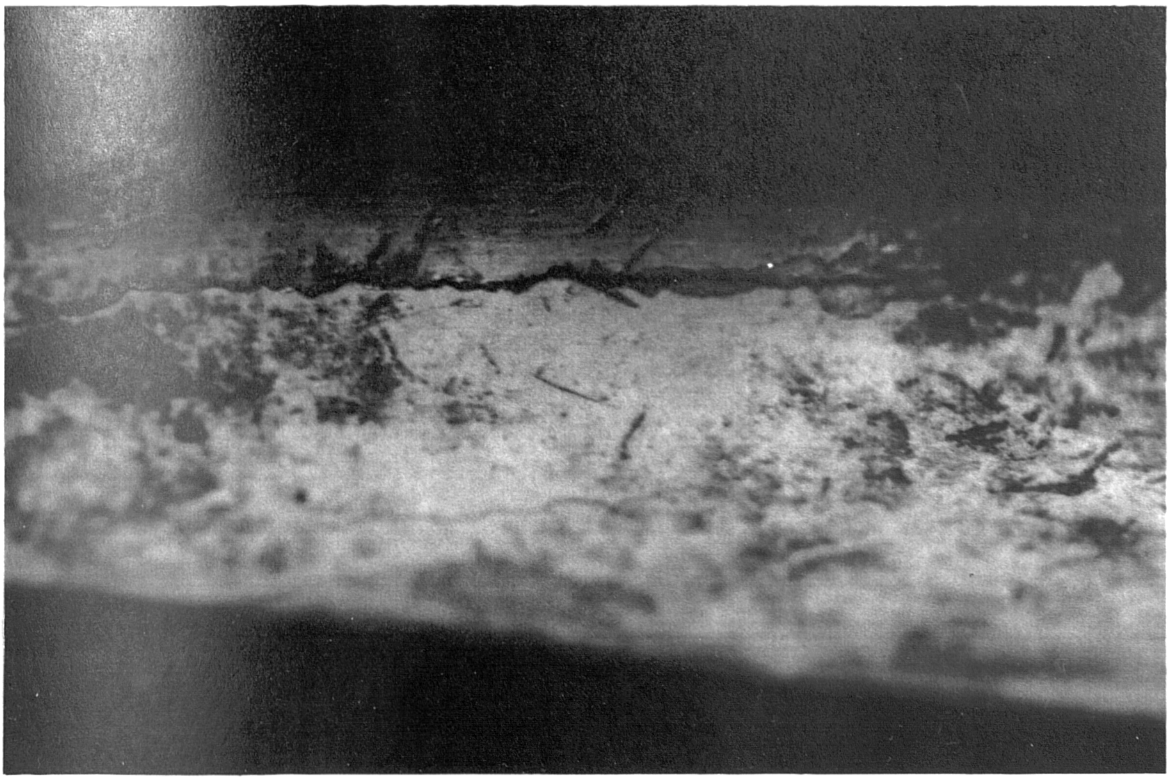


Figure 8.6 - A cut mark on the same red deer radius from context 8 at Mondeval

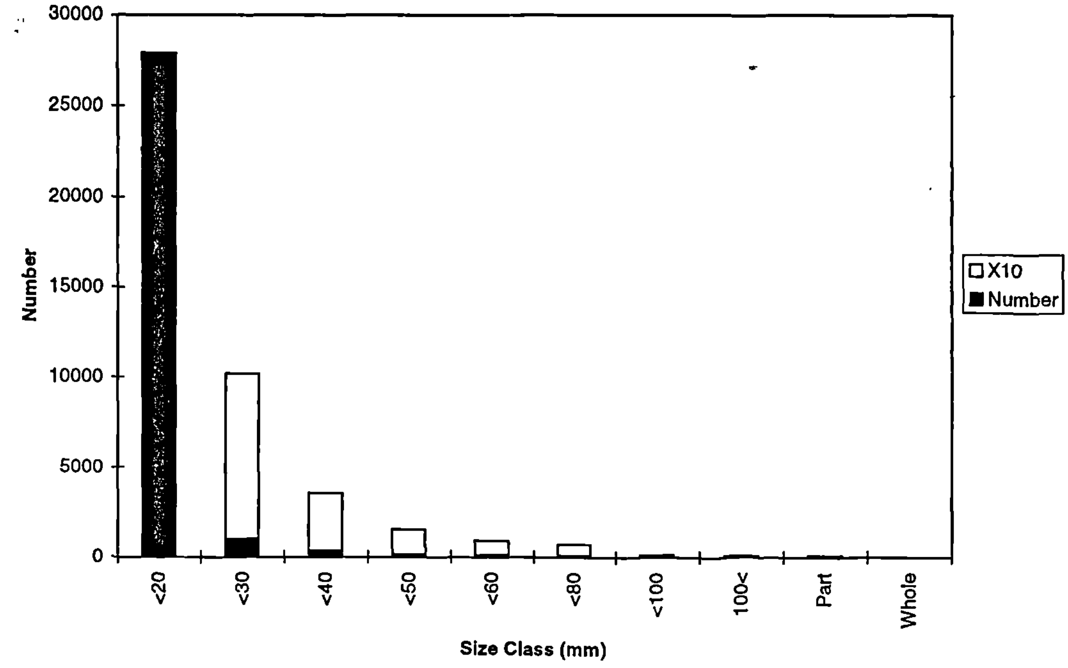


Figure 8.7a - A graph to show the number of fragments in each size class in context 8I (Sauveterrian)at Mondeval (there is a X10 exaggeration on all but the smallest class)

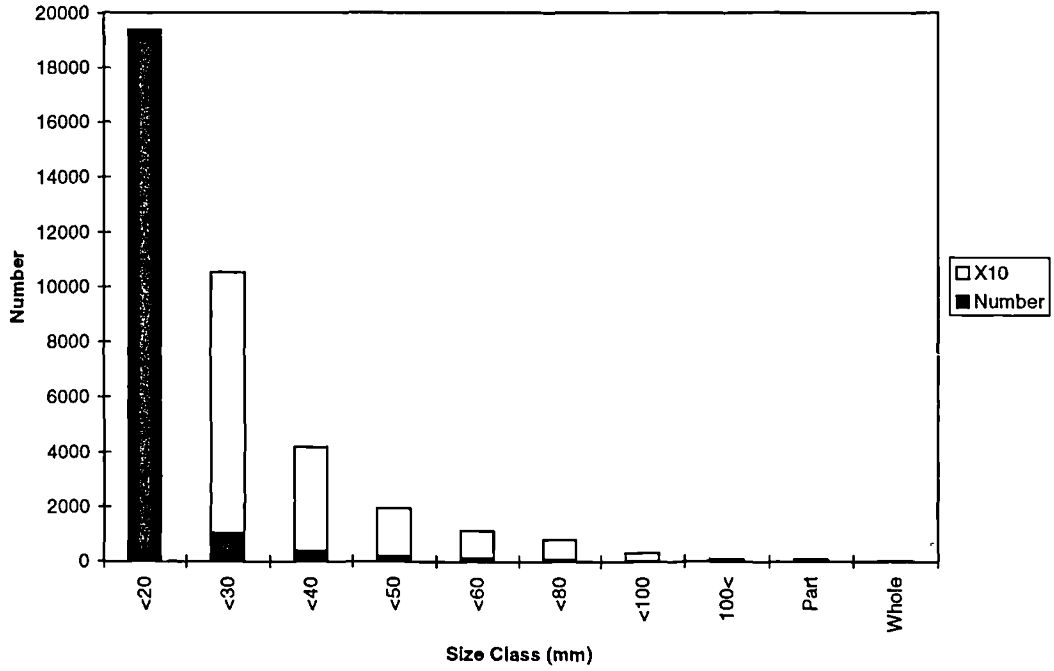


Figure 8.7b - A graph to show the number of fragments in each size class in context 8II (Sauveterrian) at Mondeval (there is a X10 exaggeration on all but the smallest class)

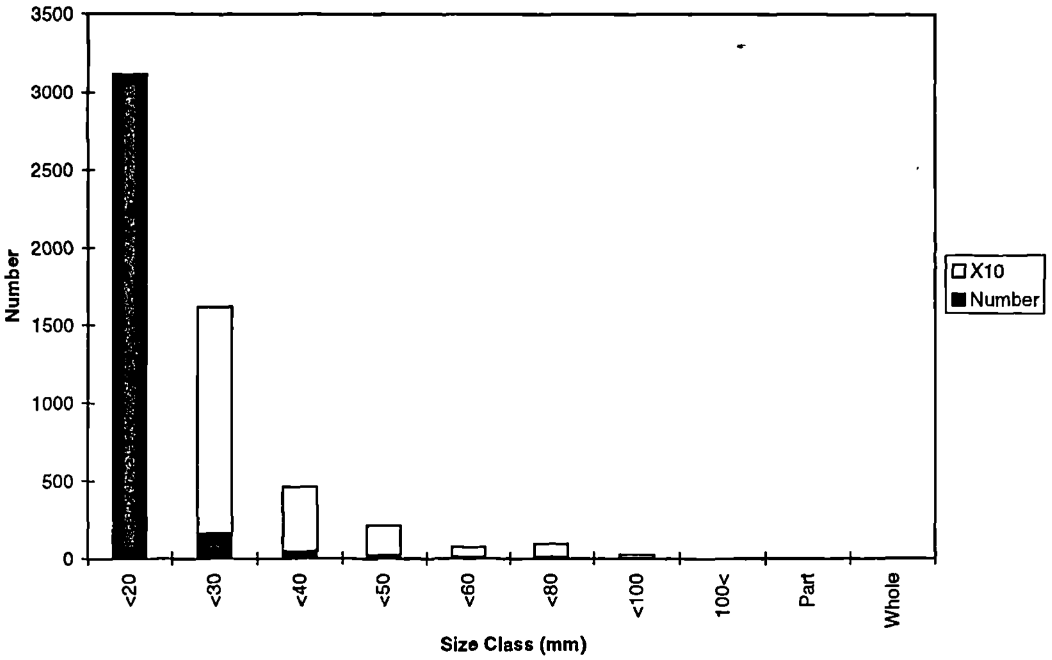


Figure 8.7c - A graph to show the number of fragments in each size class in context 31 (Sauveterrian) at Mondeval (there is a X10 exaggeration on all but the smallest class)

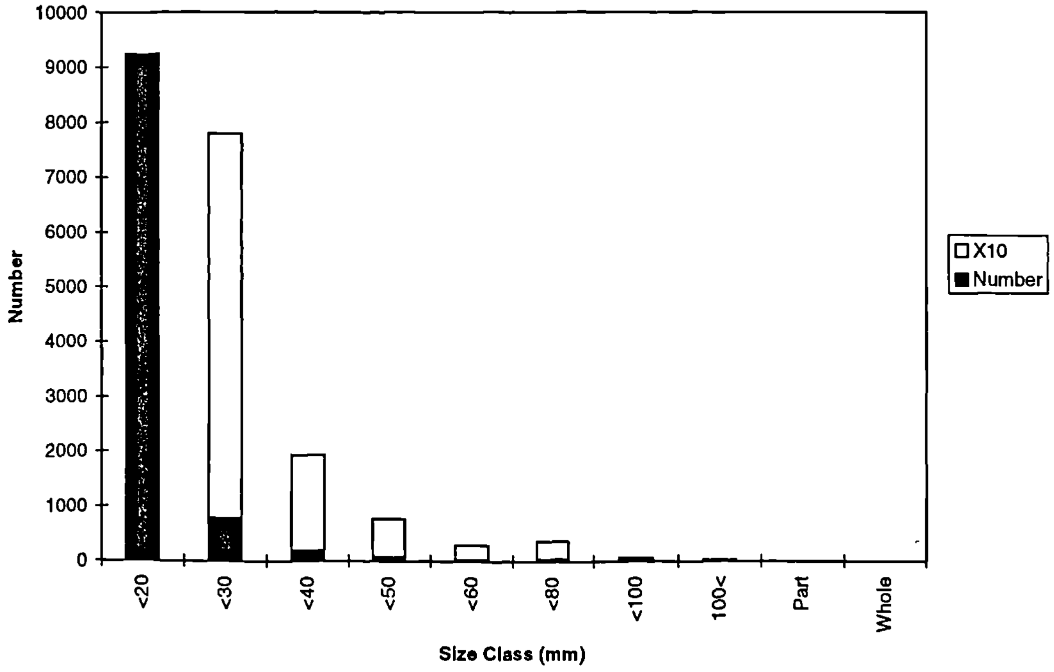


Figure 8.7d - A graph to show the number of fragments in each size class in context 4 (Castelnovian) at Mondeval (there is a X10 exaggeration on all but the smallest class)

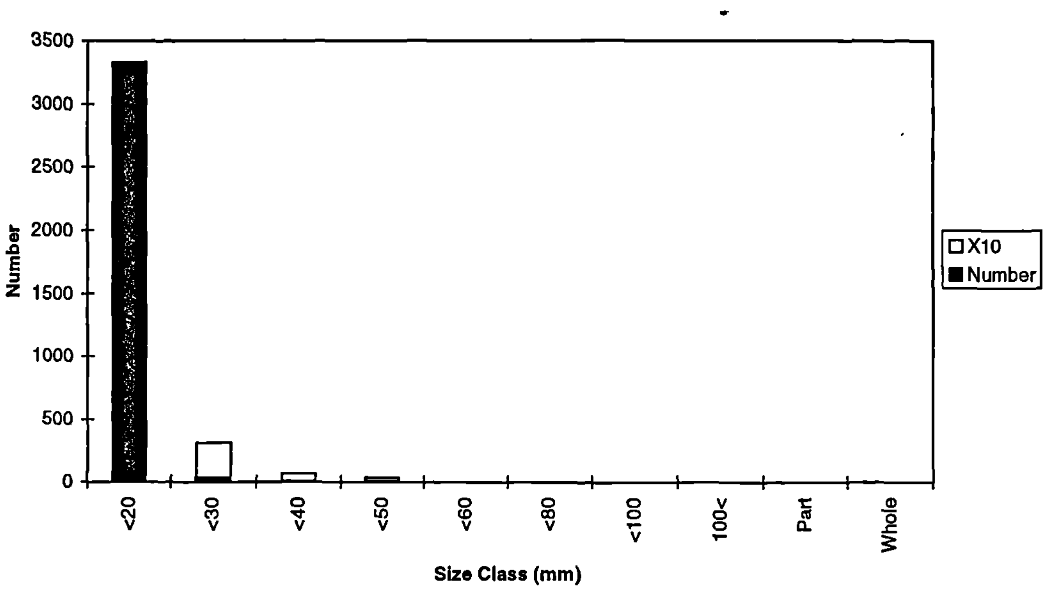


Figure 8.7e - A graph to show the number of fragments in each size class in context 20 (Castelnovian) at Mondeval (there is a X10 exaggeration on all but the smallest class)

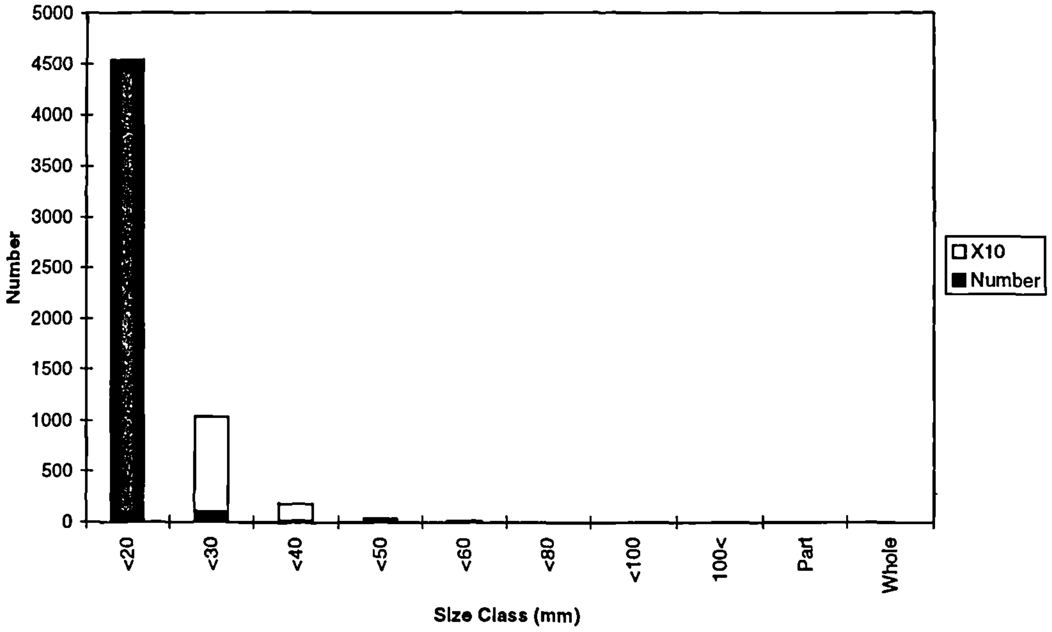


Figure 8.7f - A graph to show the number of fragments in each size class in context 21 (Copper Age) at Mondeval (there is a X10 exaggeration on all but the smallest class)

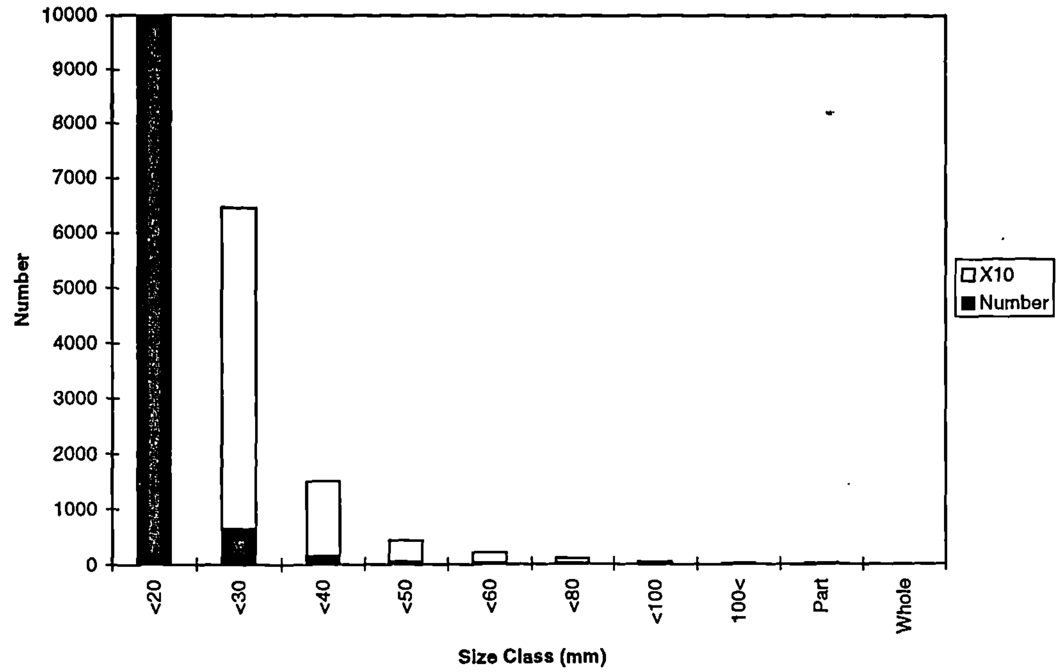


Figure 8.7g - A graph to show the number of fragments in each size class in context 3 (Copper Age) at Mondeval (there is a X10 exaggeration on all but the smallest class)

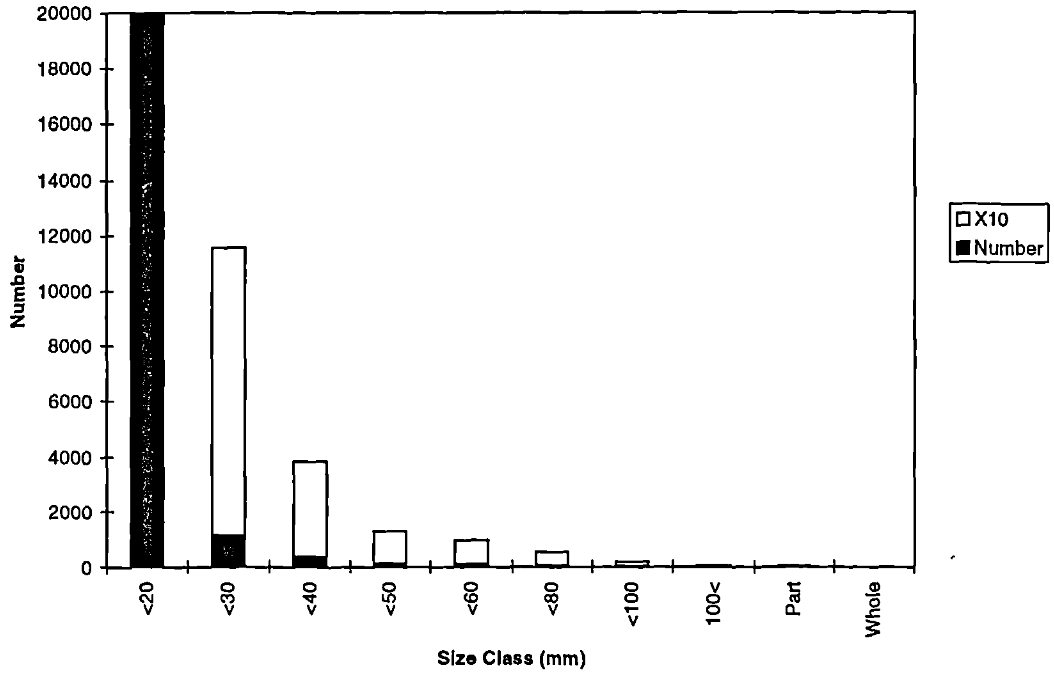


Figure 8.7h - A graph to show the number of fragments in each size class in context 7 (Copper Age) at Mondeval (there is a X10 exaggeration on all but the smallest class)

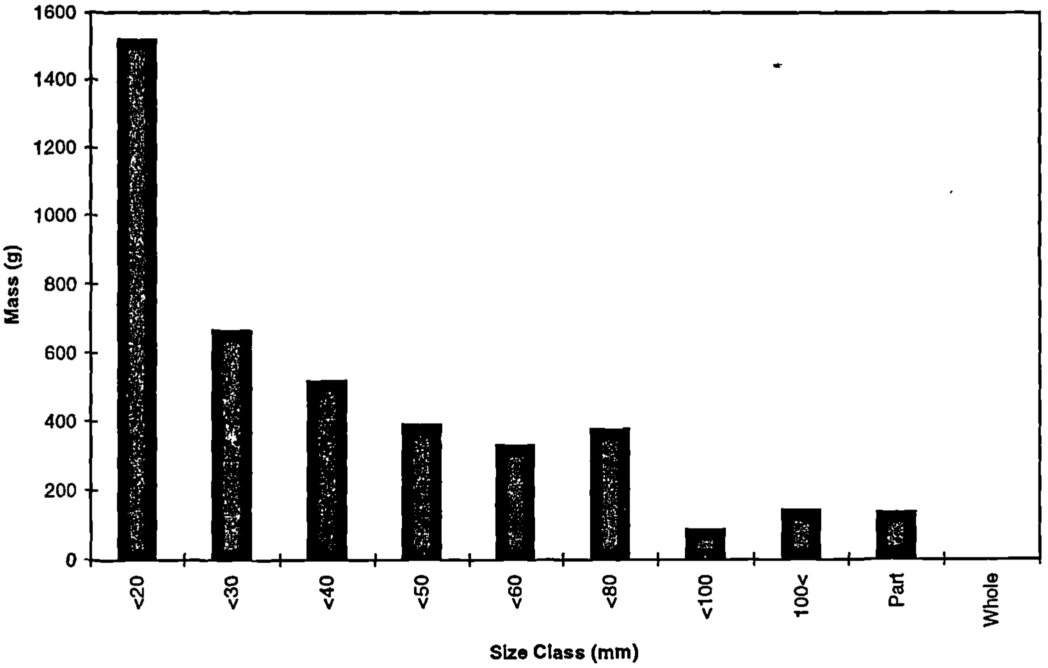


Figure 8.8a - A graph to show the masses of fragments in each size class in context 8I (Sauveterrian) at Mondeval

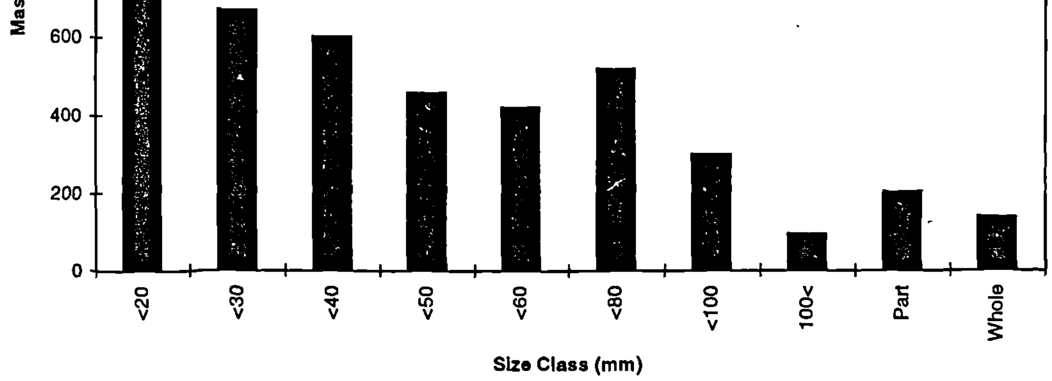


Figure 8.8b - A graph to show the masses of fragments in each size class in context 8II (Sauveterrian) at Mondeval

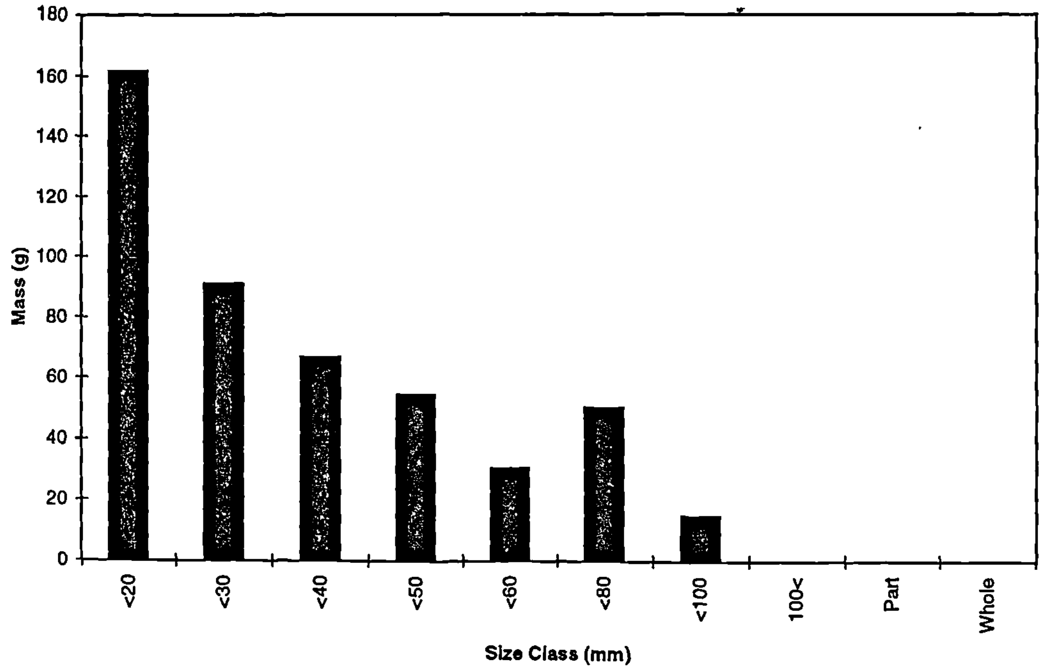


Figure 8.8c - A graph to show the masses of fragments in each size class in context 31 (Sauveterrian) at Mondeval

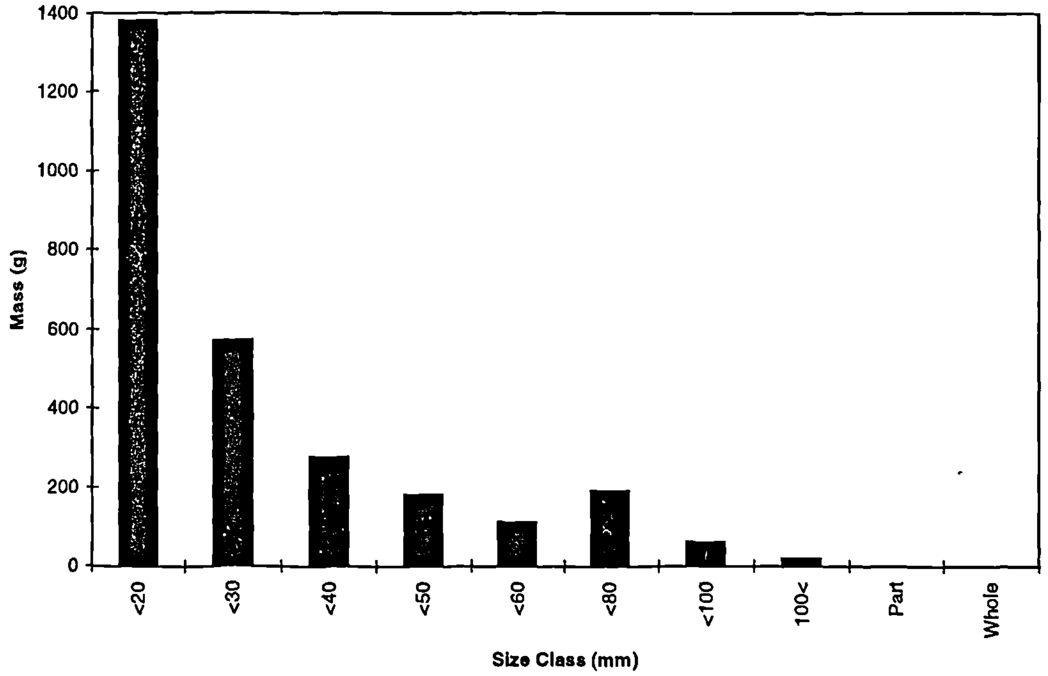


Figure 8.8d - A graph to show the masses of fragments in each size class in context 4 (Castelnovian) at Mondeval

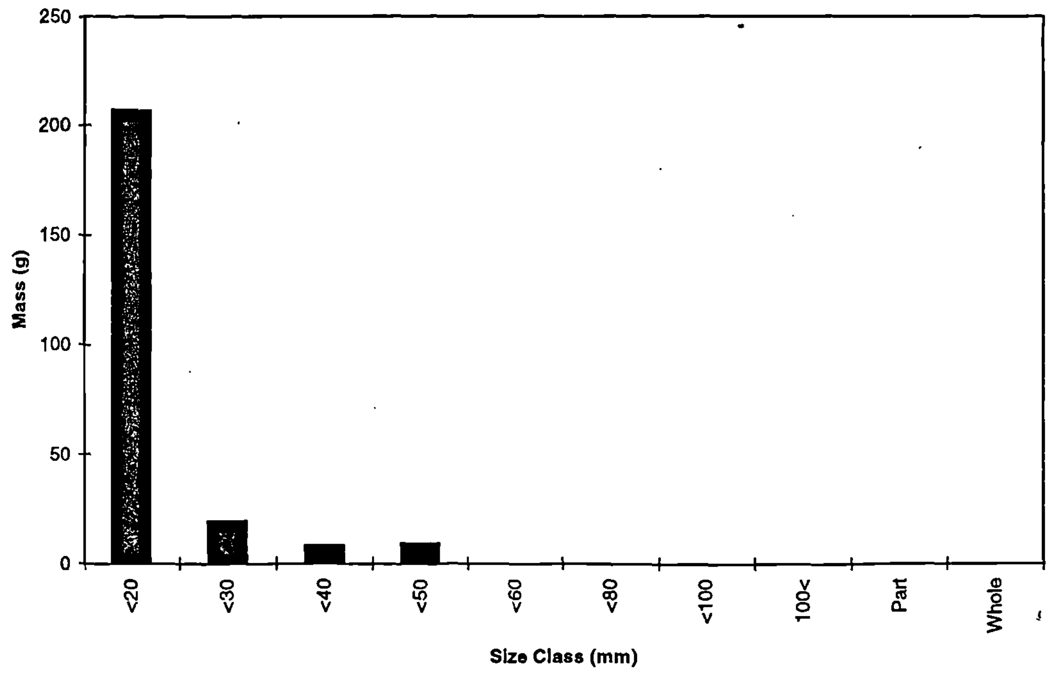


Figure 8.8e - A graph to show the masses of fragments in each size class in context 20 (Castelnovian) at Mondeval

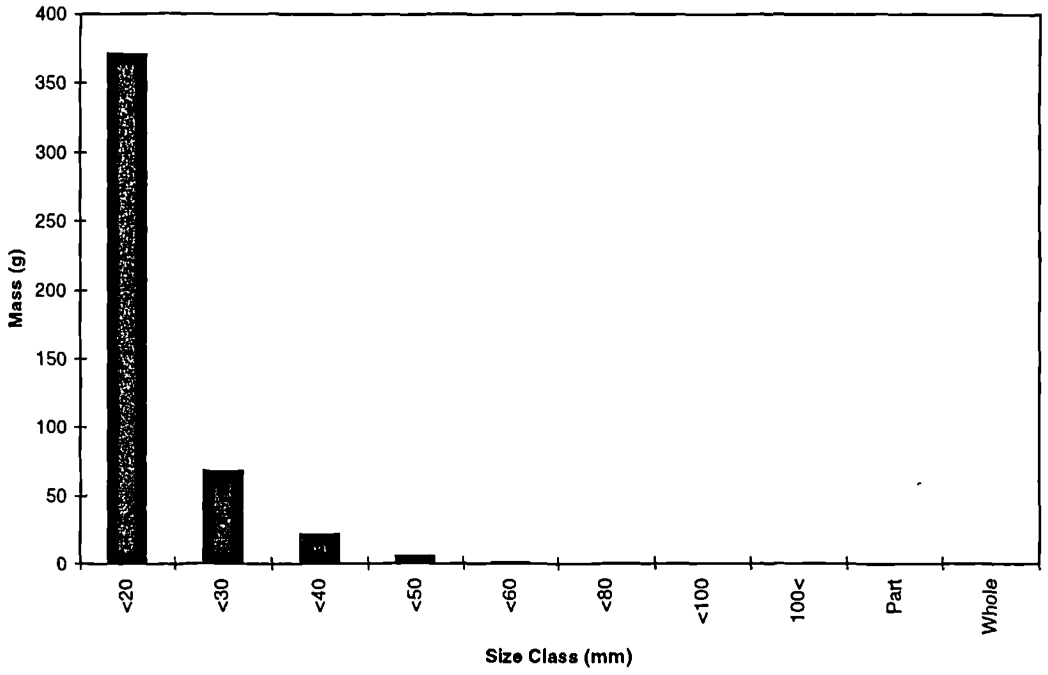


Figure 8.8f - A graph to show the masses of fragments in each size class in context 21 (Copper Age) at Mondeval

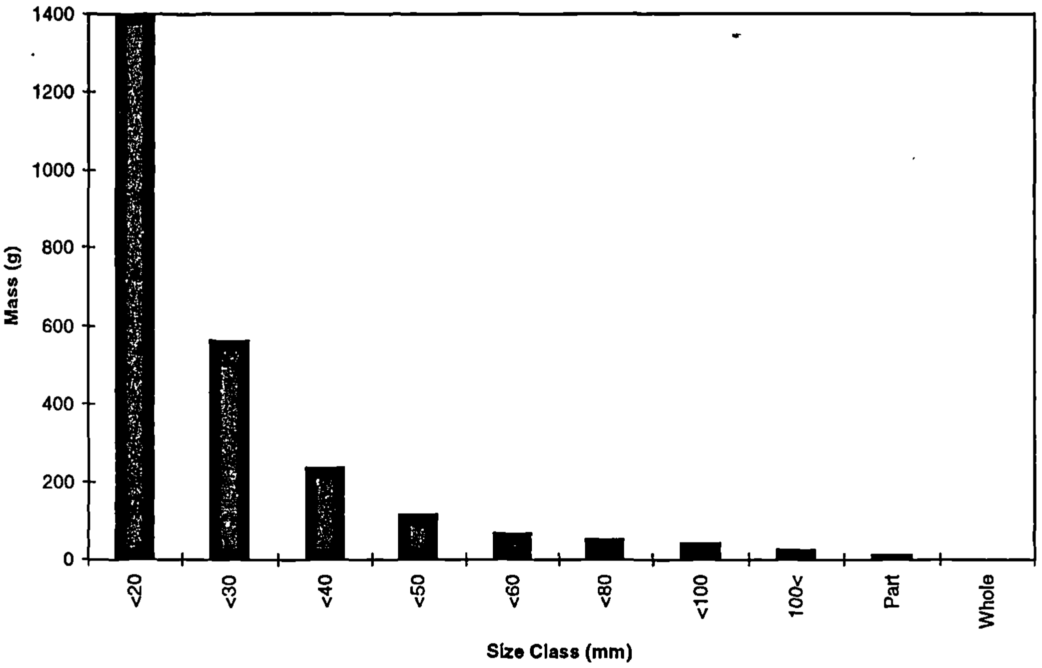


Figure 8.8g - A graph to show the masses of fragments in each size class in context 3 (Copper Age) at Mondeval

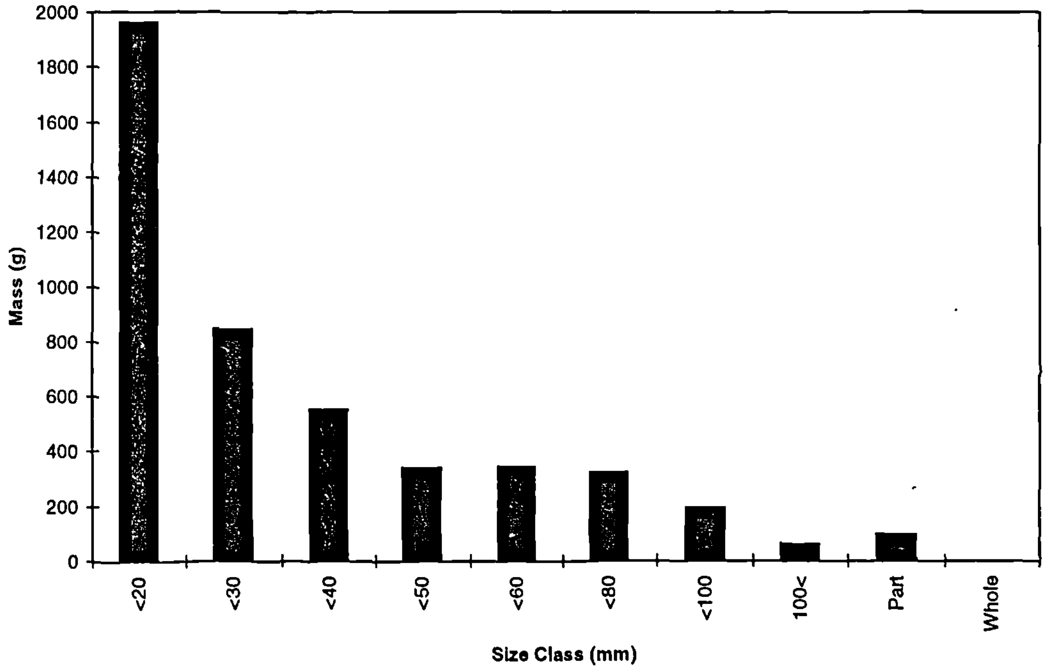


Figure 8.8h - A graph to show the masses of fragments in each size class in context 7 (Copper Age) at Mondeval

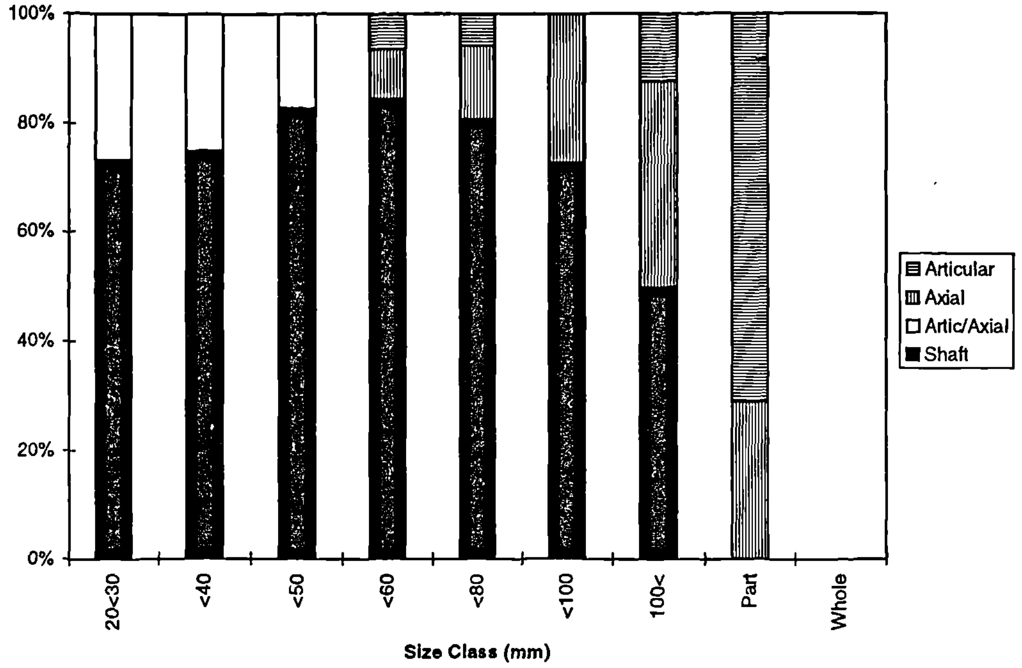


Figure 8.9a - A graph to show the proportions of different fragment types in each size class in context 8I (Sauveterrian) at Mondeval

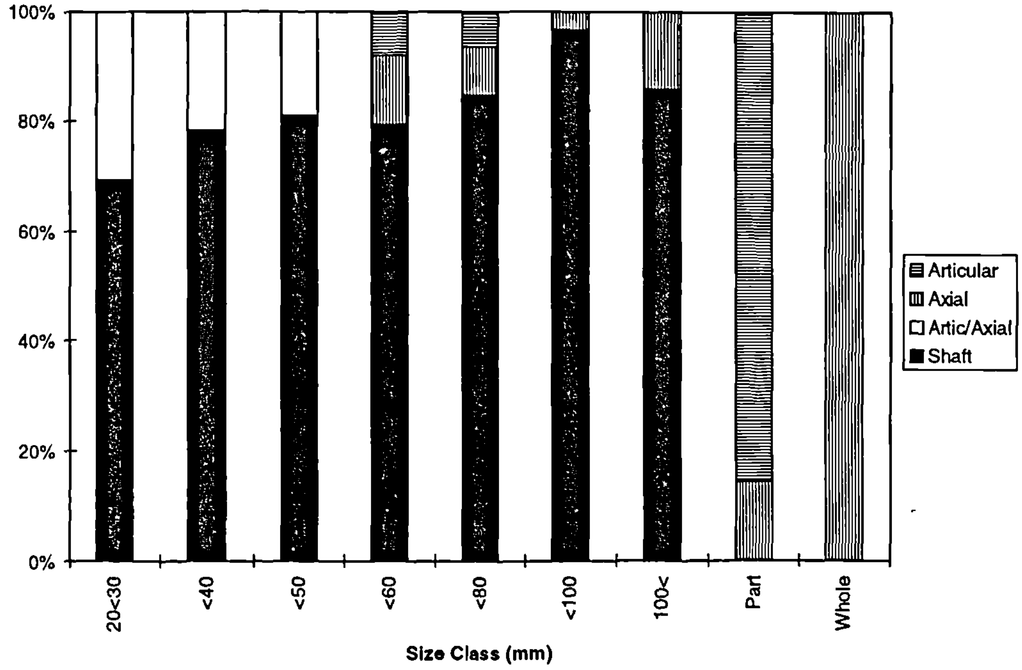


Figure 8.9b - A graph to show the proportions of different fragment types in each size class in context 8II (Sauveterrian) at Mondeval

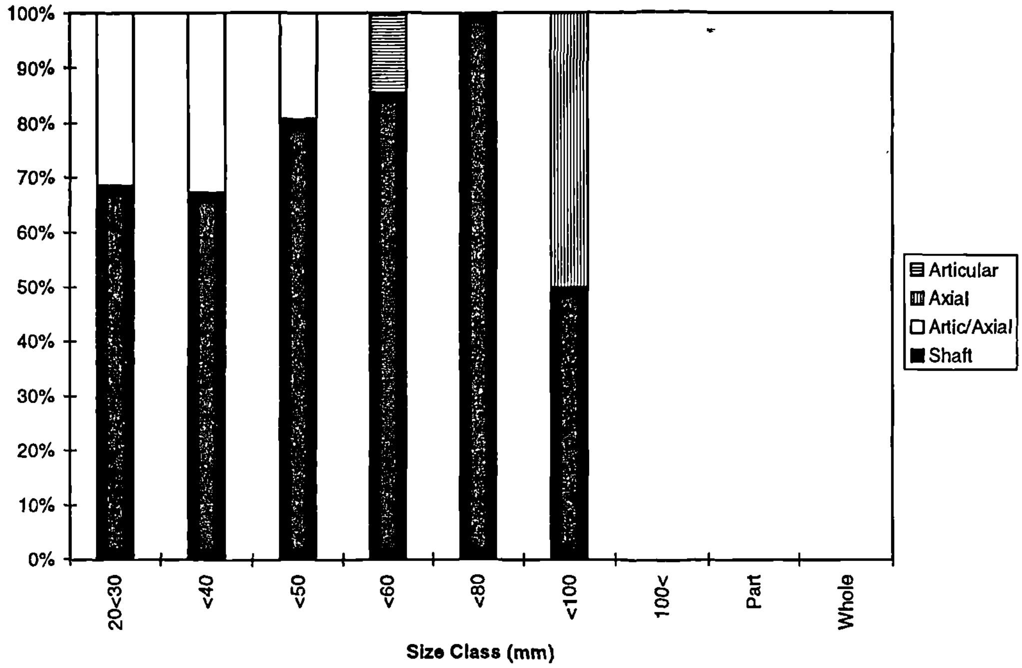


Figure 8.9c - A graph to show the proportions of different fragment types in each size class in context 31 (Sauveterrian) at Mondeval

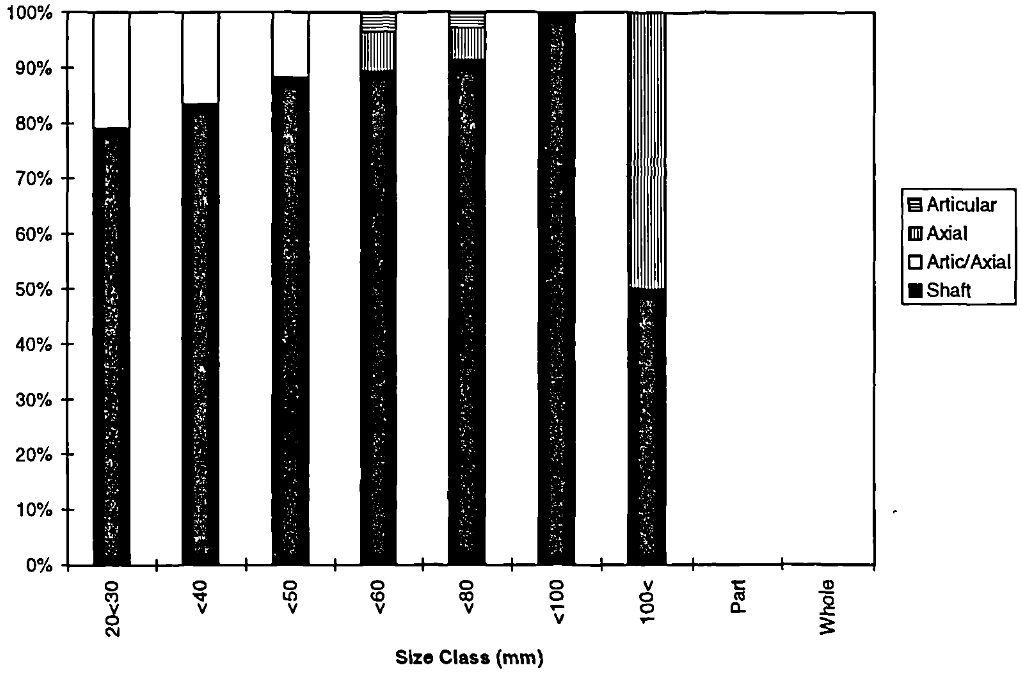


Figure 8.9d - A graph to show the proportions of different fragment types in each size class in context 4 (Castelnovian) at Mondeval

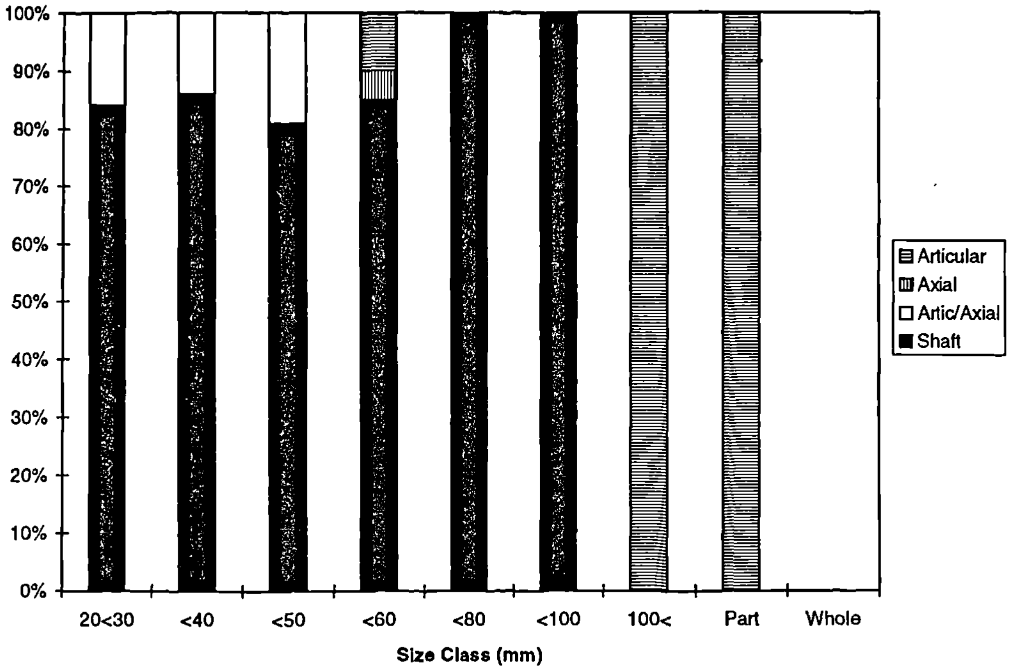


Figure 8.9e - A graph to show the proportions of different fragment types in each size class in context 3 (Copper Age) at Mondeval

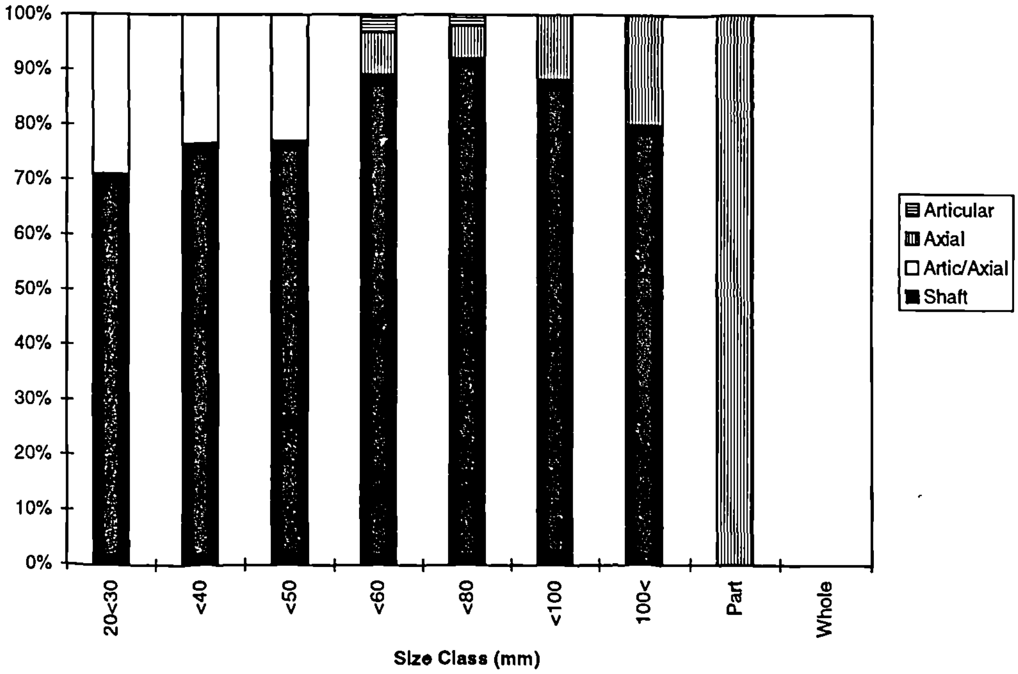


Figure 8.9f - A graph to show the proportions of different fragment types in each size class in context 7 (Copper Age) at Mondeval

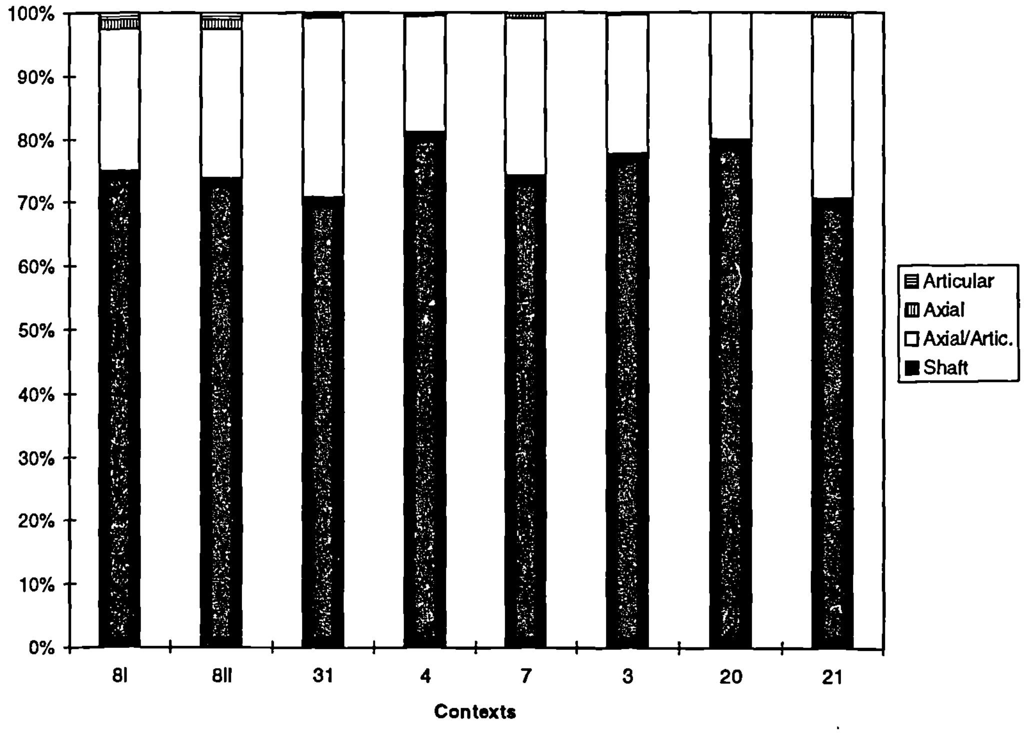


Figure 8.10 - A graph to show the proprtions of fragment types, for fragments over 30mm, for all contexts studied at Mondeval

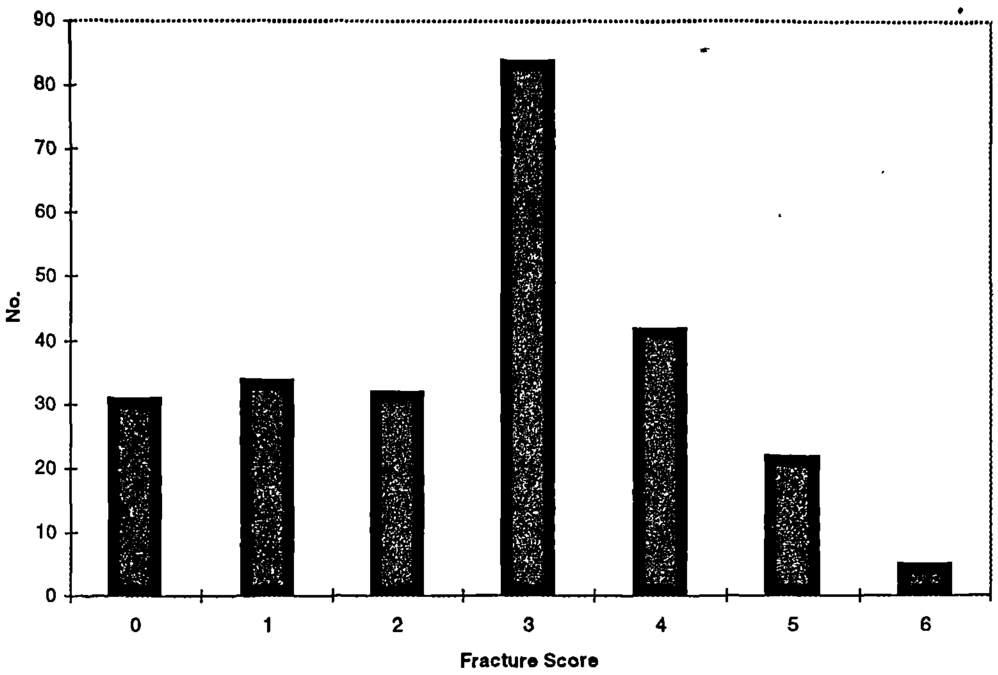


Figure 8.11a - A graph to show the frequencies of fracture freshness index scores for context 8I (Sauveterrian) at Mondeval

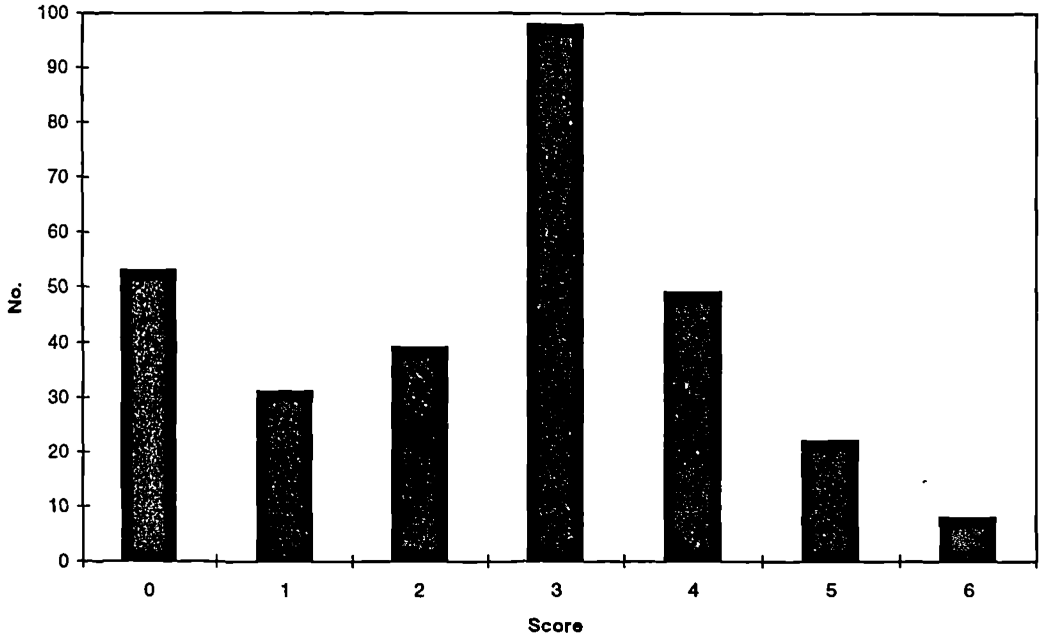


Figure 8.11b - A graph to show the frequencies of fracture freshness index scores for context 8II (Sauveterrian) at Mondeval

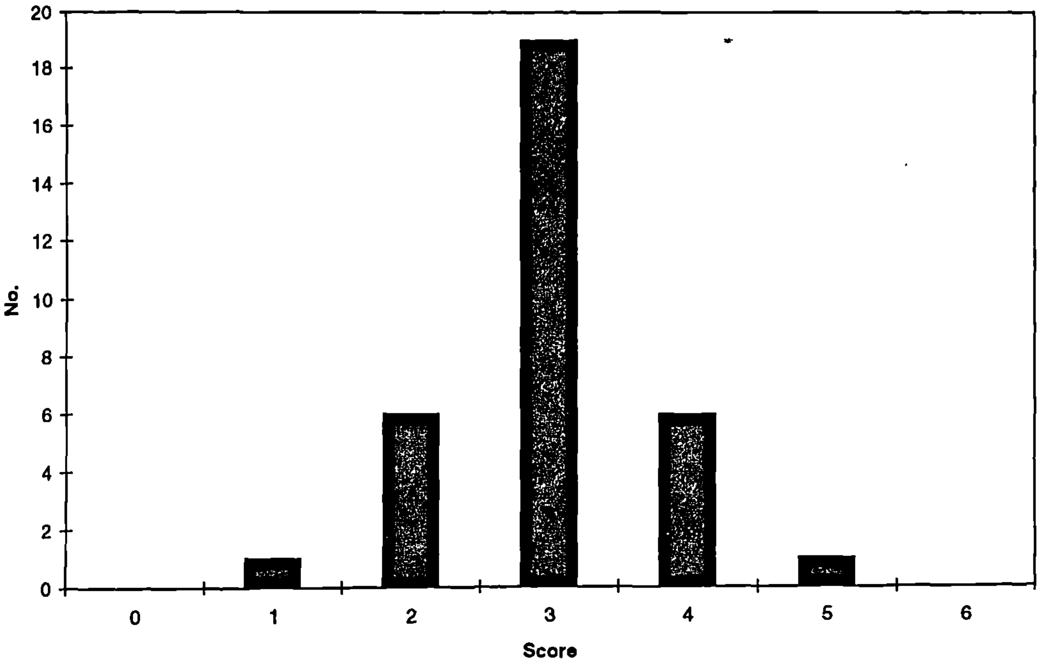


Figure 8.11c - A graph to show the frequencies of fracture freshness index scores for context 31 (Sauveterrian) at Mondeval

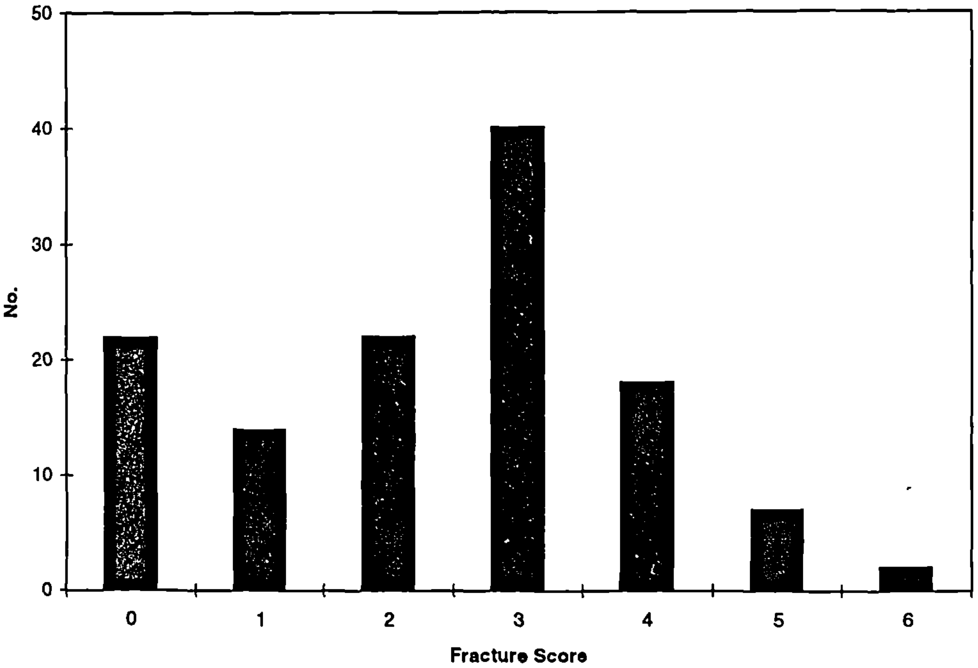


Figure 8.11d - A graph to show the frequencies of fracture freshness index scores for context 4 (Castelnovian) at Mondeval

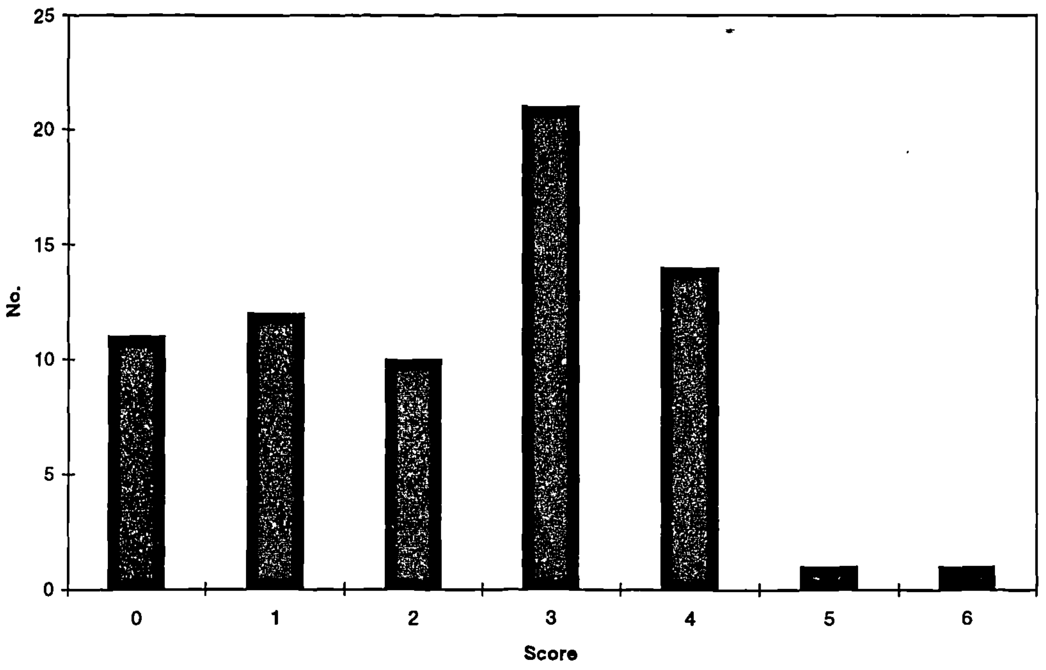


Figure 8.11e - A graph to show the frequencies of fracture freshness index scores for context 3 (Copper Age) at Mondeval

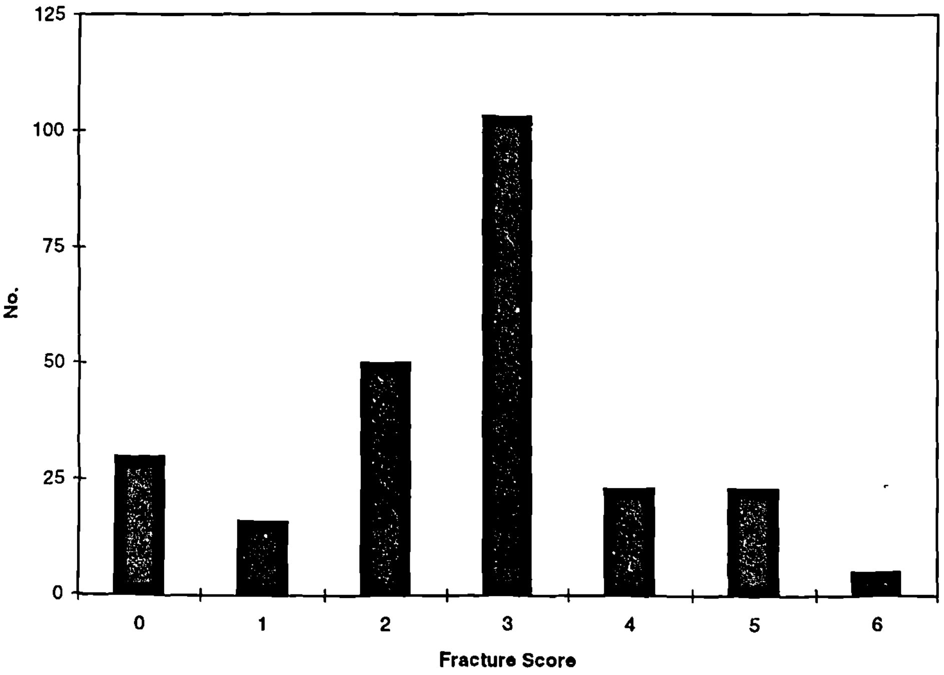


Figure 8.11f - A graph to show the frequencies of fracture freshness index scores for context 7 (Copper Age) at Mondeval

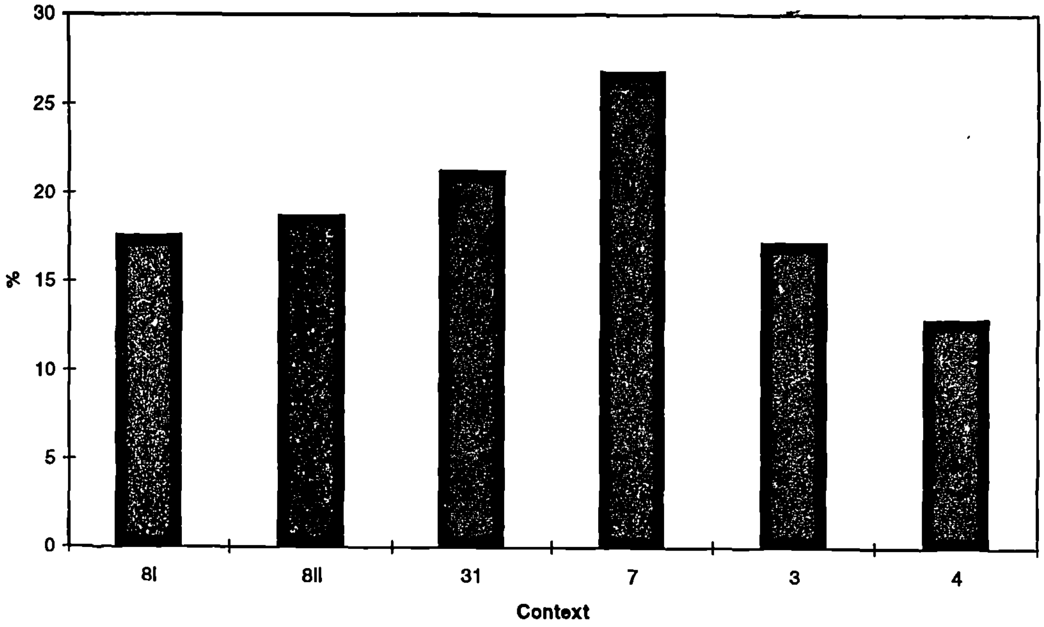


Figure 8.12 - A graph to show the percentages of fragments studied which displayed obvious mineralised fractures for all contexts studied

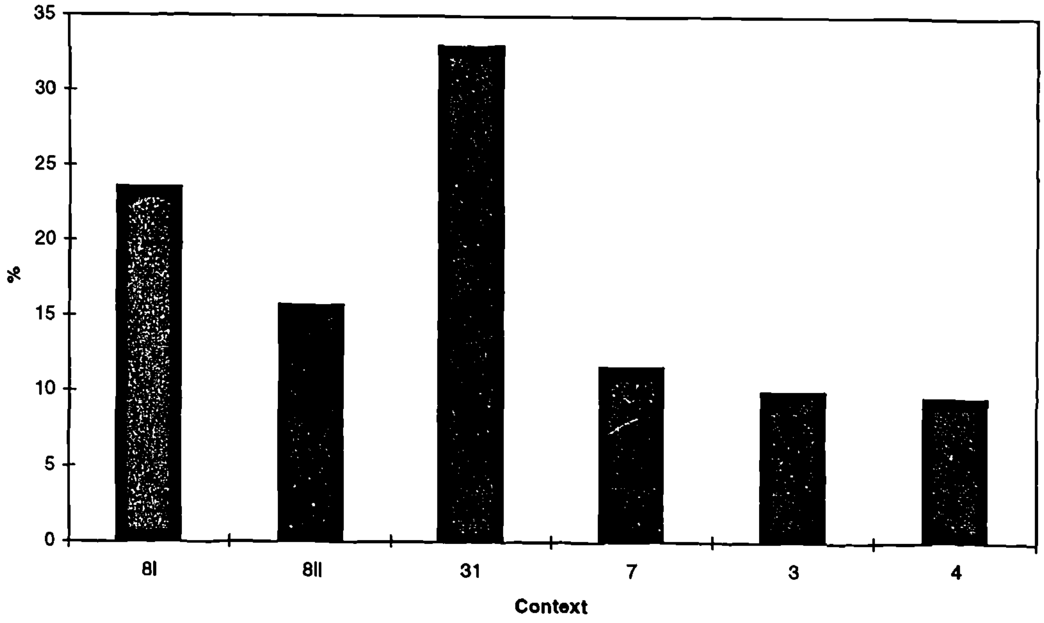


Figure 8.13 - A graph to show the percentages of fragments studied which displayed obvious modern breaks for all contexts studied

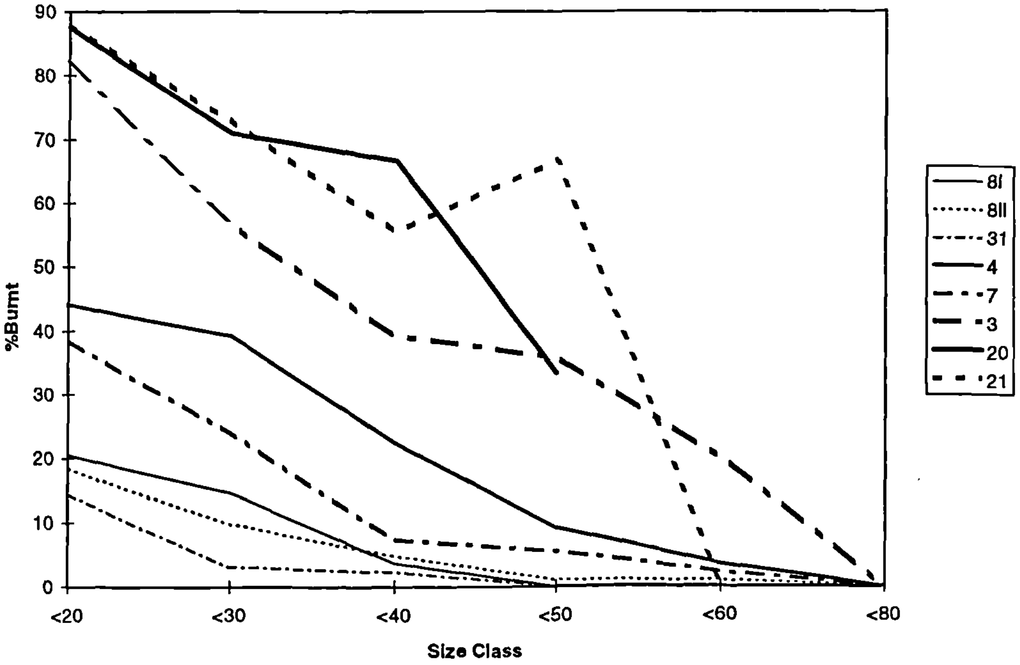


Figure 8.14 - A graph to show the percentage of burnt fragments in each size class for all contexts studied

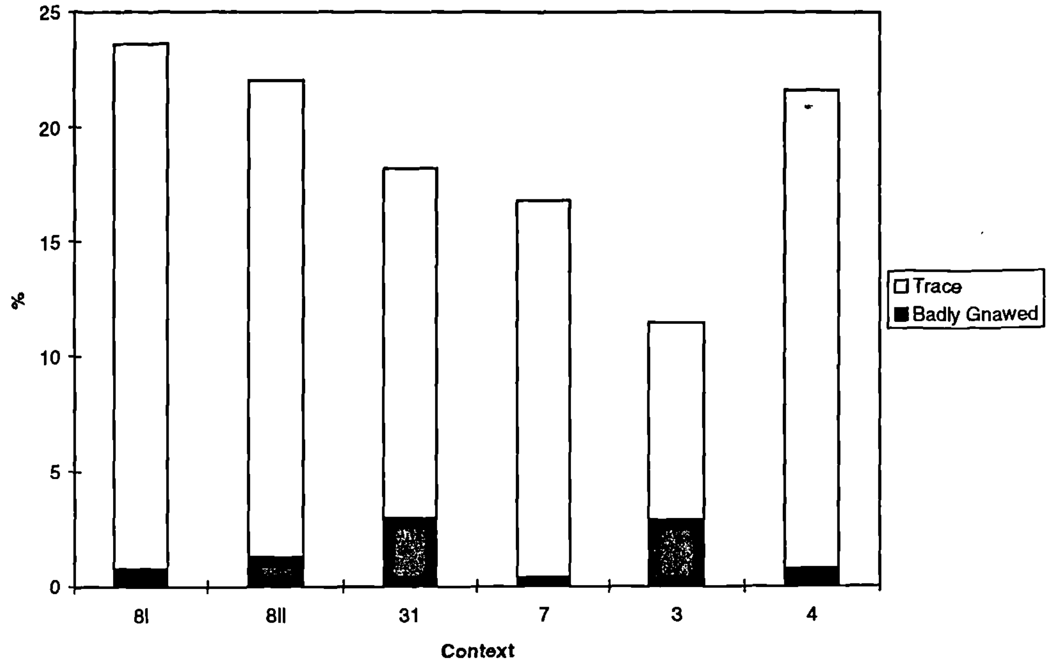


Figure 8.15 - A graph to show the percentages of fragments studied which displayed traces of animal gnawing for all contexts studied (possible traces and more obvious cases are distinguished)

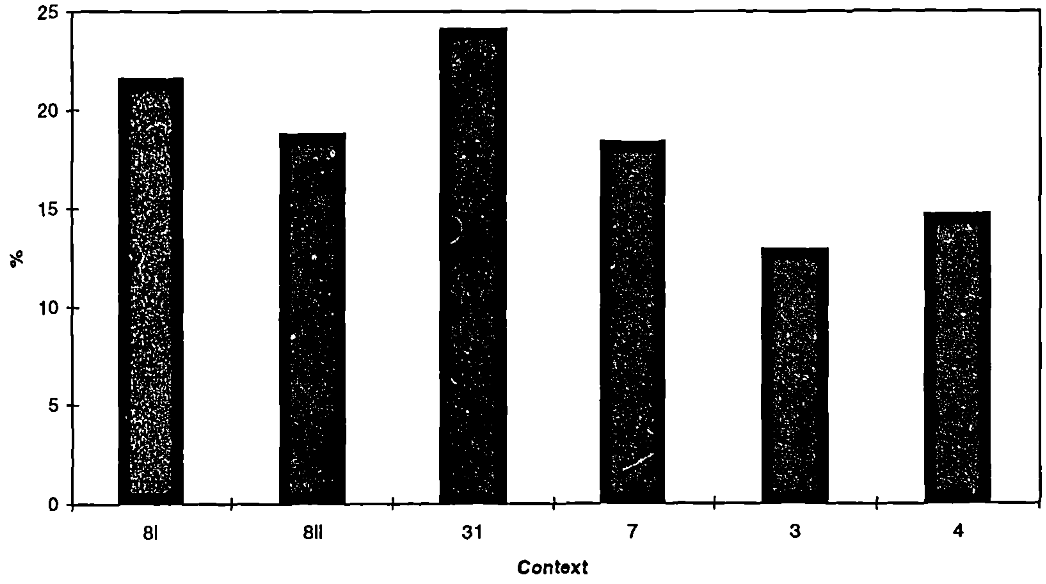


Figure 8.16 - A graph to show an index of post-depositional damage for each context studied (the index is the mean of the percentages of mineralised breakage, modern breakage and animal gnawing)

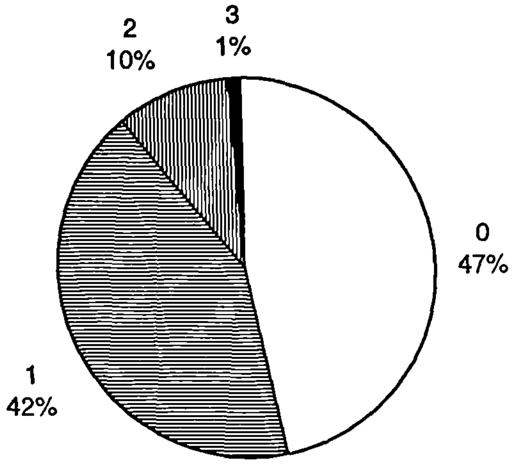


Figure 8.17a - A pie chart to show the proportions of fragments in context 8I (Sauveterrian) which had 0, 1, 2 or 3 indicators of post-depositional damage (N=250) (indicators are gnawing, mineralised fractures and modern breaks)

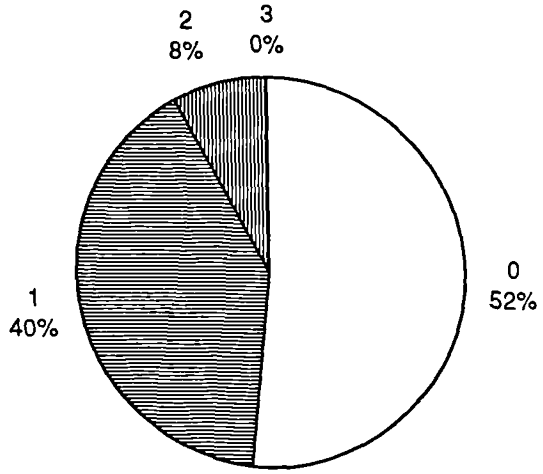


Figure 8.17b - A pie chart to show the proportions of fragments in context 8II (Sauveterrian) which had 0, 1, 2 or 3 indicators of post-depositional damage (N=300) (indicators are gnawing, mineralised fractures and modern breaks)

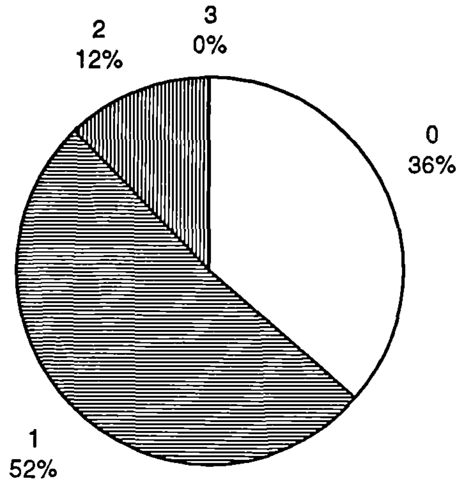


Figure 8.17c - A pie chart to show the proportions of fragments in context 31 (Sauveterrian) which had 0, 1, 2 or 3 indicators of post-depositional damage (N=31) (indicators are gnawing, mineralised fractures and modern breaks)

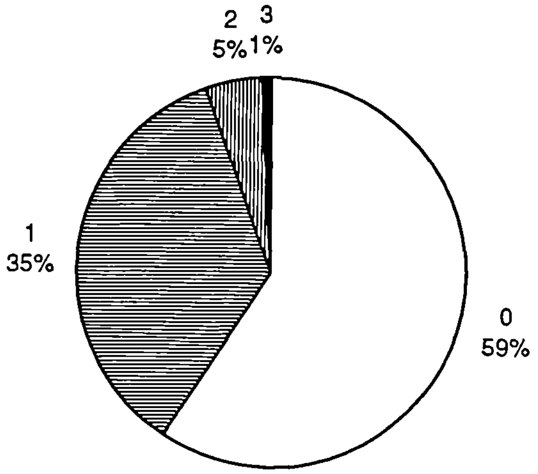


Figure 8.17d - A pie chart to show the proportions of fragments in context 4 (Castelnovian) which had 0, 1, 2 or 3 indicators of post-depositional damage (N=125) (indicators are gnawing, mineralised fractures and modern breaks)

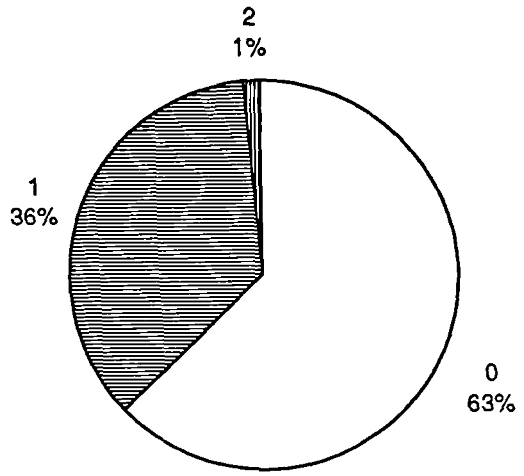


Figure 8.17e - A pie chart to show the proportions of fragments in context 3 (Copper Age) which had 0, 1, 2 or 3 indicators of post-depositional damage (N=70) (indicators are gnawing, mineralised fractures and modern breaks)

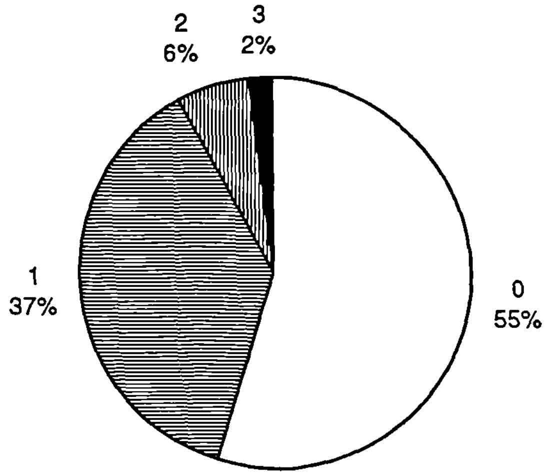


Figure 8.17f - A pie chart to show the proportions of fragments in context 7 (Copper Age) which had 0, 1, 2 or 3 indicators of post-depositional damage (N=250) (indicators are gnawing, mineralised fractures and modern breaks)

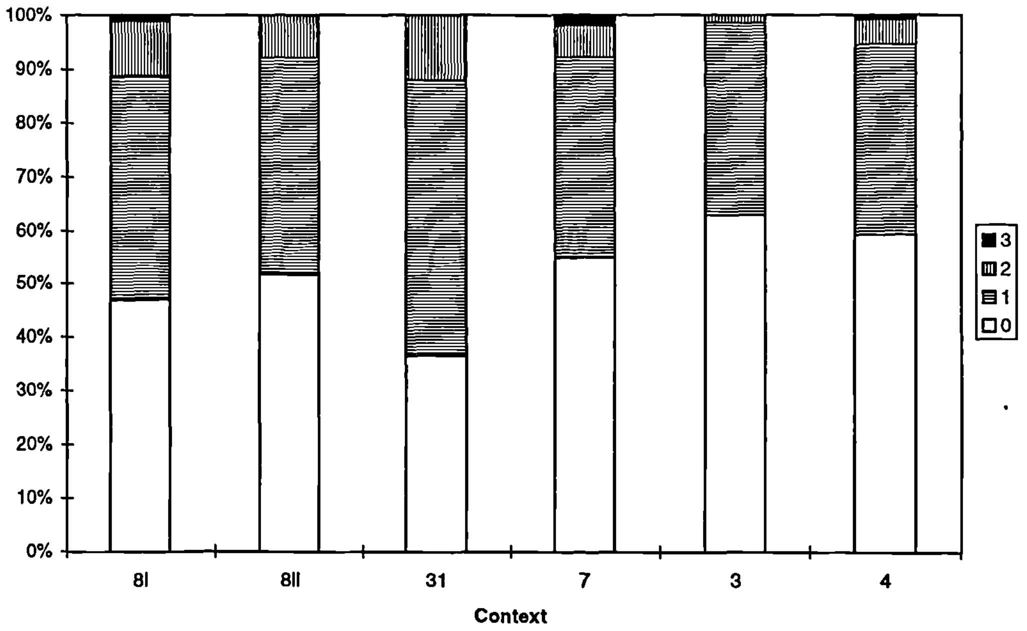


Figure 8.18 - A graph summarising the proportions of fragments in selected contexts which had 0, 1, 2 or 3 indicators of post-depositional damage (indicators are gnawing, mineralised fractures and modern breaks)

CHAPTER NINE

A CONTROL STUDY

9.1 Introduction

The interpretation of the Mondeval de Sora material, in the previous chapter (chapt. 8), revolved around the contention that the bones were extremely fragmented and, in particular, the cancellous epiphyses and axial elements had been so comminuted as to result in only a tiny number of such fragments surviving in larger size classes. The interpretation also relied on the fact that it could be demonstrated that most damage had occurred whilst bones were fresh and that there was evidence of deliberate breakage. In order for this argument to be convincing the reader has to agree with this author's assumptions regarding what an extremely fragmented site might look like and what levels of comminution of epiphysial and axial bone might be considered to be very high.

Most zooarchaeologists practiced in assemblage analysis would no doubt accept the contentions regarding fragmentation levels at Mondeval from their own experiences of the levels of fragmentation commonly encountered in assemblages. Some form of control study, using the same methodology, would however be useful in demonstrating the point more clearly. But what should one use as a control? No archaeological assemblage is a true "control" and no archaeological assemblage has a "normal" level of fragmentation, in the strictest sense of those words. The taphonomy on each site is individual and deserving of an interpretation in its own right.

The best we can attempt, therefore, is the study of a site where grease exploitation is an unlikely proposition. Such a study will hopefully have contrasting fracture and fragmentation patterns which will serve to put the fragmentation at Mondeval de Sora in perspective.

The site chosen for this study is the Roman site of Wallsend, Camp Road, a fort site situated at the terminus of Hadrian's Wall in Newcastle upon Tyne, England. This site has been under excavation by Tyne and Wear Council since 1988 and the archive bone reports are being carried out by Archaeology Biological Laboratory, University of Durham. The site is not yet published. This assemblage was not scrutinised prior to its selection as a control, but was selected randomly from suitable assemblages (i.e. ones where large scale grease extraction seamed an unlikely possibility). The sample was a randomly selected large box containing bones from four random contexts (WV97: WBB 4035, 4014, 4014, 4023, 4004). Exactly the same methodology was applied to this material as was applied to Mondeval de Sora.

9.2 Results

Raw data relating to Wallsend is given in Appendix B.

9.2.1 Fragmentation

The graph of size class representation as quantified by number can be seen in figure 9.1, and as quantified by mass in figure 9.2. The graph by number shows a near normal distribution of fragment size with most fragments being between 30mm and 80mm. There is not the extreme domination by the smaller size categories. It should be noted, however, that the material examined did not contain any sieved material. This could result in the relative lack of very small fragments. Even if the lack of sieving affects the relative picture it does not affect the fact that, in absolute terms, there are many large fragments and part and whole bones surviving. The larger categories in the Mondeval had to be exaggerated by ten times to make them visible on the graph! There is clearly a very different picture here.

This is further supported by the graph of mass of size classes (fig. 9.2). Here the domination is by the large size classes. The most represented is the 60mm to 80mm size class but all the large categories, including the part and whole classes, are very well represented. It is clear that this site is far less fragmented than Mondeval de Sora (though it is worth noting that it is far from being the best preserved or least broken up site seen by the author).

9.2.2 Types of Fragment

The study of the proportions of bone types in different size classes is particularly informative (see fig. 9.3). Unlike Mondeval, size classes are not dominated by diaphysis fragments but, instead, cancellous bone dominates in all classes. If anything, this domination increases with size which is the exact opposite of the situation at Mondeval. At Wallsend cancellous bone has not been particularly comminuted. It is clear that a very substantial amount of axial bone survives. This should not be surprising when one considers the quantity of bone in the vertebral column. There is also a substantial amount of undamaged articular cancellous bone. This is a clear indication of how much cancellous material must have been lost as a result of extreme comminution at Mondeval, particularly considering that Mondeval was very thoroughly water sieved.

9.2.3 Fracture Type

Figure 9.4 shows a graph of the numbers of different scores on the fracture freshness index. Out of the sample of 88 fragments studied for fracture most scored 3. The distribution is not like that at Mondeval, however, since there is a strong representation of fracture scoring 6 (i.e. having no indicators of fresh fracture). The mean average of fracture freshness scores is 3.16, whereas the Mondeval samples scored around 2.5.

It is clear that there was a reasonable quantity of fresh fracture at this site, from the not insignificant number of fragments scoring less than 3. This should not be unexpected, however. It is very likely that the Roman occupants of the site often wished to gain access to the marrow cavities. It is clear, however, that a larger proportion of the fracture at this site occurred on unfresh bones.

6.82% of fragments had suffered obvious mineralised (but pre-modern) breakage. What was far more surprising was the level of modern damage. 52.63% of fragments had been recently broken. Somewhere in the excavation, processing and storage of the bones much damage had taken place. The site was in firm clay (S. Stallibrass, pers. com.) and probably dug with heavy tools. It should be noted that, within the methodology, modern breaks are not considered with regard to the fracture freshness index. Therefore, the modern breaks are over and above the unfresh breaks noted in the fracture freshness index study.

9.2.4 Other Features

There was a certain amount of burning noted in the small size categories: 2.8% in the <20mm class, 12.2% in 20-30mm, 6.5% in 30-40mm, 2.0% in 40-50mm, 4.8% in 50-60mm. This is not unexpected at a consumer site where food was being cooked.

7.37% of fragments were carnivore gnawed. Again, not unexpected for the type of site and its date. The same proportion of bones had evidence of butchery.

9.3 Conclusion:

The assemblage at Wallsend seems indicative of an expected range of butchery and cooking practices which probably included some marrow extraction. Although the assemblage has suffered a fair degree of post-depositional damage, not least in its recent history, the assemblage appears far less fragmented than the assemblage at Mondeval de Sora. In particular much cancellous bone survives at Wallsend.

This study gives a clear contrast to the Mondeval assemblage and one which puts the extreme and very particular pattern of that site in perspective.

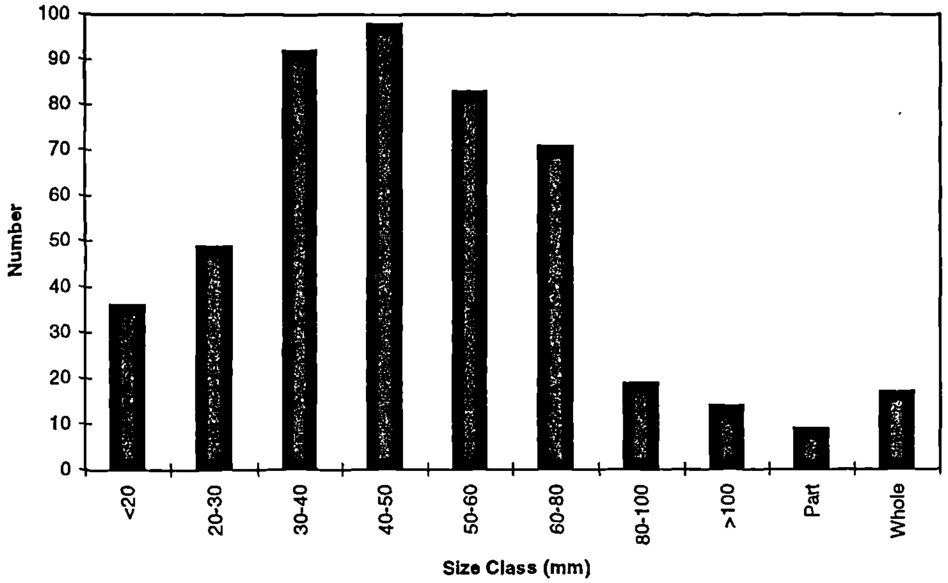


Figure 9.1 - A graph to show the numbers of fragments in different size classes in the sample contexts from Wallsend (WV97)

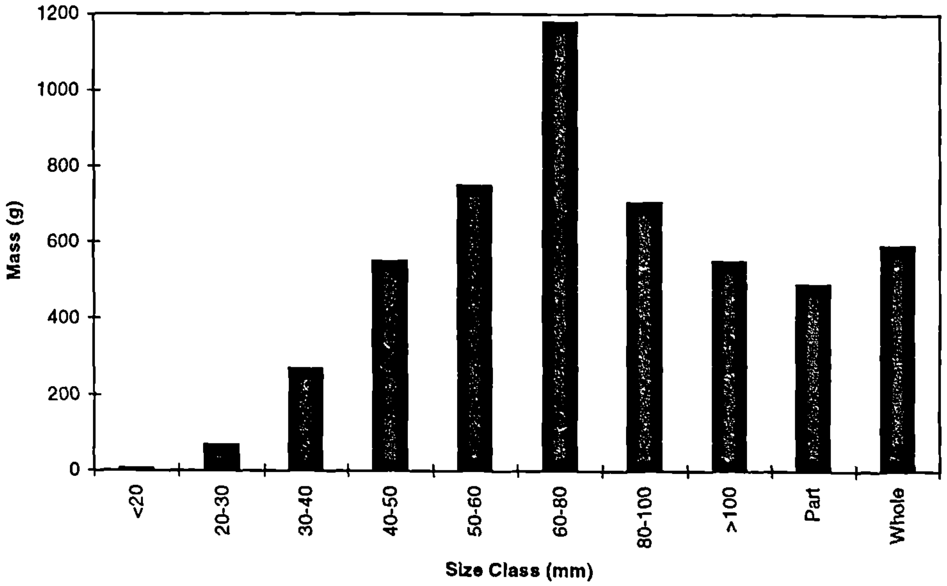


Figure 9.2 - A graph to show the masses of fragments in different size classes in the sample contexts from Wallsend (WV97)

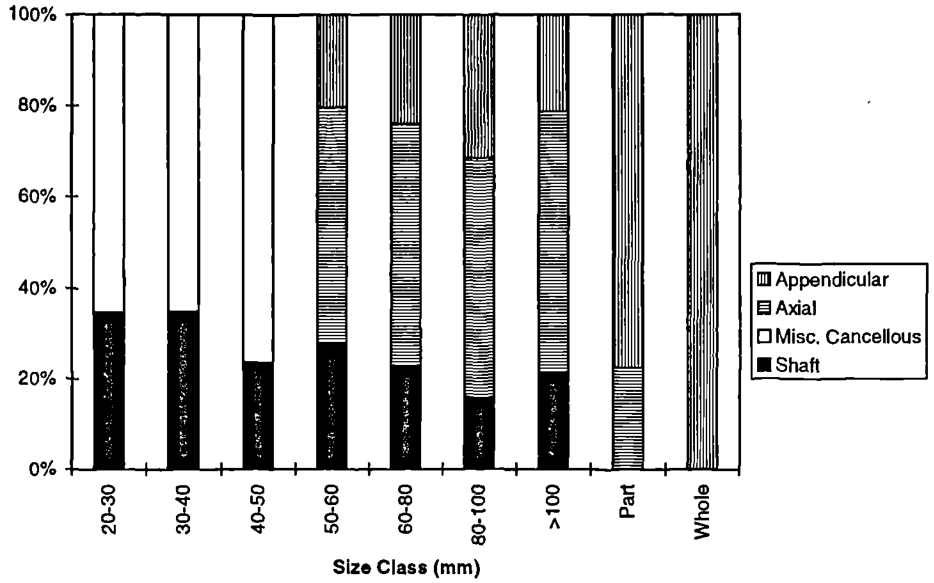


Figure 9.3 - A graph to show the proportions of different fragment types in different size classes in the sample contexts from Wallsend (WV97)

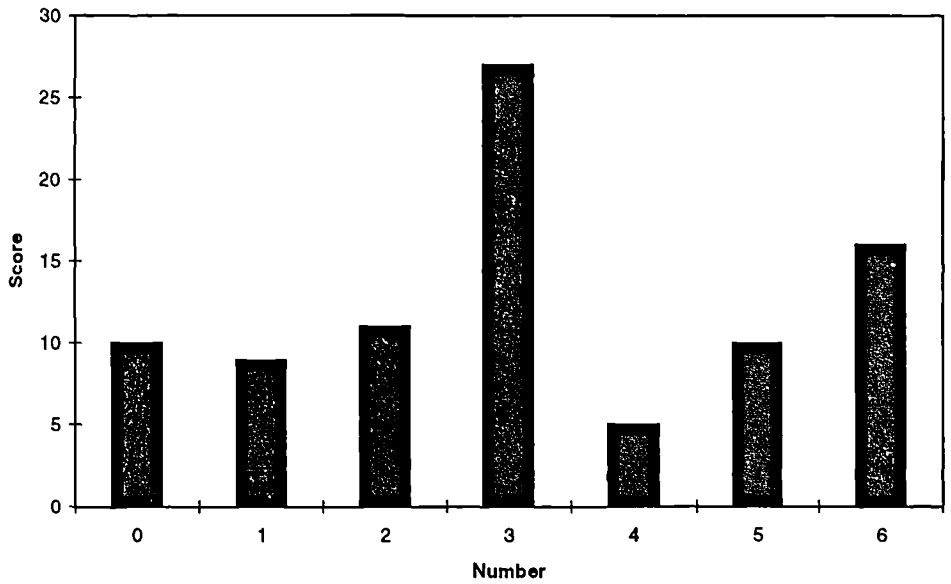


Figure 9.4 - A graph to show the distribution of fracture freshness index scores for the sample contexts from Wallsend (WV97)

CHAPTER TEN

CASE STUDY TWO: A COMPARISON OF PALAEO-ESKIMO AND MEDIAEVAL NORSE BONE FAT EXPLOITATION IN WESTERN GREENLAND

10.1 Introduction

The principal aim of this thesis is to develop a methodology for the study of bone fat exploitation in prehistory, with a view to generating more palaeoeconomic data regarding questions related to subsistence strategies. In particular, it may be of interest to study resource use changes leading up to and beyond the adoption of farming. Whilst not all the sites under consideration here are prehistoric, they are exceptional sites which are very worthy of study for a number of reasons.

Firstly, it would be useful to make a comparison between a hunter-gatherer group and a pre-modern farming group who shared the same environmental stresses. Secondly, the faunal material from Greenland is exceeding well preserved, undisturbed by later occupations and well excavated. Finally, there is far more supporting evidence available regarding the subsistence activities of these peoples than one could ever hope for in the study of the Mesolithic and Neolithic in Europe. We have much in the way of detailed ethnography regarding modern Inuit groups and Binford's (1978) ethnoarchaeological study of the Nunamiut. With regard to Medieval Norse settlement, there are historical references. Furthermore, excavations of both Inuit and Palaeo-Eskimo sites in Greenland have tended to include much environmental work, particularly in recent years.

The above aspects make this an ideal case study for testing out a methodology for the study of bone fat exploitation. A further reason for undertaking this study is that there is a recently postulated theory regarding bone fat exploitation levels at these Greenlandic sites and study of the bone assemblages can test this. This theory is based upon environmental evidence other than the bone assemblages (Buckland *et al* 1996). This theory, and the background to the sites being studied, will be discussed briefly below.

Mediaeval texts indicate that Norse colonisation of Greenland commenced sometime around AD 985 (Buckland *et al* 1996). There were two main areas of settlement, one in the West and one in the East (ibid.). The Western Settlement, located in the area of the modern Nuuk (Godthåb), is the one under consideration here. This settlement, which consisted of several farmsteads, centred around the farm of Sandnes with its stone church (McGovern 1983, Buckland *et al* 1996). The principle subsistence for the settlement came from the milk and meat of domestic livestock; cattle, sheep and goat. This was subsidised by the land-based hunting of seals, birds and caribou (ibid.). What is most surprising is that the Norse settlers did not take more advantage of marine resources. There is a virtual absence of fish bones on the sites and the equipment to carry out fishing (ibid.). Despite their proximity to Thule Inuit, from whom they could have learned much, the Norse did not develop the technology to exploit animals such as ringed seals and whales that are found out on the sea ice (Buckland *et al* 1996). They appear to have only hunted seals which could be captured on land. Nor were many plant foods exploited (ibid.). Life was clearly very hard, and Buckland *et al* (ibid.) argue that with worsening climate making the maintenance of domestic animals more difficult, a decline in trade of items, such a walrus ivory, with the mainland and a lack of will to adapt to Inuit type hunting methods rather than farming, led to the downfall of the Norse settlements. By the end of the 15th century the settlements were abandoned.

Entomological examination of the Sandnes waste middens (ibid.) shows a distinct lack of diptera (true flies) pupae, the maggots from which feed on fat. This leads Buckland *et al* (ibid.) to the conclusion that the subsistence stressed Norse had rendered all their bone waste to extract much needed fat leaving no fat for the flies to feed on. They support their theory by drawing attention to the Palaeo-Eskimo site of Qeqertasussuk. The midden at this site produced much evidence for fat-loving diptera (Böcher and Fredskild 1993). This leads Buckland *et al* (1996) to the further conclusion that the Inuit, being more suitably adapted to their environment, were under less subsistence stress than the Norse farmers and, hence, did not need to process their bone waste as extensively for fat resources.

The aim of this case study, therefore, is to see whether bone fracture and fragmentation evidence is in agreement with the above scenario put forward by Buckland *et al* (ibid.), which is based upon other environmental and palaeoeconomic evidence, with regard to the exploitation of bone marrow and grease. Four sites are studied below. Both Sandnes and Qeqertasussuk have been analysed along with another Norse farmstead, Niaquussat, and another Palaeo-

Eskimo site, Itivnera. Descriptions of each of these sites will be given below, as each is discussed in turn. Raw data relating to the Greenlandic sites can be seen in Appendix C.

10.2 Methods

The methodology applied to the Greenland assemblages was, in almost all respects, the same as that applied to Mondeval in (chapt. 8). The bone assemblage was first classified into fragment size categories and these categories quantified by both mass and number of specimens. Separation, within size classes, of different types of bone fragment was then undertaken. In some cases this was carried out to a greater level of detail than was attempted for Mondeval. Fracture index scores were calculated for all diaphysis fragments over 40mm maximum measurement but on some sites, due to excellent preservation, it was possible to study fragments down to 30mm for fracture type. These fragments were also studied for modern damage, mineralised breaks, cut marks, dynamic impact marks and gnawing. Incidences of burning were noted for all fragments in all classes. Details of differences in methodology from site to site will be discussed in the relevant sections, below.

The presence of phocid remains in the assemblages also called for changes in methodology. Seal bones do not have marrow cavities or dense diaphyseal bone. Because of this major difference, they needed to be considered separately. Seal bones were therefore separated out from the land mammal assemblage during size classification. They were themselves placed into size classes and quantified in the same way as the land mammals. Bone type separation was carried out where it was thought appropriate. Appendicular bone fragments, however, were not separated into articular and shaft, like land mammals were, since, from a fat exploitation point of view, the bones are the same along their entire length; all filled with cancellous bone. It was also impossible to carry out fracture type analysis on seal bones due to the absence of dense diaphysis bone. The details of the treatment of seal bones will be discussed in the sections on the relevant sites below.

10.3 Sandnes

10.3.1 The Site

The farmstead of Sandnes (site code V51) is the largest farm in the Norse Western Settlement and, having a church, was almost certainly at the centre of the community (McGovern 1985). Excavations at the site date back to the 1930s (Degerbøl 1936) but more recent excavations have been undertaken in the 1970s and 1980s (McGovern 1985).

The bone assemblage of the site consists of 17.57% TNB (Total Number of Bones) cattle, 12.44% TNB caprine, 32.08% TNB caribou and 37.92% TNB seal (McGovern 1985, table 6). The Sandnes site, possibly because it was of higher social status, has a higher proportion cattle, in relation to sheep and goat, a lower proportion of seal and a higher proportion of hunted caribou than the other farmsteads in the Western Settlement (McGovern 1985).

10.3.2 Sampling and Methods

The sample taken for the fracture and fragmentation study came from the 1980s excavations (McGovern *et al* 1996), since these modern excavations were likely to have produced the best level of recovery. A practical problem was encountered in the taking of the sample. This was due to the way the material was being stored. The assemblage had been separated into species classes and bones of the same contexts were not stored together. The sample for the current study needed to contain the complete contents of a given context. The difficulty in re-creating a large number of very small contexts, to make a large enough sample, meant that the choice of contexts was limited to those of sufficient size to enable a relatively large sample to be put together in a feasible amount of time. This, in practice, meant that a context from the surface of the midden had to be used as the sample. Whilst a less contextually secure surface sample would not have been the first choice, given that stratigraphic dating and later disturbance is not an issue here, it was considered that the use of this context would not affect the outcome of the study. It should be as good a bulk sample as any other from the midden.

One advantage of the species classification was that the seal component had already been removed and could be considered separately. It should be noted, however, that the indeterminate fragments, considered here along with the land mammals, may contain a proportion of unidentifiable seal cancellous bone.

The main difference in the methodology applied to this site, is that a more detailed separation of bone types in size classes was carried out. This was undertaken because a pattern soon became obvious that would not have shown up with coarser analysis. The axial category was therefore expanded into four separate categories; rib, vertebrae, cranial/girdle and miscellaneous.

10.3.3 The Land Mammals

Of the land mammal/indeterminate fragments the vast majority, in terms of number, fell into the smaller size classes (see fig. 10.13) with very few "whole" or "part" bones surviving. The numerical domination of the smaller size classes is not, however, on anything like the same scale as that found at the Mondeval site (chapt. 8). When one quantifies the size classes by mass the result is quite the opposite (see fig. 10.14), with many fragments surviving to over 100mm maximum dimension. At Mondeval the smaller size classes dominated by mass as well as number. It should be noted, however, that there are very few "whole" or "part" bones surviving at Sandnes, irrelevant of quantification method.

On the face of it, it appears that Sandnes does not represent a site of extreme bone grease exploitation like Mondeval. If the proportions of fragment type in size classes are considered (fig. 10.15), though, bone grease exploitation becomes the most likely explanation for the pattern. It can be seen that the bulk of the smaller size classes consist of miscellaneous fragments of articular and axial cancellous bone (see fig. 10.1). In the larger size classes shaft fragments become much more dominant (fig. 10.2), whilst both vertebral and articular bone is very rare. The principle reason why the shaft fragments are not more dominant in the larger size classes, and these size classes are well represented in terms of mass, is that much relatively undamaged rib material survives (fig. 10.3).

Analysis of fracture type on shaft fragments (including those in the 30-40mm class due to good preservation) showed that the vast majority of fractures were fresh (see examples in fig. 10.2). Fracture index scores of zero by far dominated with hardly any fragments scoring above three (fig. 10.16). The fracture freshness index average score was 0.83 (table 10.1). This is very low, indicating that the assemblage has suffered little breakage since the bones were fresh. Furthermore, there is much direct evidence of deliberate fragmentation of the fresh bones by humans. The incidence of dynamic impact scars (e.g. fig. 10.4) on shafts is 8.94%, which is very high when one considers that only the fragments at the place of striking will carry the marks of impact.

There is little evidence of post-depositional attrition. Only 3.41% of specimens studied had any traces of possible animal gnawing. As few as 3.83% of specimens showed any trace of having been broken after the bone had become mineralised and only 1.28% had been broken during or since excavation. Figure 10.17 shows the proportions (to nearest 1%) of specimens that carry 0,1,2 and 3 of these indicators of post-depositional attrition. As can be seen, all but a few showed no indicators. It seems indisputable that almost all the breakage in this assemblage occurred prior to deposition, while the material was fresh, and largely by human hand. The site had very much less post-depositional damage than at Mondeval (chapt. 8).

Levels of burning in the assemblage were low (under 1%) in all size classes (see fig. 10.18).

The overall interpretation, regarding the land mammal bones at Sandnes, is that marrow has been exploited from almost all appendicular elements, and that almost all appendicular epiphyses and vertebrae were being broken in the process of bone grease rendering. Ribs were not being exploited. The general absence of epiphyses cannot easily be explained in any other way. Although one normally expects a lower representation of vertebrae and some of the low density epiphyses, as they are more prone to attrition than dense shaft material, this cannot be the explanation in this case. Firstly, the pattern is more excessive than normal. Secondly, the equally attrition-prone ribs survive well. Thirdly, there is strong evidence that little post-depositional attrition took place.

This, coupled with the good evidence for deliberate human fragmentation and the lack of fat eating diptera maggots in the midden (see above), provides a strong argument that most sources of bone grease, with the interesting exception of the ribs, were being exploited. The reasons for the overall lesser degree of fragmentation at Sandnes, when compared to Mondeval, are likely to be that at Mondeval ribs were also fragmented and the assemblage at Mondeval had suffered a greater level of post-depositional attrition.

10.3.4 The Phocid Remains

The number of seal bones recovered from this sample was not huge but useful comment may still be made. In numerical terms, the distribution of fragments across the size classes was relatively even (see fig. 10.19), unlike the land mammal (fig. 10.13), and there were few in the smallest class or the part/whole classes. When quantified by mass (fig. 10.20), the distribution, like with the land mammals (fig. 10.14), is biased to the larger size classes, but still with few whole or part bones represented. The interpretation, however, must be different.

Almost all seal elements are made up of cancellous bone, and as such, must be considered in an analogous fashion to land mammal axial and epiphysial fragments, from a bone fat resource point of view. The seal bone assemblage, therefore, represents a large quantity of unprocessed material (see fig. 10.5), if one considers how little cancellous bone survived in large size classes in the land mammal assemblage. One must conclude that seal bones were probably not being rendered for bone grease and cannot have been exploited for marrow due to their lack of medullary cavities.

10.4 Niaquussat

10.4.1 The Site

The farmstead of Niaquussat (V48) also lies in the Western Settlement, but has a somewhat different representation of species within its faunal assemblage. It can probably be regarded as a site of lower status than the Church farm of Sandnes and, as such, is worthy of study in giving as fuller picture of Norse subsistence activities.

The site was excavated between 1976-77 and is very rare amongst the sites in providing a well stratified midden which can be phased (McGovern 1985). The three phases have very similar statistics regarding species composition. There are far fewer cattle at Niaquussat by comparison to Sandnes; only 1.15-2.96% TNB. The proportion of caprine bones is similar at 9.11-11.21% TNB. There are fewer hunted caribou, at only 4.75-6.56% TNB, the major constituent of the assemblage being seal at 79.27-84.99% TNB (McGovern 1985, table 6).

10.4.2 Sampling and Methods

The sample taken for fracture and fragmentation study came from the area of the midden which stands to the greatest height (circa 140cm) (unpublished archive material, Copenhagen Zoological Museum). The bones studied came from a metre squared column (column C9) that was dug through the entire depth of the midden and included material from all three phases. Unfortunately, there was not sufficient material from the earlier phases to give a large enough sample size to study changes in fracture/fragmentation temporally. Most of the material studied can be attributed to the latest phase (phase III).

Unlike Sandnes, the material from Niaquussat had not been segregated according to species. This made sampling easier but also meant that phocid and land mammal bones had to be separated during analysis. The separation carried out on this material was thorough in the larger size classes, but it is possible the separation was not complete in the smallest size classes. The indeterminate fragments were counted with the land mammal bones. Once again, it was possible to include the 30-40mm size class in the fracture study due to good preservation of fracture surfaces.

10.4.3 Results

If the numerical distribution of fragments across size classes, for the whole assemblage (including seal), is considered (fig. 10.21), it can be seen that the small categories very much dominate, but there is a slight recovery in representation in the "whole" class. If the data is plotted with seal bones discounted (fig. 10.22) the domination of the smaller size classes becomes more complete with virtually no representation in very large, "part" and "whole" classes.

Figure 10.23 shows the size classes as quantified by mass. Seal and land mammal bones are indicated by different shading. Taking the assemblage as a whole, it is dominated, in terms of mass, by the larger size classes. If one examines the land mammals alone, however, it is clear that, although there is a dip on the smallest class, the smaller classes dominate. There are very few "whole" or "part" land mammal bones. The land mammal assemblage can, therefore, be characterised as very fragmented.

It is fairly clear that the vast majority of seal bones remain relatively unfragmented. Although, as previously intimated, some unidentifiable seal bone fragments will have been classified with the land mammals, the absence of seal from the mid-range size categories cannot be explained by this, suggesting that the seal assemblage does indeed survive in largely unfragmented state. In fact, there are many very well preserved whole bones (fig. 10.6) representing all portions of the skeleton.

If fragment types in each size class are considered (fig. 10.24), it can be seen that axial/articular bones dominate until the 80-100mm class. The amount of shaft bone increases with size (with the exception of the >100mm class). It is clear that most of the cancellous bone surviving in the large size classes is axial (once again it was mainly rib) rather than articular fragments. Very little articular material survives without much fragmentation.

The fracture type study once again pointed towards most breakage having resulted from fresh fracture. Figure 10.25 shows the distribution of fracture freshness index scores. Fragments scoring zero once again dominate. The average of fracture index scores was 1.11 (N=208) (table 1). Examples of fresh-fractured shaft splinters from Niaquussat can be seen in figure 10.7. Indicators of post-depositional damage were once again scarce. 3.84% of specimens showed evidence of animal gnawing, only 2.4% had clearly been broken after mineralisation and 1.92% appeared to have been broken during excavation or storage. Most fragments (circa 94%) showed none of these indicators of post-depositional damage, the rest showed only one (fig. 10.26).

Like Sandnes, Niaquussat showed a high incidence of dynamic impact marks at 8.65% (table 1). This is, once again, suggestive of most fracture being deliberately carried out by human hand.

Levels of burning were significantly higher than at Sandnes. Over 30% of fragments appear to be burnt at Niaquussat in the smallest size class, but the incidence of burning drops off in the larger size classes (fig. 10.27). This is not surprising if bone grease rendering was being practised, with many small fragments being treated in the proximity of fire. It is more surprising that the level of burning at Sandnes was so low, unless fire discharge was middened separately. Only 0.48% of Niaquussat fragments bore obvious evidence of butchery cut marks (table 1).

10.4.4 Discussion

It appears that, at Niaquussat, there was very similar exploitation of bone fat to that at Sandnes. Once again, the land mammal assemblage is heavily fragmented. This fragmentation is not due to post-depositional attrition. It occurred largely whilst the bones were fresh and there is good evidence that it was by human hand. Most articulations appear to have been fragmented along with much axial material, but not all. It seems that marrow was being exploited and bone grease rendered from epiphyses and some axial elements. Once again the ribs appear not to have been exploited much for their fat content.

It is very clear at this site that seal bones were not being fragmented and, as such, do not appear to have been exploited for bone fat.

10.5 Qeqertasussuk

10.5.1 The Site

The Palaeo-Eskimo site of Qeqertasussuk is located in the Southern part of Disco Bay (Grønnow 1988; Böcher and Fredskild 1993) and is of the Saqqaq Culture

(2400-1000 BC cal.) (ibid.). The site itself has ^{14}C dates giving a range of occupation from 3900-3100 BP uncal. (Böcher and Fredskild 1993). The site was excavated between 1984-87 and very well preserved organic remains were recovered from the permafrost peat (ibid.). The specialist zooarchaeological report is not yet published, but the faunal assemblage includes many species including seal, fish, whale, caribou and many bird species including the great auk (ibid.).

It is, however, clear that the vast majority of the assemblage is phocid (J. Møhl pers. com.) and the other component species form a very small proportion. The site is effectively a specialist seal hunting site. This was certainly born out in the sample studied here for fragmentation.

10.5.2 Sampling and Methods

The sample taken for study came from one of the main midden areas (Felt C Vest, 82/250:2) and was a discrete contextual unit that remained unsorted. There were literally only a handful of bones that were not phocid; a few bird bones and only two indeterminate land mammal specimens. This study is, therefore, just a study of seal bone fragmentation. As previously intimated, seal bones cannot be studied for fracture type, not having dense diaphysis bone.

10.5.3 Results

Figure 10.28 shows the assemblage split into size classes by number. This graph also distinguishes between bone types (miscellaneous, appendicular, misc. axial, vertebral, rib). Fragments below 30mm, where identification of bone type was difficult, have been classed in a single category as miscellaneous. It can be seen that, in numerical terms, the smaller categories dominate but there is a recovery in values in the "part" and "whole" categories. All parts of the skeleton are represented and many appendicular elements survive whole.

If one considers the size class divisions by mass (fig. 10.29), it is the "part" and "whole" categories that by far dominate, with both axial and appendicular (particularly appendicular elements) surviving undamaged. The degree of preservation at this site is excellent and it was just about possible to create whole reference skeletons from the archaeological material. Figures 10.8 and 10.9 show some of the undamaged phocid assemblage.

From the distinct lack of fragmentation it must be concluded that seal bone was not broken up for bone grease rendering in any quantity. The seal bones were therefore being middened with their full fat content, explaining the high incidence of fat eating diptera in the midden deposits (Böcher and Fredskild 1993, Buckland *et al* 1996).

10.6 Itivnera

10.6.1 The Site

Itivnera is a Palaeo-Eskimo hunting camp of the Saqqaq culture and is located at the head of a fjord in the Godthåbsfjord complex (Møhl 1972). This is relatively close to the area of the Norse Western Settlement. The site has been radio-carbon dated to 2960±100 BP uncal. It was excavated in 1960 (ibid.).

The site is a specialist caribou hunting site with caribou comprising circa 95% of the bone assemblage. Around 2% of the assemblage is seal and the remaining 3% is comprised of various sea bird species. There are 6 specimens of arctic fox (ibid.).

10.6.2 Sampling and Methods

Due to the earlier date of the excavation it is possible that recovery was not as complete as that attained in the other, more recent, excavations studied here. Certainly no sieving took place (J. Møhl pers. com.). As a result, values in the smallest size categories may be artificially depressed. This will be borne in mind during discussion.

The sample taken for the fracture and fragmentation study was taken from a midden context of area B (Pose 3, V-1). This assemblage was previously unstudied; area A was studied for Møhl's (1972) report. This made sampling easier since, like Sandnes, the studied Itivnera material had been separated according to bone type, not context. The area B material remained in discrete contextual units.

10.6.3 Results

When the Itivnera assemblage is divided into size class by number (see fig. 10.30), the smaller size classes dominate (apart from the smallest class which is likely to be depressed through lower recovery levels). There are, however, not an insignificant number of "part" and "whole" elements when compared to Sandnes or Niaquussat. Taken by mass (fig. 10.31) the larger size classes dominate. This is a picture not too dissimilar to that at Sandnes except for very strong representation of "part" or "whole" bones. Some examples of relatively undamaged elements can be seen in figure 10.10.

If the separation of bone type by size class (fig. 10.32) is examined, it is clear that shaft fragments dominate, particularly in the larger classes. Many of the large shaft pieces are in fact complete diaphysis cylinders (see fig. 10.11) exhibiting fresh spiral fractures at both ends. This suggests the deliberate removal of the epiphyses of bones. This is a practice noted by Binford amongst the Nunamiut Eskimo (Binford 1978). The removal of the epiphyses was primarily carried out so the articular ends could be stored up for bone grease rendering. It also meant that the contents of the medullary cavity could be easily poked out (see chapt. 1).

It should also be noted that, like at Sandnes, very little articular material survives in the large size categories (apart from the part/whole classes).

The assemblage at Itivnera is even more dominated by fresh fractures than at the other sites discussed (see fig. 10.33) and no fracture index score of above three has been recorded. The fracture freshness index score average is an extremely low 0.36 (N=544) (table 1). Evidence of post-depositional damage is, again, slight. 0.18% of specimens studied displayed mineralised fractures, no carnivore gnawing was noted (although bone surface preservation was not as good at this site as the others) and only 3.12% displayed modern breaks (table 1). Considering all the indicators of post-depositional damage together, circa 94% of fragments displayed no indicators at all and the remaining 6% displayed only one (fig. 10.34).

A very large number of dynamic impact marks were noted at the site. In fact, 15.07% of fragments had such marks. A number of these specimens displayed both impact and rebound marks (see chapt. 4.1) (see fig. 10.12). This feature is indicative of the use of a hammer and anvil in fracturing bones. The impact mark is created by the hammerstone but an equal and opposite force is exerted upon the other side of the bone, from the rebound off the anvil, creating a similar mark. The very strong evidence for much dynamic fresh fracture and the lack of post-depositional damage suggests that the vast majority of breakage occurred by human hand.

Only a small proportion of burning was noted in the small size categories (fig. 10.35). No obvious cut marks were noted (again this might be related to cortical surface condition).

10.6.4 Discussion

It is very clear that marrow was regularly exploited at Itivnera with the presence of some classic indicators. If one discounts the part/whole classes, the fragmentation pattern very much resembles that at Sandnes. That is, one in which fresh fractured shaft fragments dominate the larger size classes and very little articular bone survives. This is a pattern indicative of bone grease rendering. This is further supported, at Itivnera, by the presence of bones with the articulations deliberately removed. This practice is ethnographically associated with bone grease production.

It seems likely that bone grease rendering was taking place at Itivnera. However, given that there are also a fair proportion of bones and bone parts that survive undamaged, it also seems unlikely that the exploitation of bone grease was as intensive at Itivnera as it was at Sandnes or Niaquussat. At those sites very few potential bone grease sources were ignored (perhaps just the ribs), whereas at Itivnera many, some whole, appendicular bones and articulations seem to have been disposed of unprocessed.

10.7 Discussion

10.7.1 Phocid Bone Lipids

In all three sites where seal bones were studied, Sandnes, Niaquussat and Qeqertasussuk, it appears that phocid bones were not being utilised for their fat content. The reason why both Norse and Inuit peoples ignored an apparently useful resource may, in part, lie in the lipid chemistry of marine mammals.

Seal fats, or oils as we should correctly call them since they are liquid at room temperature, contain many highly unsaturated fatty acids (Hilditch and Pathak 1947; Shahidi *et al* 1994; Erasmus 1986) which can have up to six double bonds (see chapt. 2.4) in their carbon chain (ibid.). Some of the constituent fatty acids in seal oil, such as eicosapentaenoic acid (20:5), docosapentaenoic acid (22:5) and docosahexaneoic acid (22:6) (Shahidi *et al* 1994; Erasmus 1986), have melting points as low as -40°C or -50°C (Erasmus 1986, p206). Preparation of seal oils for analysis, in fact, requires a low-temperature rendering process (Hilditch and Pathak 1947; Shahidi *et al* 1994).

The ethnographically encountered Inuit method of rendering bone for its fat content (see chapt. 1) is to boil bone fragments in water, whereupon the molten fat floats to the surface. This surface layer of fat is then congealed by cooling it by the addition of cold water or snow (Binford 1978). Clearly this method would not work for seal bones whose lipid contents are low melting oils. In fact, it is hard to envisage how any rendering process could be attempted on seal bones at the given technological level. This provides one very cogent reason for the low level of fragmentation in the seal bone assemblages.

Furthermore, this author cannot find any ethnographic account of seal bones being rendered for fat. Balikci (1970, p85) describes, in great detail, the use and processing of seal carcasses by the Netsilik Eskimo. He states that "with the *exception of the bones*, the whole seal was utilized" (ibid., emphasis added) and goes on to detail how the blubber is utilised for oil. There is, therefore, on both theoretical and ethnographic grounds, good reason to believe that seal bones are not fragmented for the extraction of lipids.

10.7.2 Fat Exploitation and Seasonality

A second reason why seal bones are not exploited for their bone lipids, whilst land mammal bones are, may be related to seasonal levels of fat supply (Buckland and McGovern, pers. com. 1997). Seals provide a very large quantity of fat from their blubber and, as a result, when sealing is taking place, there will be a glut of fat.

Exploitation of seal bones for fat at this time may be an irrelevance. In the case of the Norse settlers, sealing most likely took place in the spring (McGovern 1985 p101) and, at this time, fat supply was probably good. Slaughter of domestic mammals would almost certainly have taken place in the autumn, in order to reduce the number of animals requiring fodder over the winter. The supply of fat for the winter months would, therefore, probably have come from the bones of those slaughtered animals. Land mammal bones are, therefore, heavily fragmented.

10.8 Conclusion and Implications

It seems clear, from examination of the Sandnes and Niaquussat assemblages, that the Medieval Norse settlers of Greenland were fairly exhaustively exploiting the bones of land mammals for bone marrow and grease. This agrees with the conclusion of Buckland *et al* (1996), based on entomological evidence, that the subsistence stressed Norse needed to exploit all their available resources. These resources, however, did not extend to the rendering of seal bones (for the reasons discussed above), which remain relatively unfragmented.

Buckland *et al*'s (ibid.) conclusion that, based upon the presence of many fat eating diptera in the middens, the Palaeo-Eskimo inhabitants of Qeqertasussuk were less stressed than the Norse and able to ignore bone fat as a resource, is, however, slightly flawed. Since the Qeqertasussuk assemblage contains little other than unutilisable seal bones, the middens would be full of oily bones and, hence, fat eating diptera. The presence of these diptera cannot, therefore, be taken as an index of degree of resource stress at sites with seal dominated faunal assemblages.

The basic premise put forward by Buckland *et al* (ibid.), that the well-adapted Palaeo-Eskimos were less stressed, may still prove correct. At the Palaeo-Eskimo caribou hunting site of Itivnera there is good evidence for both marrow and bone grease exploitation. However, at that site, processing does not appear to have been as exhaustive as that noted for the Norse sites. This suggests that the Palaeo-Eskimo were less stressed and able to leave some sources of fat unutilised. It would, however, be valuable to assess other types of Palaeo-Eskimo sites, rather than just a specialist hunting camp, to see whether this is a uniform pattern.

A further implication of the dichotomy between unprocessed, unfragmented seal bones and exhaustively processed, very highly fragmented land mammal bones is that quantification of species abundances by zooarchaeologists will be badly distorted. The vast majority of land mammal bones will be rendered (literally) unidentifiable and will not be quantified, whereas most seal bones will survive in an identifiable state and be counted. This suggests that many of the species representation statistics for Norse sites will seriously over-represent seal remains.

This case study has demonstrated the usefulness of bone fracture and fragmentation analysis as a palaeoeconomic tool. It has also highlighted the need to be wary of assumptions regarding the utility of different species of animals and indicated the importance of bone grease rendering as a taphonomic agent. The Mondeval case study (chapt. 8) dealt with a single site, a limited number of animal species and simply demonstrated that bone grease exploitation almost certainly took place. This case study illustrates the application of bone fracture and fragmentation analysis to sites where there are more complex palaeoeconomic issues. It has been demonstrated that the methodology is successful in bringing more light to bear on these issues, including the comparison of different economies in the same region and climate, the differential use of different animal food species and the effects of seasonality in a marginal environment.

	Sandnes	Niaquussat	Itivnera
Fracture Study Sample Size	235	208	544
Mean Fracture Index Score	0.83	1.11	0.36
% Gnawed	3.41	3.84	0.0
% Impact Marked	8.94	8.65	15.07
% Mineralised Fractures	3.83	2.40	0.18
% Cut Marked	0.43	0.48	0.0
% Modern Fractures	1.28	1.92	3.12

Table 10.1 - Summary of fracture study statistics for Sandnes (V51), Niaquussat (V48) and Itivnera

Figure 10.1 - Small fragments of cancellous bone from Sandnes (V51) (5cm scale)

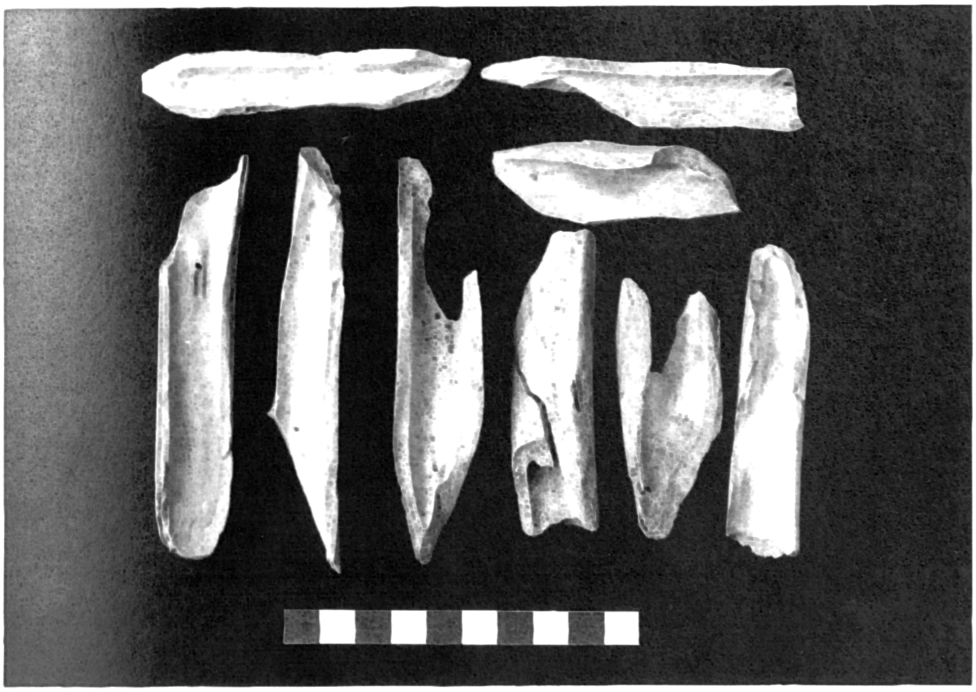


Figure 10.2 - Fresh-fractured shaft splinters from Sandnes (V51) (10cm scale)

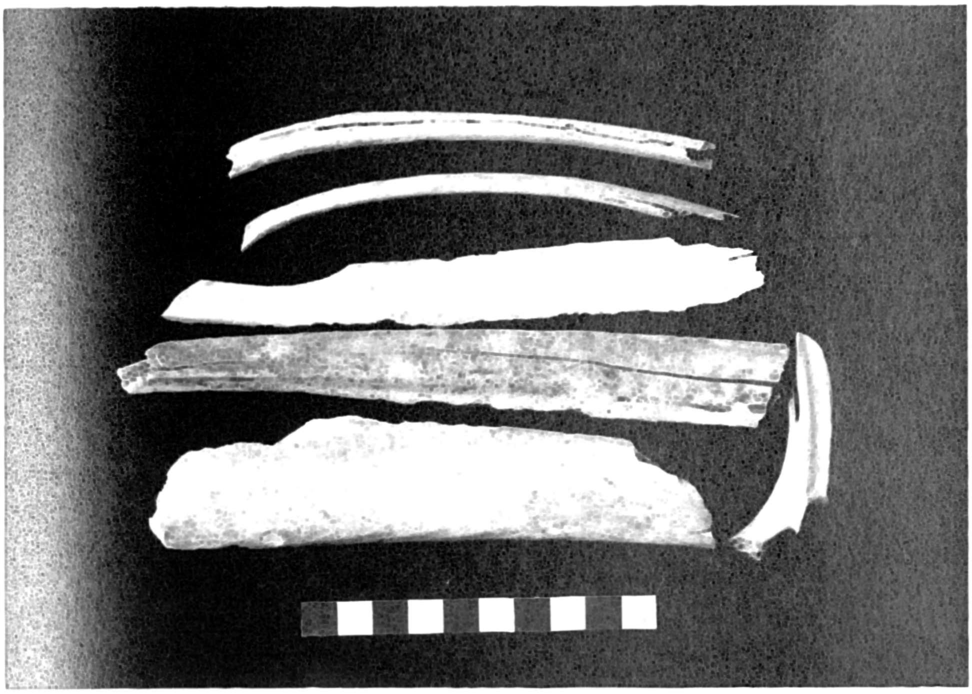


Figure 10.3 - Large fragments of ribs from Sandnes (V51) (10cm scale)

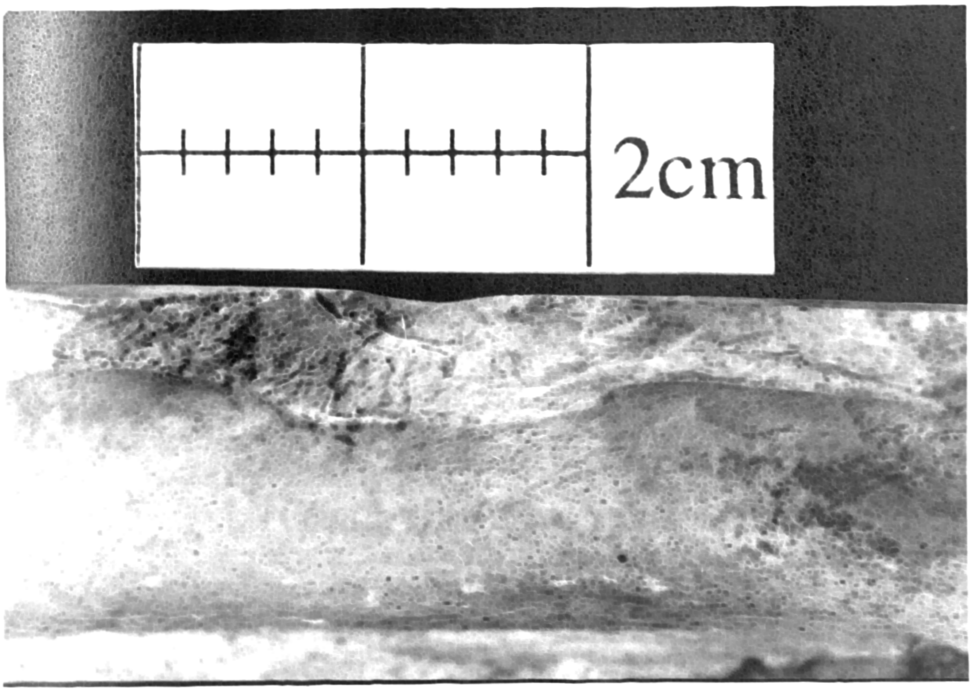


Figure 10.4 - A dynamic impact scar on a shaft fragment from Sandnes (V51)

Figure 10.5 - Various phocid bone fragments from Sandnes (V51) (10cm scale)

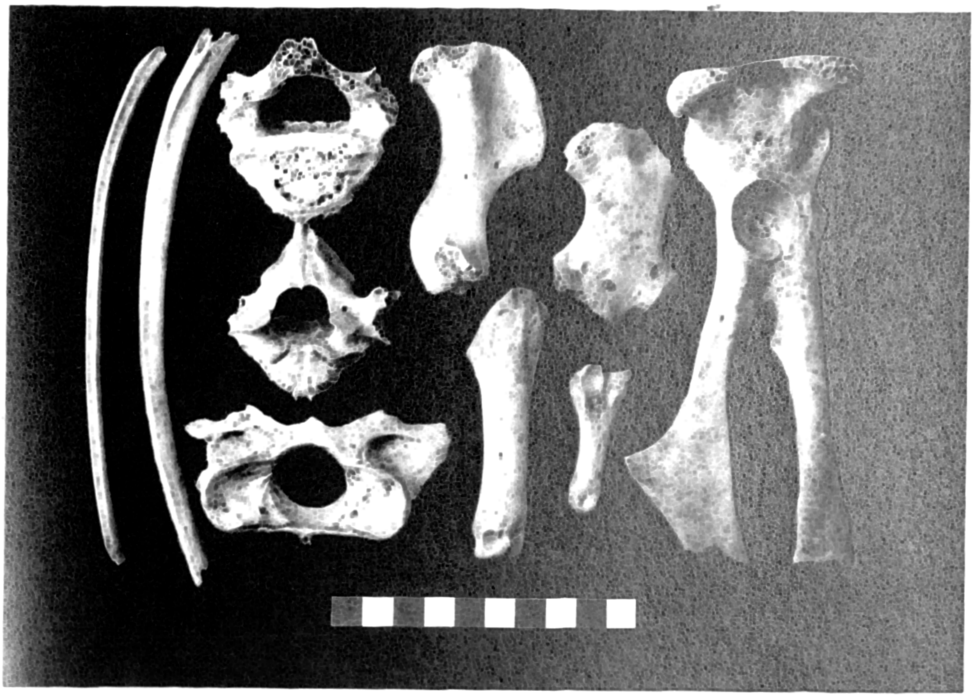


Figure 10.6 - A number of relatively undamaged phocid elements from Niaquussat (V48) (10cm scale)

Figure 10.7 - Fresh-fractured shaft splinters from Niaquussat (V48) (5cm scale)

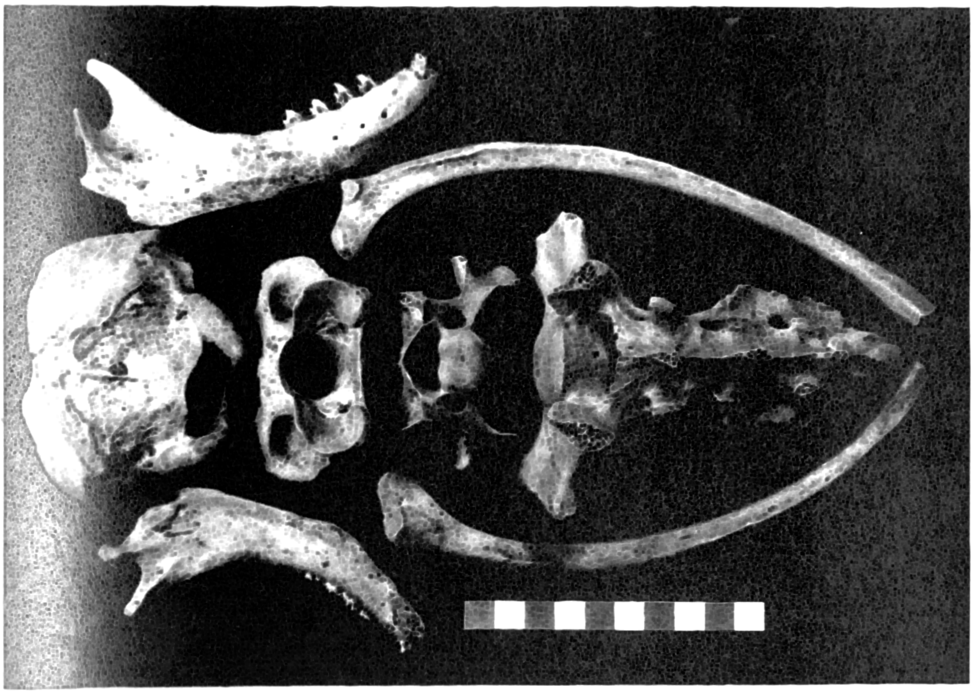


Figure 10.8 - Undamaged axial and cranial phocid elements from Qeqertasussuk (10cm scale)

Figure 10.9 - Undamaged appendicular phocid elements from Qeqertasussuk (10cm scale)

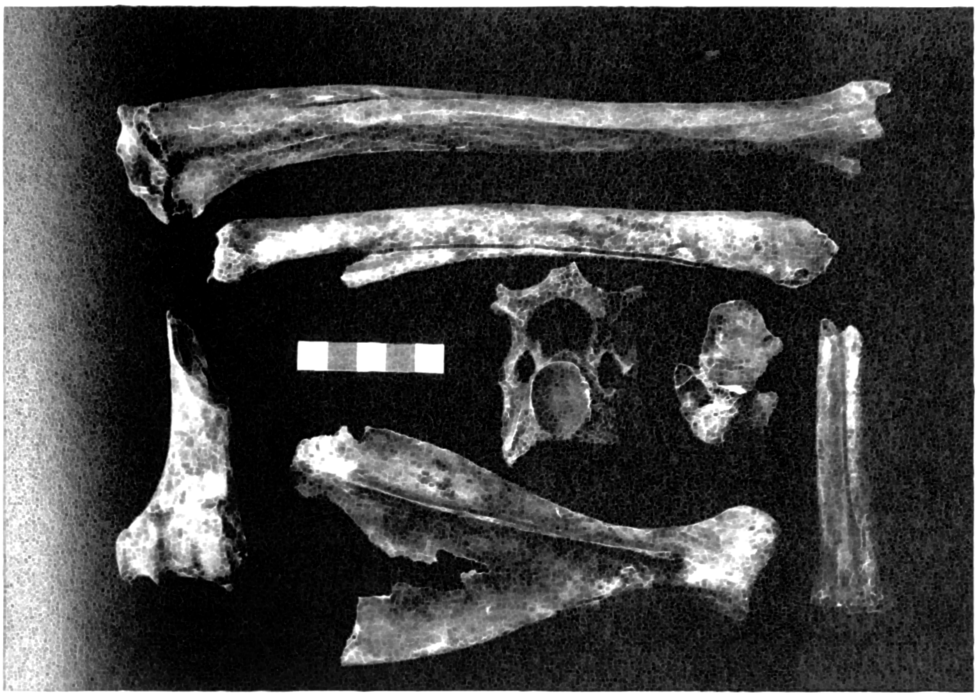


Figure 10.10 - Several relatively undamaged caribou elements from Itivnera (10cm scale)

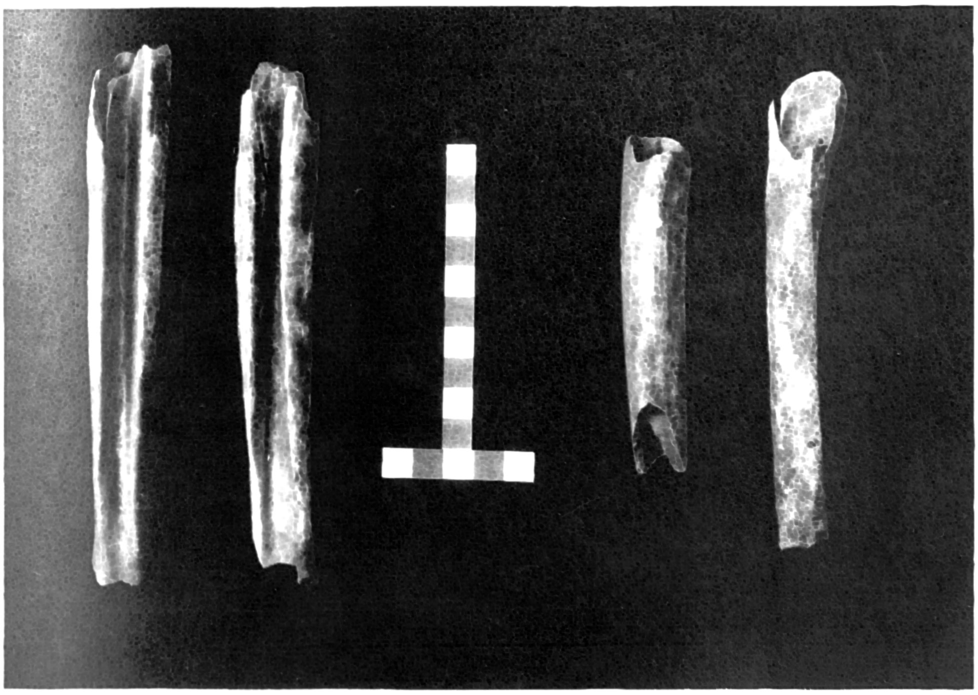


Figure 10.11 - Two tibia shaft cylinders (right) and two metatarsal shaft cylinders (left) of caribou from Itivnera, with fresh fracture types (scale in 1cm divisions)

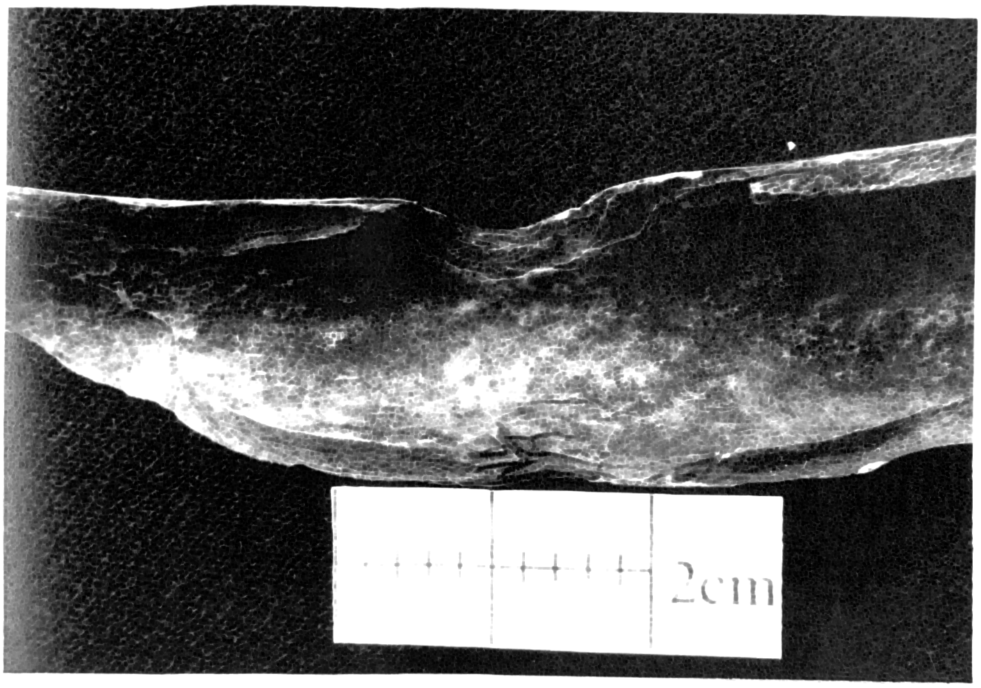


Figure 10.12 - An example of dynamic impact scar with accompanying anvil rebound scar on a shaft fragment from Itivera

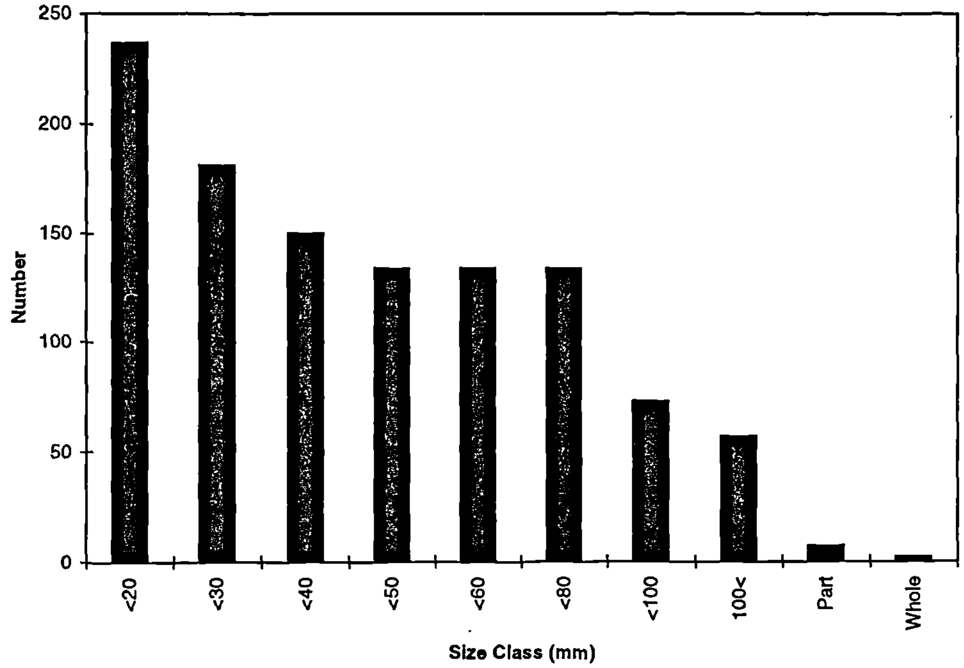


Figure 10.13 - A graph to show the numbers of fragments in each size class in the sample from Sandnes (V51) (phocid excluded)

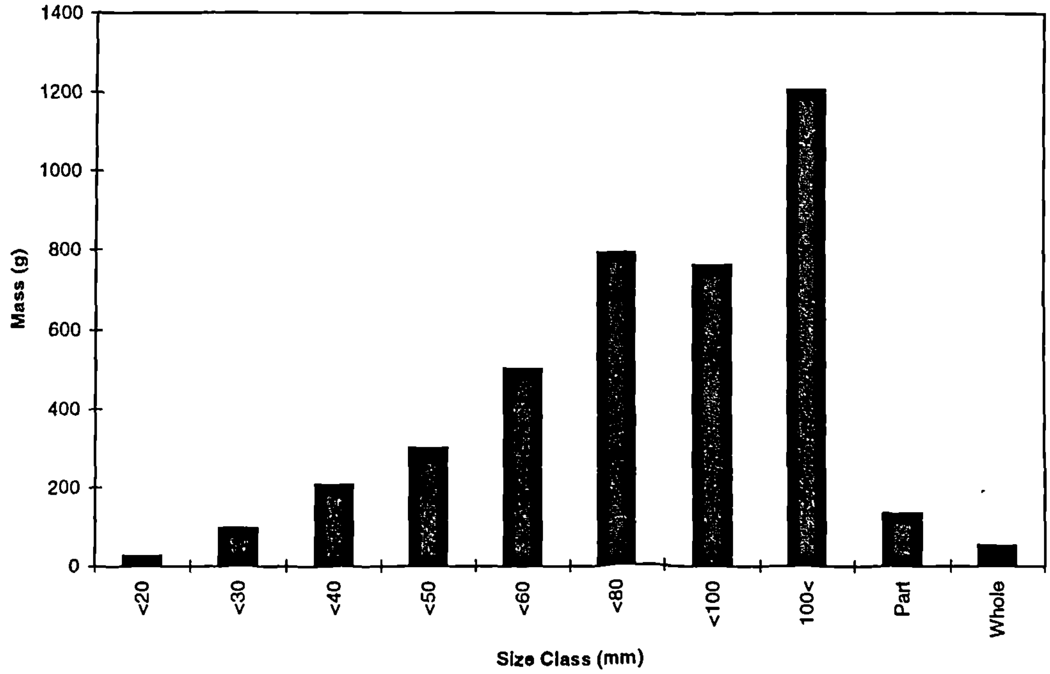


Figure 10.14 - A graph to show the masses of fragments in each size class in the sample from Sandnes (V51) (phocid excluded)

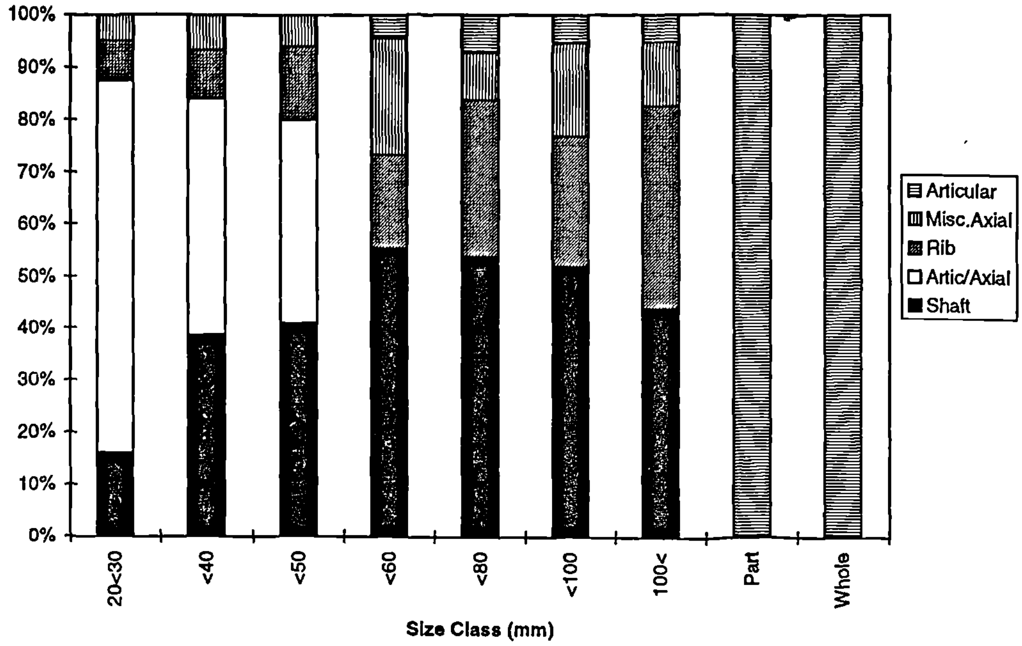


Figure 10.15 - A graph to show the proportions of different fragment types in each size class in the sample from Sandnes (V51) (phocid excluded)

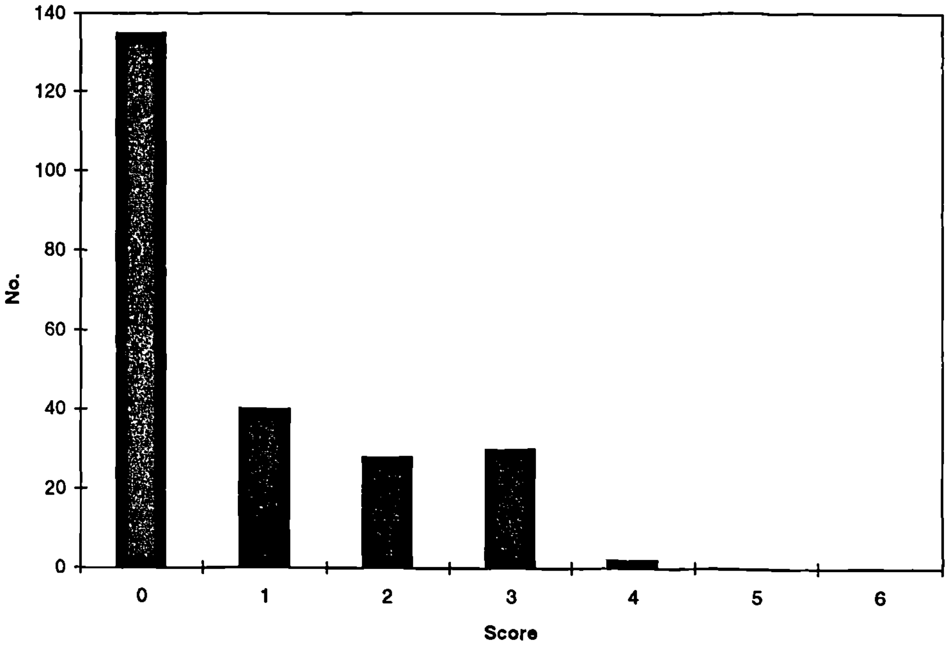


Figure 10.16 - A graph to show the distribution of fracture-freshness index scores for the sample from Sandnes (V51)

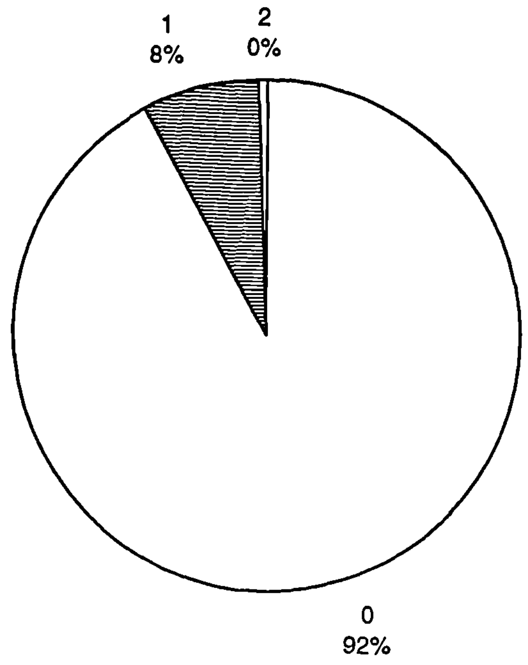


Figure 10.17 - A graph to show the proportions of fragments at Sandnes (V51) with 0, 1, 2 or 3 indicators of post-depositional damage (indicators being modern breaks, mineralised breaks and gnawing)

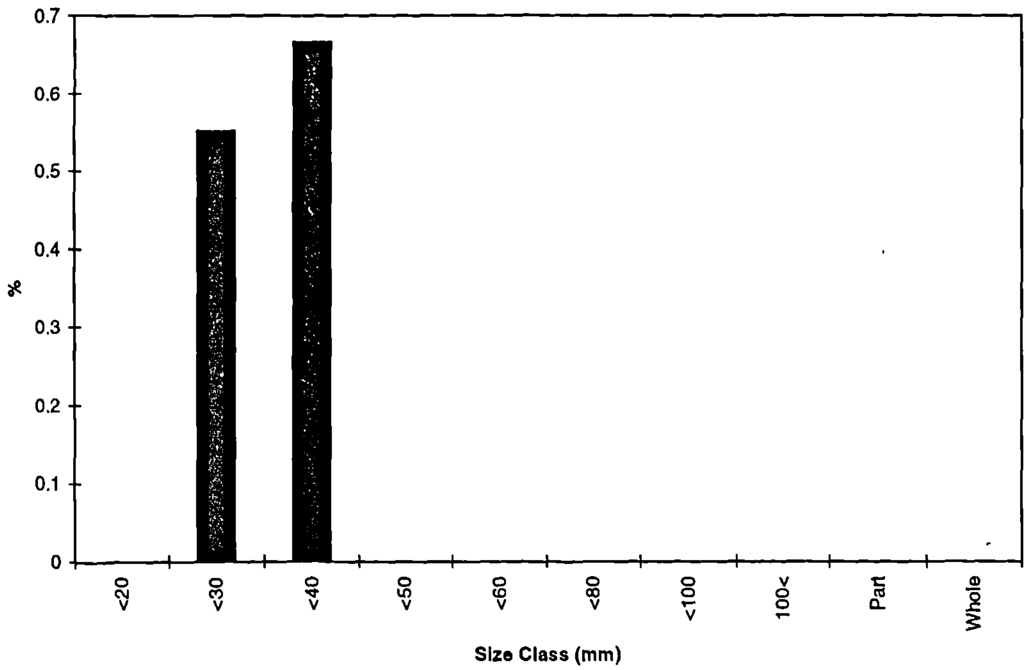


Figure 10.18 - A graph to show the numbers of burnt fragments in each size class in the sample from Sandnes (V51)

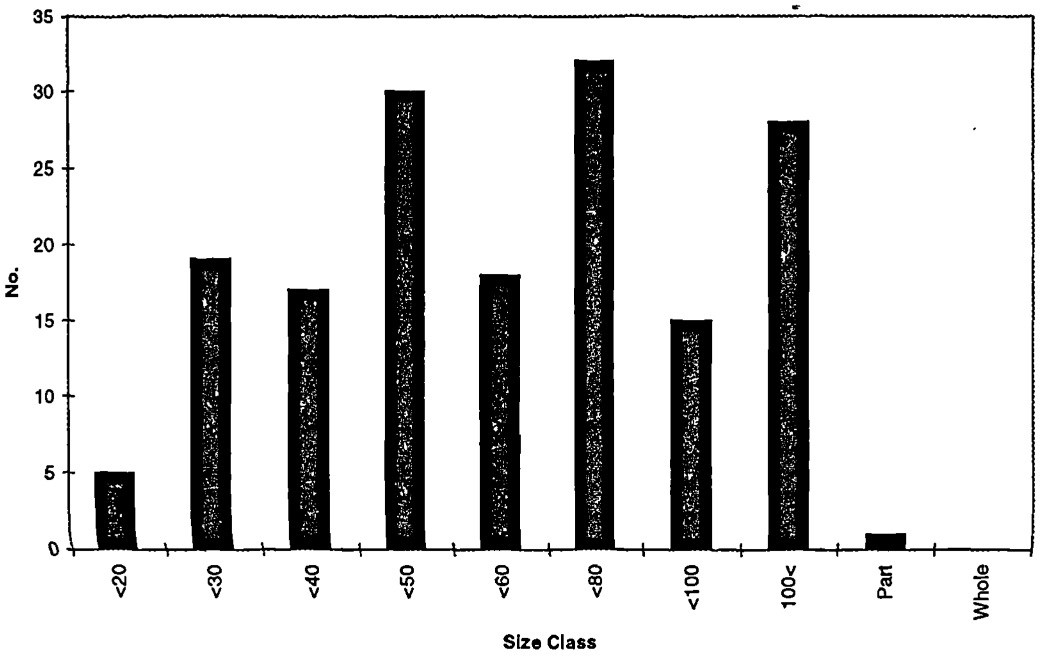


Figure 10.19 - A graph to show the number of phocid bone fragments in each size class at Sandnes (V51)

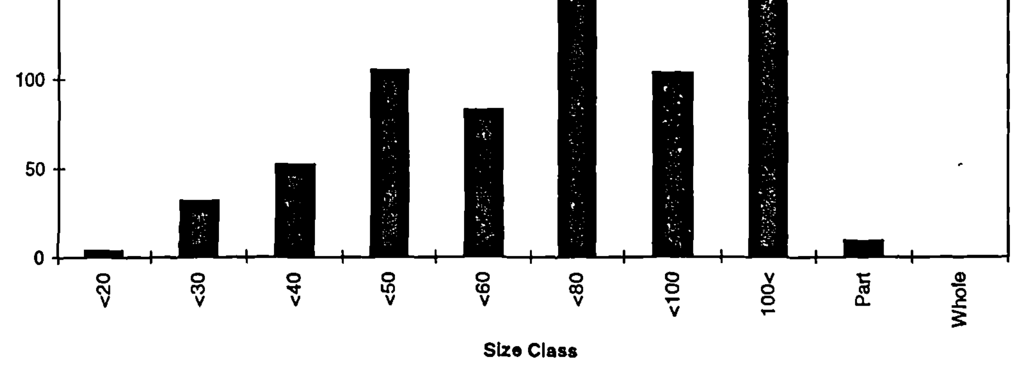


Figure 10.20 - A graph to show the masses of phocid bone fragments in each size class at Sandnes (V51)

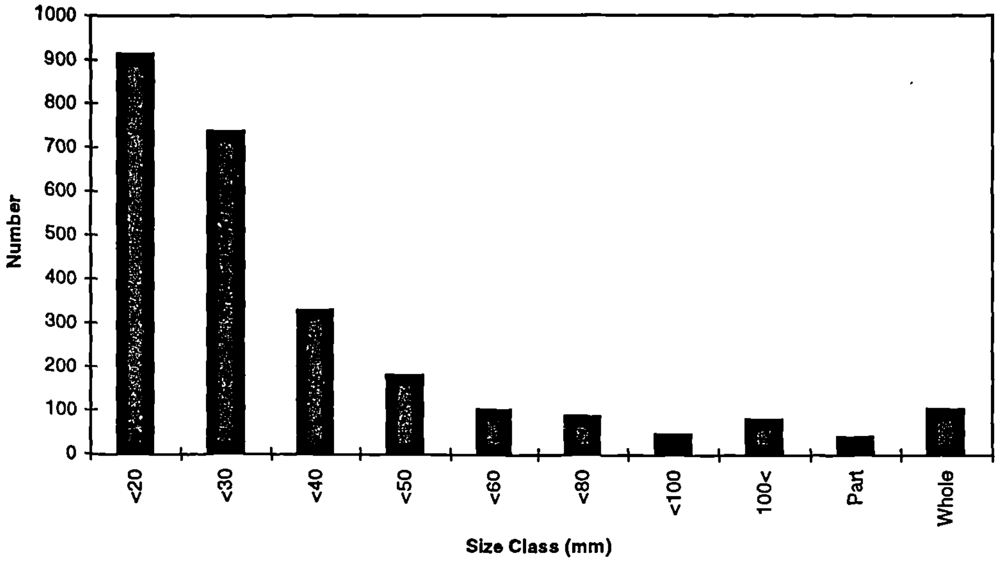


Figure 10.21 - A graph to show the number of fragments in each size class at Niaquussat (V48) (all fragments)

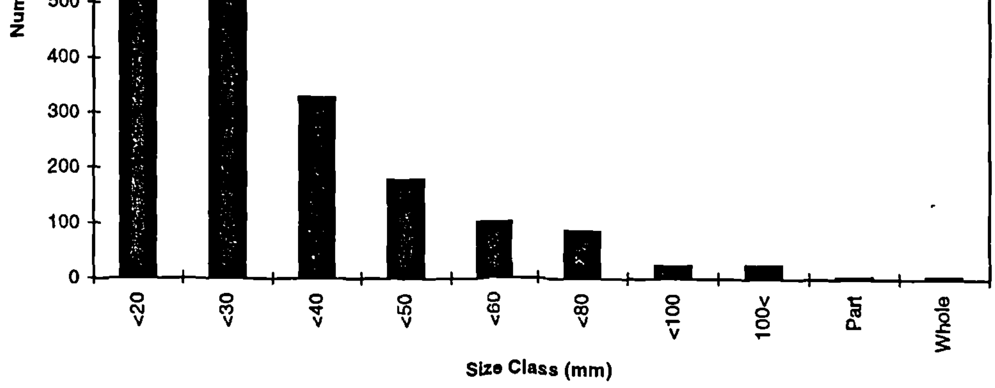


Figure 10.22 - A graph to show the number of fragments in each size class at Niaquussat (V48) (phocid excluded)

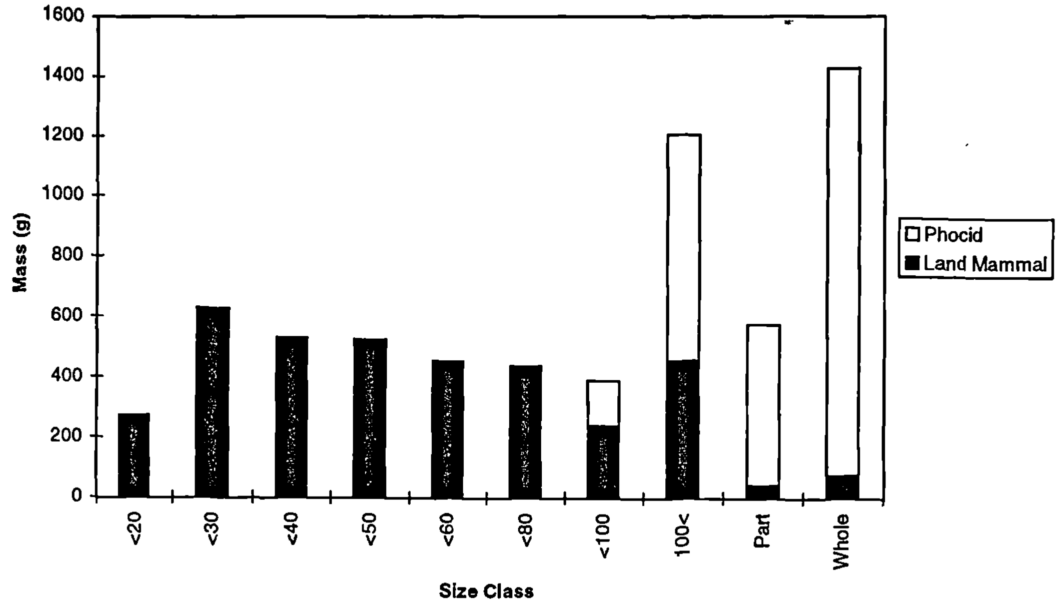


Figure 10.23 - A graph to show the masses of fragments in each size class at Niaquussat (V48), with distinction between land mammal (plus indeterminate) fragments and phocid fragments

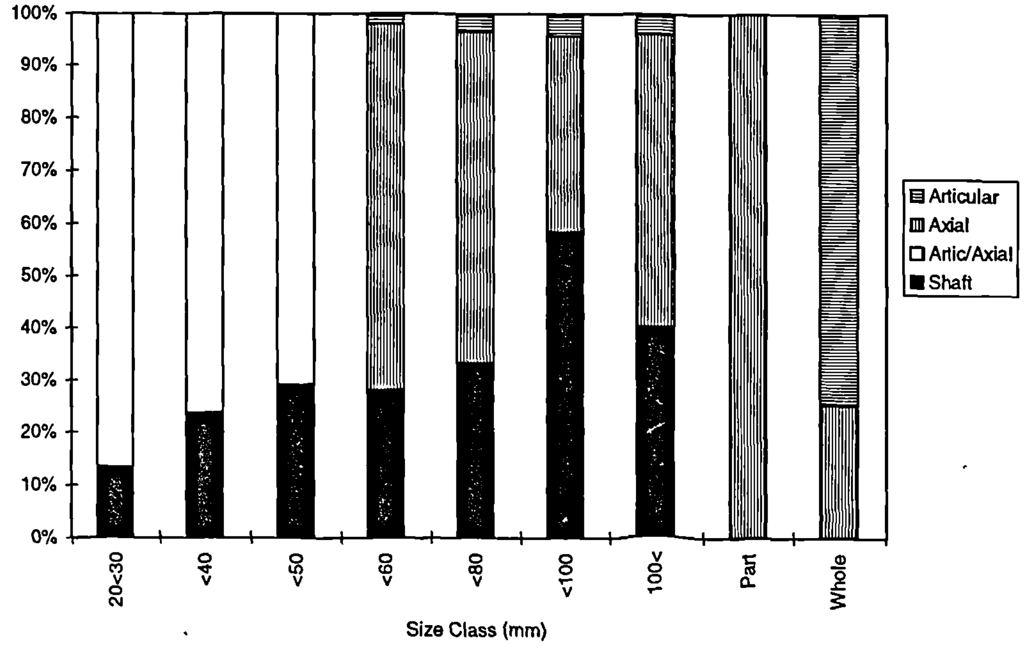


Figure 10.24 - A graph to show the proportions of different fragment types in each size class at Niaquussat (V48) (phocid excluded)

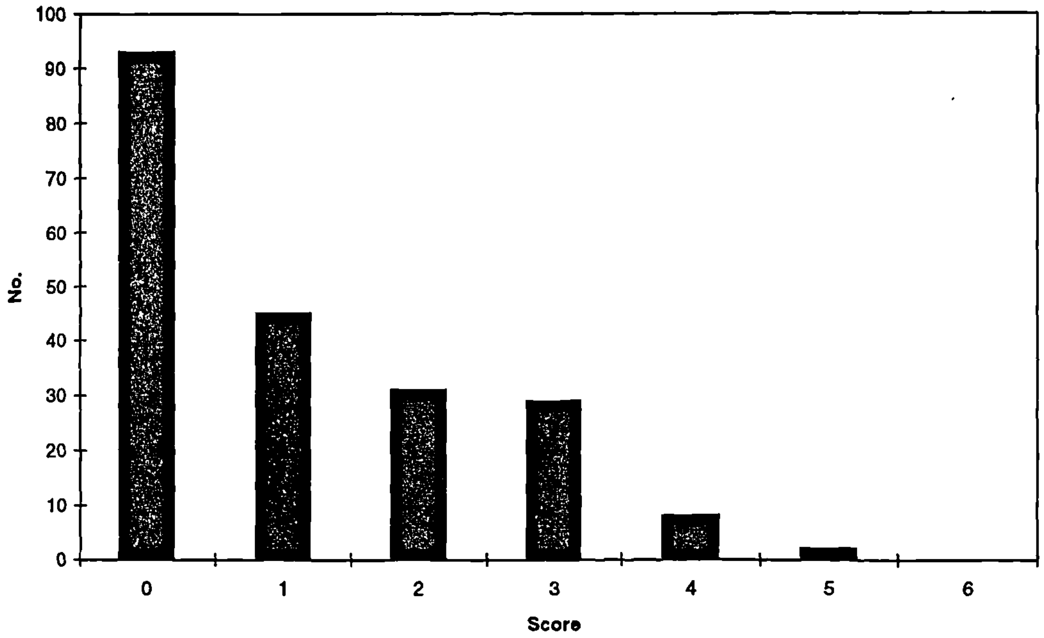


Figure 10.25 - A graph to show the distribution of fracture-freshness index scores for the sample from Niaquussat (V48)

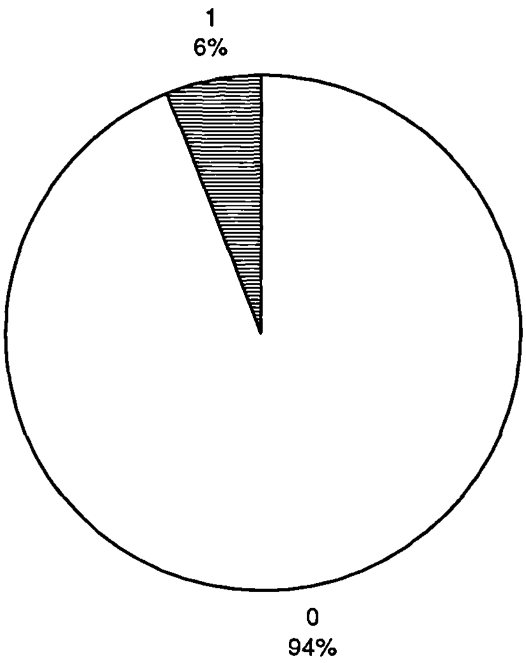


Figure 10.26 - A graph to show the proportions of fragments at Niaquussat (V48) with 0, 1, 2 or 3 indicators of post-depositional damage (indicators being modern breaks, mineralised breaks and gnawing)

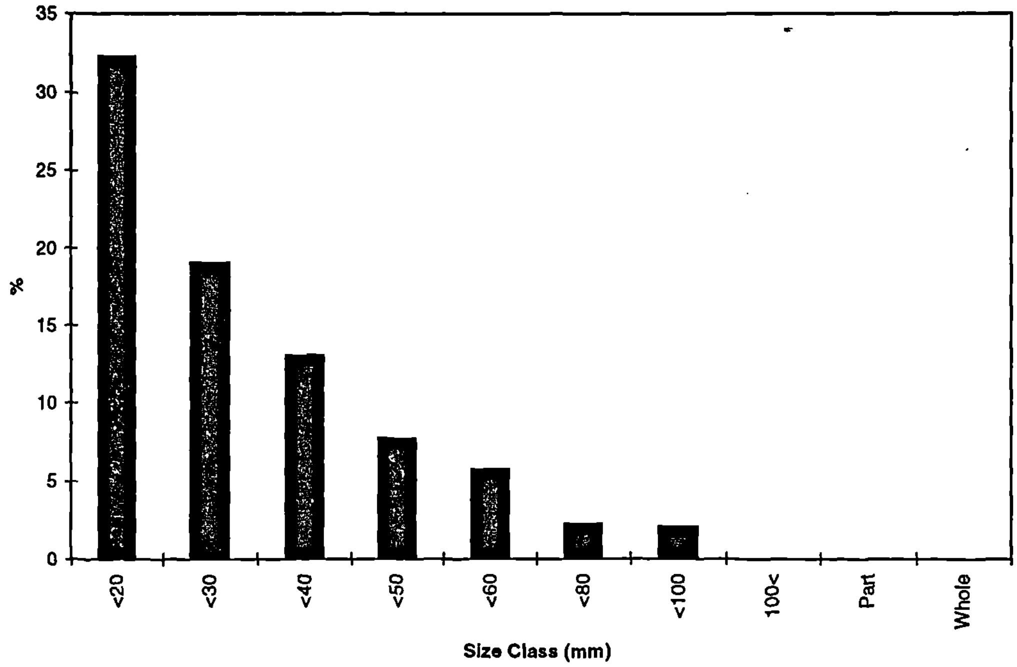


Figure 10.27 - A graph to show the numbers of burnt fragments in each size class in the sample from Niaquussat (V48)

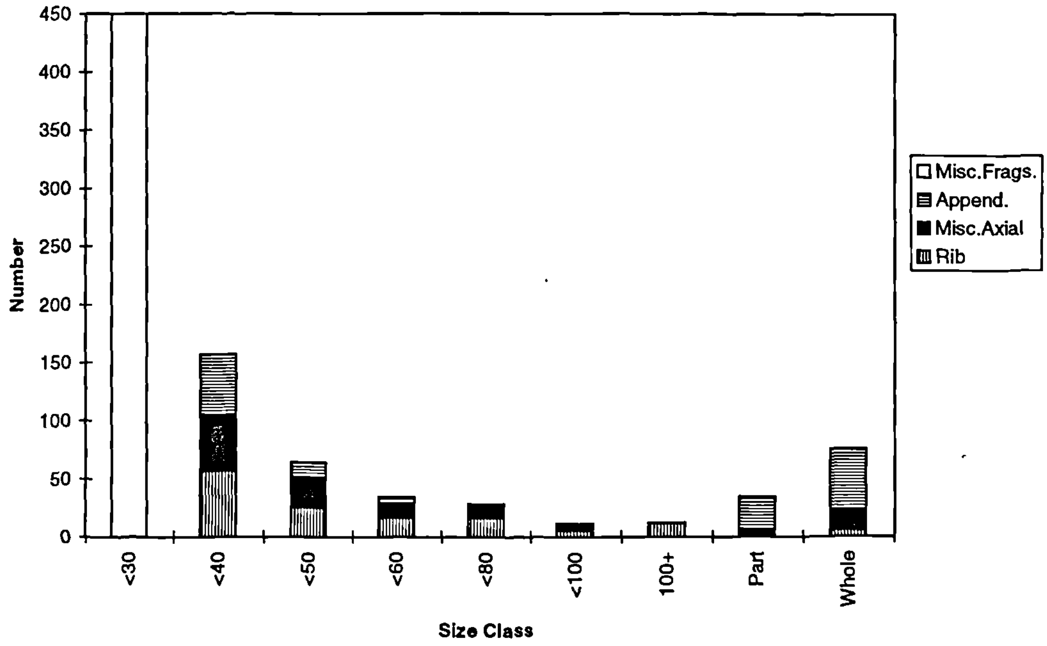


Figure 10.28 - A graph to show the number and type of bone fragments in each size class at Qeqertasussuk

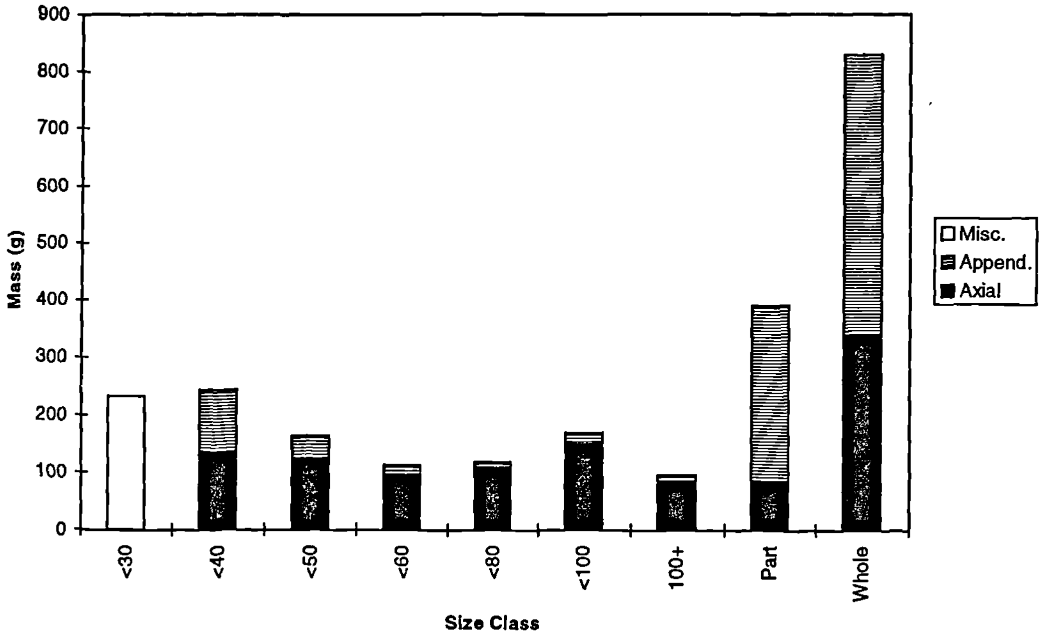


Figure 10.29 - A graph to show the masses and type of bone fragments in each size class at Qeqertasussuk

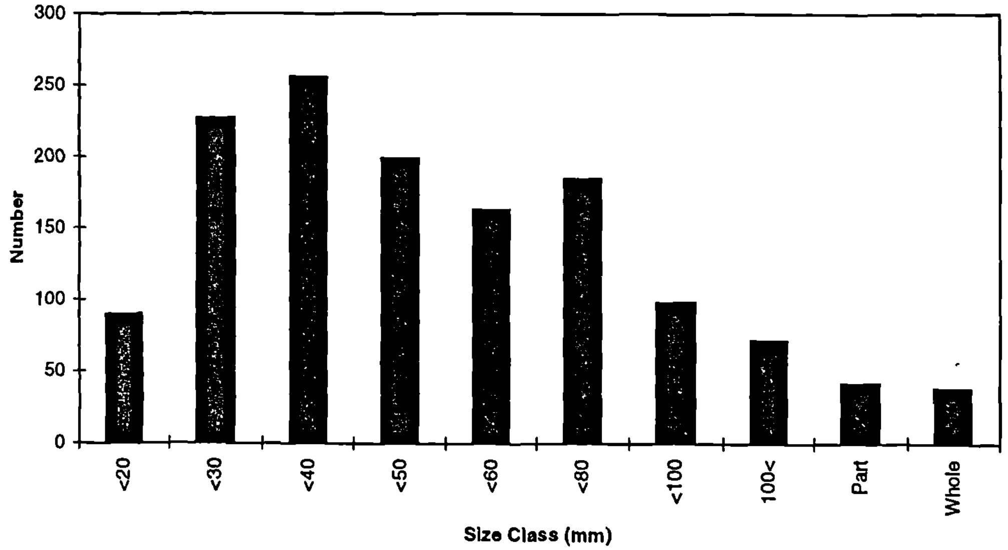


Figure 10.30 - A graph to show the numbers of fragments in each size class in the sample from Itivnera

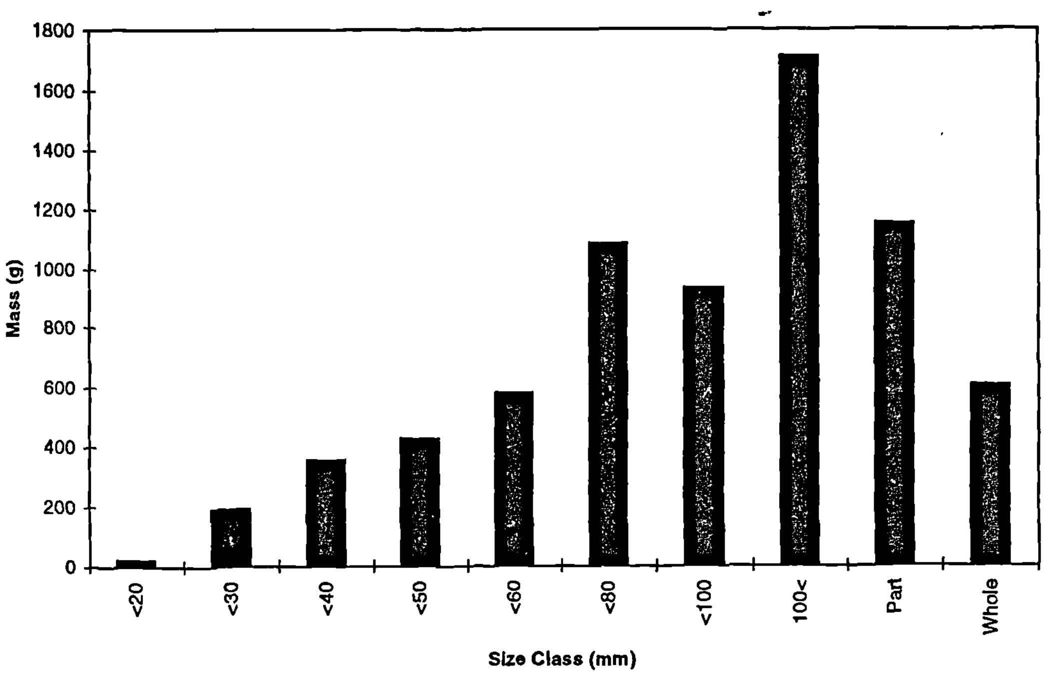


Figure 10.31 - A graph to show the masses of fragments in each size class in the sample from Itivnera

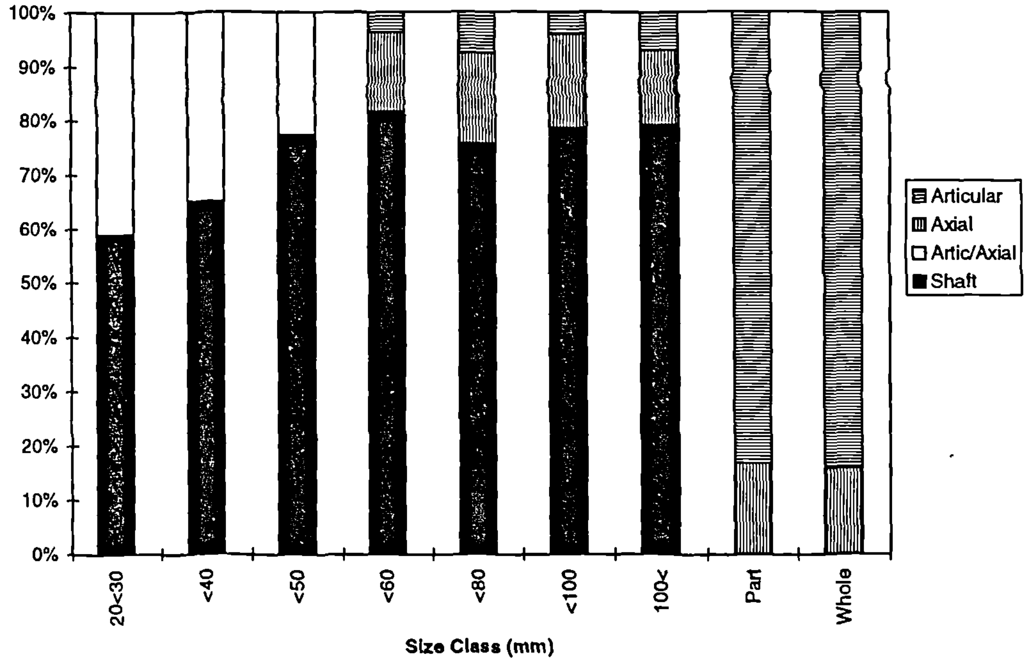


Figure 10.32 - A graph to show the proportions of different fragment types in each size class in the sample from Itivnera

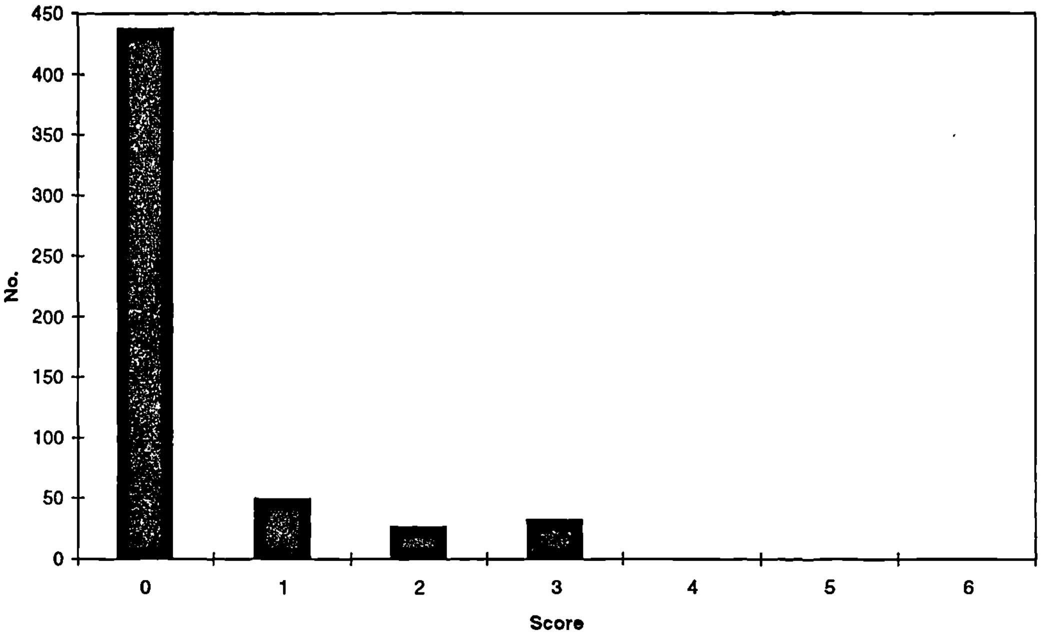


Figure 10.33 - A graph to show the distribution of fracture-freshness index scores for the sample from Itivnera

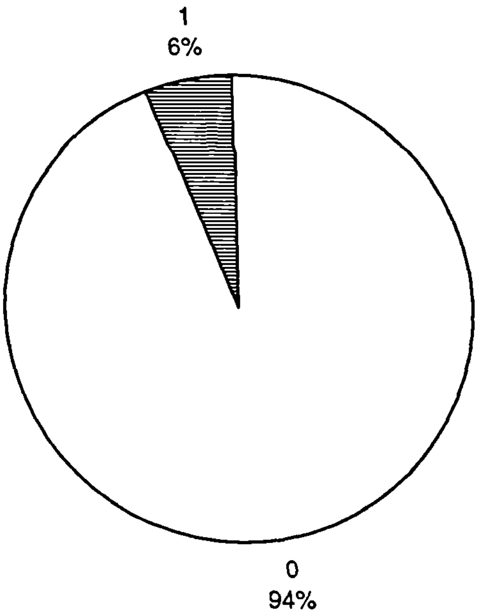


Figure 10.34 - A graph to show the proportions of fragments at Itivnera with 0, 1, 2 or 3 indicators of post-depositional damage (indicators being modern breaks, mineralised breaks and gnawing)

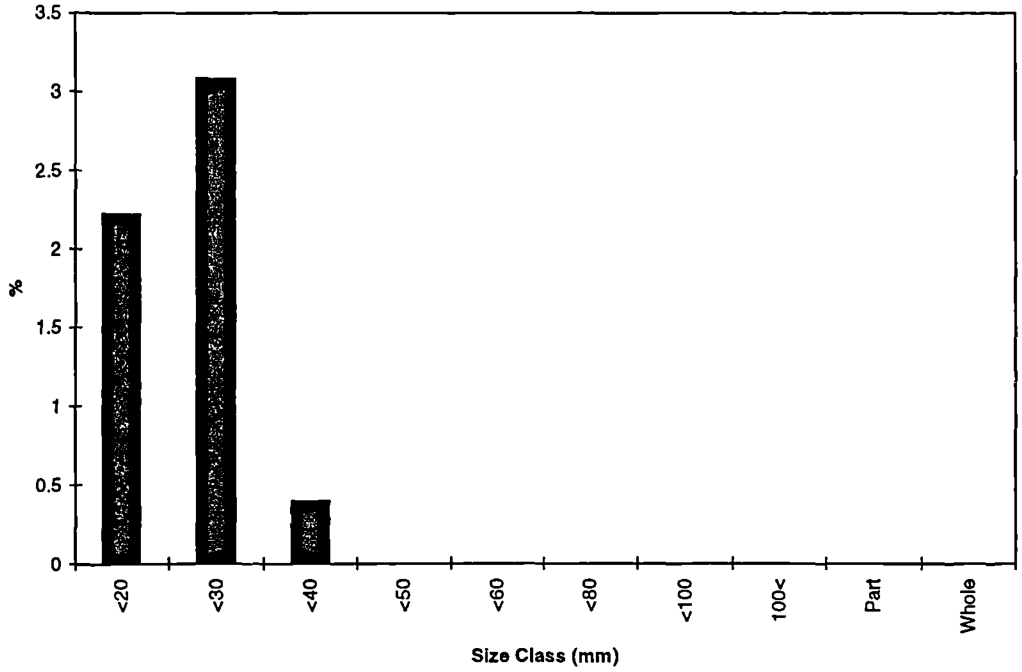


Figure 10.35 - A graph to show the numbers of burnt fragments in each size class in the sample from Itivnera

CHAPTER ELEVEN

CASE STUDY THREE:
THE FRACTURE AND FRAGMENTATION OF PIG AND SEAL BONES AT THE MIDDLE NEOLITHIC SITE OF AJVIDE, GOTLAND

11.1 Introduction

Ajvide is a large (circa 200,000 square metres) site on the coast of Gotland which has yielded evidence of activity spanning from the late Mesolithic to the Middle Bronze Age (Burenhult, 1997). Most activity on the site appears to have occurred between 3100 - 2700 Cal. BC, in the Middle Neolithic period ('Pitted Ware' culture). It appears that the site suffered a marine transgression during this time (circa 2900 Cal. BC) (ibid.).

One of the principle features of the site is a large burial area comprised of 54 graves. These graves are sometimes occupied by more than one person and in some cases they are empty, perhaps being cenotaphs (Burenhult, 1997). The graves date to slightly later than the main "Pitted Ware" use of the site (2700 - 2300 Cal. BC) (ibid.). Another important feature of the site is an area of very dark earth near the graves. This layer contains artefacts, pottery and animal bones and may have had a ceremonial use (ibid.). Chemical analysis of this area indicates that much seal train oil has been incorporated into the soil.

In the late Mesolithic, the subsistence economy of the settlement appears to have been based around fishing and the hunting of grey seal, ringed seal, harp seal and porpoise (Lindquist and Possnert, 1997 p29). With arrival of the Neolithic, domestic animals were introduced including cattle, sheep and pigs. During the Early Neolithic (circa 3,900 - 3,400 Cal. BC) $\delta^{13}C$ levels in human bone suggest a mixed terrestrial/marine diet (ibid.). The Middle Neolithic sees a return to a seal hunting and fishing economy but pigs are also exploited in this period. Cattle and sheep are re-introduced in the Late Neolithic/Early Bronze Age. There has been much debate over whether the pigs exploited during the Middle Neolithic period were wild or domestic and it is difficult to resolve this question (Rowley-Conwy and Storå, 1997). Rowley-Conwy (ibid.) argues that a suitable niche did not exist, during this time, for domestic pigs and suggests that the island was stocked with a wild population which was hunted.

The animal bone assemblage of Ajvide is, in general, quite fragmented. The assemblage from the aforementioned dark area (the "black layer") is particularly heavily broken up (see Fig. 11.1). This area contains much seal fat. Was land mammal fat also being exploited, and to what extent? The site has yielded some interesting specimens of pig jaws. The marrow cavities on these jaws (see Fig 11.2) appear to have been very carefully accessed without actually breaking the jaw in two. It has been suggested (Jan Storå, pers. com.) that the marrow was being exploited whilst leaving the jaw in tact for ritual purposes. Many pig jaws associated with inhumations have been found at other Pitted Ware sites (P. Rowley-Conwy pers. com.).

A study of fracture and fragmentation patterns at this site will be interesting for a number of reasons. Firstly, there is the added complication of possible ritual activity surrounding this burial site. Secondly, the exploitation of bone marrow and grease in an assemblage of land mammals dominated by animals as small as pigs has not yet been attempted in this volume. Thirdly, the palaeoeconomic context of this study is complex. The main period of occupation at the site is in a period when domestication has apparently been abandoned, having previously existed for some time. This case study, therefore, presents a different set of challenges to the previous case studies and adds further complexities.

11.2 The Material Studied

All the material studied comes from the Middle Neolithic period of the site. Two areas of the site have been examined; Test Area 1 and a sample from the "black layer".

11.2.1 Test Area 1

This area was chosen for study because it lies outside the burial ground area and, as such, might better represent the domestic, rather than ritual, activities of the site. This eight square metre trench was dug in six, 10cm thick layers (Rowley-Conwy and Storå, 1997). The upper two layers (1 and 2) represent material deposited after the marine transgression, layer 3 contains the transgression material and 4, 5 and 6 are below the transgression (Storå pers. com.). In this study the layers were recorded separately so that a comparison could be made between material above and below the transgression layer.

The bone assemblage from this area has been studied by Rowley-Conwy and Storå (1997). They found that there was a very high proportion of fish in the assemblage (see fig. 11.3). By weight there were 9295.94g of identifiable mammal bone, 6901.96g of fish bone (circa 40,000 NISP), 24.61g of bird bone and 5395.50g of indeterminate fragments (ibid. table 1). Of the identifiable mammal remains pig had a NISP of 970, dog 33, fox 57, hare 7, hedgehog 2, seal sp. 2499, harp seal 348, ringed seal 106 and porpoise a NISP of 6 (Total = 4028) (ibid. table 2). Seal therefore dominates in terms of number with pigs also significantly represented.

11.2.2 The "Black Layer"

The highly fragmented bone from the black layer (fig. 11.1) is currently undergoing analysis for species content. It has a similar composition to Test Area 1. For this study a sample was taken from near the centre of the area covered by the black layer.

Chemical analysis of the matrix of the black layer revealed that it contained seal train oil (see above), but the blackness seems likely to be caused by much fine charcoal in the soil (from the author's own experience of the soil covering the bone fragments examined).

11.3 Methodology

The methodology employed followed that applied to Mondeval and the Greenland sites, with three principal exceptions. In the previous studies small elements like phalanges were always simply classed according to size and were not included in the "whole" category during fragmentation analysis. The Ajvide assemblage has many small whole bones from pigs and seal, like metapodials and phalanges, which frequently survive whole. In this study they have been classed with the whole bones but distinction has been made in the number count between small whole bones (phalanges, carpals and metapodial) and larger whole bones (long bones, girdle bones and vertebrae). The second change in methodology is the creation of a type category for cranial material. In previous studies this was classed along with axial material. At Ajvide, however, there appears to be much cranial material and, as such, it was decided to record it separately. Thirdly, in this study the under 20mm class was also separated into cancellous and diaphysis bone types, and the full separation into shaft, epiphysial, axial and cranial bone was attempted in the 20 - 30mm size class and above. This increased detail in the smaller classes was attempted for two reasons. The animals being dealt with were generally smaller than in previous studies, which tended to make fragments more diagnostic in smaller classes, and the analyst, becoming more experienced, had greater confidence in making the separation at that level.

For reasons discussed in chapter 10, seal bones must be considered separately from land mammal bones with respect to the study of bone fat use. This causes difficulty when indeterminate categories are being studied. This problem will be addressed, below, in the discussion of the results.

11.4 Results

Raw data relating to Ajvide can be seen in Appendix D.

11.4.1 Test Area 1 Land Mammal

The land mammal fracture and fragmentation study included all identified pig fragments and material from the indeterminate category that was clearly of land mammal origin (usually shaft bone). Thus, cancellous bone in small size categories, which could be either seal or land mammal, was ignored. This will have the effect of slightly depressing the smaller size categories and altering their type composition. The effects of this will be discussed, below.

With regard to fragmentation level, smaller size classes dominated both in terms of number and mass (see figs. 11.12 and 11.13). The low values in the very smallest classes, particularly in terms of mass, may be the result of ignoring indeterminate cancellous bone. The "part" and "whole" bone classes are quite well represented in terms of mass (fig. 11.13), but it can be seen from the number count (fig. 11.12) that many of the whole bones were "small whole" bones, as defined above.

If one considers the representation of different bone types by size class (see fig. 11.14) it can be seen that diaphysis bone is quite poorly represented by comparison to sites like Mondeval. A fair proportion of cancellous bone (whether epiphysial or axial) survives, as does cranial bone. Figure 11.4 shows an average bag of identified pig bone. One can see a fair proportion of cancellous bone surviving in large pieces and a number of whole phalanges and metapodials. If the indeterminate seal/pig cancellous material had been studied, the proportion of diaphysis material in smaller categories would have been depressed still further.

Only 135 specimens of shaft were large enough to be studied for the fracture freshness index, due to the aforementioned low proportion of diaphysis material. The average index value was 3.28. Figure 11.15 shows that most fragments scored three, but more had high values than low ones. There were a few fresh fractured specimens, however, (see fig. 11.5) but none that scored zero on the index. Seven specimens appeared to display dynamic impact scars (5.2%, N = 135). The relatively high average fracture score might be related to the generally high level of burning in the assemblage. In most size categories between 20% and 40% of fragments showed signs of burning (see fig. 11.16). This, unusually, includes the "part" and "whole" size classes. Incidence of carnivore gnawing was quite low, with six specimens showing possible signs of gnawing (8.1%, N = 135).

11.4.2 Comparison of Land Mammal Results Above and Below the Marine Transgression in Test Area 1

If one compares the fragmentation pattern of material above the marine transgression (layers 1 and 2) with the material below it (layers 4, 5 and 6), it appears that the lower material is less severely fragmented. If the fragmentation is displayed in terms of number of fragments in size classes the pattern looks similar (figs. 11.17 and 11.18). The very smallest class is depressed in layers 1 and 2 but layers 2, 5 and 6 have slightly better representation in the mid-range size classes. This can be seen very clearly if quantification is by mass (figs. 11.19 and 11.20). In terms of mass, the lower material seems much less fragmented. Figure 11.6 shows some sizeable fragments of pig surviving in layer 4.

Both the upper and lower material show the general dominance of cancellous bone types over diaphysis fragments. Layers 1 and 2 (fig. 11.21) show a fairly even representation of shaft fragments, whilst in layers 4, 5 and 6 (fig. 11.22) there is a general decline in the representation of shaft fragments with increase in size class.

Splitting the Test Area 1 assemblage into upper and lower layers results in quite small sample sizes with regard to the fracture freshness index. Bearing this in mind, it seems that the upper layers, with a mean fracture score of 3.45 (N = 89) (see fig 11.23), have fewer specimens with fresh fracture features than the lower layers, with a mean score of 2.8 (N = 25) (fig. 11.24). This might be tied to burning levels which are very much higher in the upper layers, where burning is often in the range of 30% - 60% in most size classes, in comparison to low burning levels of under 10% in layers 4, 5 and 6 (see fig. 11.25). Figure 11.7 shows a fragment of burnt diaphysis from layer 1. It can be seen that the bone had features of fresh fracture in the fracture surfaces spiralling down the length of the bone, but after being burnt later fractures were of entirely unfresh type (note the transverse, right-angle fracture on the right end of the fragment).

11.4.3 Test Area 1 Phocid

Only the identified seal remains were studied. It is possible that the very smallest size classes may be under-represented as a result, but the separation of seal remains has been very thorough and other size classes are likely to be accurate. In terms of number, the smaller size classes dominate (fig. 11.26). This is also the case with quantification by mass, but less clearly so (fig. 11.27). The graph of size class by mass shows a large amount of whole bones, but the number graph indicates that much of these are phalanges and metapodials (as with the land mammal assemblage). There is, however, a reasonable representation of large fragments and "parts". Figure 11.8 shows an average bag of seal fragments from layer 2. Some fairly sizeable pieces of rib, vertebra and limb bone survive. Burning is generally quite high in most size classes (fig. 11.28).

If one compares the phocid fragmentation above and below the marine transgression, a similar pattern to the land mammal assemblage emerges. In terms of size class by number the patterns in the upper and lower layers look similar (see figs. 11.29 and 11.30). The graphs of size class by mass (figs. 11.31 and 11.32), however, reveal better representation of large fragments in the lower layers. The comparison of burning levels in the upper and lower layers also matches that of the land mammal assemblage (fig. 11.33). The upper layers have far more burnt specimens.

11.4.4 Discussion of Test Area 1 Results

Test Area 1 is characterised by relatively high levels of fragmentation in both land mammals and seal. Fragmentation levels and burning appear to be higher and fracture less fresh in the layers above the marine transgression. The higher level of burning could be the reason for the higher fragmentation and less fresh fracture. Burnt bones are brittle and will fracture in an entirely unfresh fashion. In the land mammal assemblage proportions of shaft fragments were quite low and much cancellous bone survived. This is not the expected pattern for bone grease exploitation where shaft fragments should dominate in larger size classes, most cancellous bone having been comminuted in the rendering process. The fact that unidentified cancellous material was not included in the study is unlikely to affect any of the patterns described above. If this mixed material had been included, the above patterns would have been strengthened. Fragmentation would appear a little more severe and diaphysis fragments would be even more poorly represented in the smaller size classes. In this instance this problematic portion of the assemblage can be safely excluded without affecting the interpretation of the material.

11.4.5 The "Black Layer" Land Mammals

Initial study of the black layer followed the same method as for Test Area 1. The potentially mixed seal and land mammal cancellous material was excluded. However, it became apparent that the black layer contained high proportions of shaft fragments. As such the exclusion of the cancellous material could have an effect on type proportions which might alter any interpretation. The solution to this problem was to study firstly the identified pig and land mammal shaft fragments together, as in Test Area 1, and then the entire assemblage including some small cancellous material that could have phocid origins. Neither of these analyses will produce the true pattern, which it seems impossible to attain, but the true pattern should lie somewhere in between the two. Whether an interpretation may be offered with regard to such a study depends on the extent to which the two possible extremes vary from each other.

Both the study of land mammal and shaft (fig. 11.34) and all fragments (fig. 11.35) show very high levels of fragmentation. In terms of number, the small size classes very much dominate, and large size classes have very little representation at all. The pattern for size class by mass tells the same story (figs. 11.36 and 11.37), but it is apparent, as one would expect, that in the study of all fragments the large size classes are even more poorly represented. The higher level of fragmentation in the "black layer" is clear to see if it is compared with Test Area 1 (see figs. 11.12 and 11.13).

With regard to fragment types, the study of identified pig and land mammal shaft (fig. 11.38) showed a great dominance of shaft fragments (circa 80 - 90%) in all but the very poorly represented large categories. This is very different to the pattern seen in Test Area 1 (see fig. 11.14). With the inclusion of the indeterminate cancellous material the dominance of the cancellous material is reduced to 40 - 50% in the smaller classes but the dominance of diaphysis fragments in the 60 - 100mm classes is maintained at around 80%. With the inclusion of all cancellous material, shaft fragments are still relatively dominant. Figure 11.9 shows a sample of identified pig fragments. Although there are a few sizeable fragments of cancellous material most of the cancellous bone is broken up and vastly outnumbered by the vast amount of unidentified land mammal shaft fragments (see fig. 11.10).

This shaft material displays relatively few signs of fresh fracture. The mean fracture freshness index score is 4.24 (N = 172), which is quite a high value. If the fracture freshness scores are displayed graphically (fig. 11.40) it can be seen that few fragments have scores under three, but many have scores of five or six, demonstrating a complete lack of fresh fracture features. There were only two examples of possible dynamic impact scars (1.2%, N = 172).

Burning was only studied in the identified pig and shaft fragments. This was because of the large amount of time required to assess levels of burning amongst huge numbers of small fragments. Burning levels are generally fairly high in the small size categories but the levels decline into the middle size classes (to under 10%) (fig. 11.41). Burning levels are high in the "part" and "whole" classes but the sample size is small in these categories. There was little evidence of carnivore gnawing. Only six specimens had potential gnaw marks (3.5%, N = 172).

11.4.6 The "Black Layer" Phocid Remains

The black layer seal bones are also very fragmented and little survives, in terms of numbers, in the larger size classes (fig. 11.42). In terms of mass, the small size classes still dominate but less impressively (fig. 11.43). An average bag of identified seal from the black layer can be seen in figure 11.11. Burning levels are around 30% in the small size classes but the medium size classes are not burnt at all. The "part" class is 100% burnt, but the sample size is tiny (see fig. 11.44).

11.4.7 Discussion of the "Black Layer" Results

Fragmentation is very high in the black layer amongst both land mammals and seal. The seal is slightly less fragmented, however. The land mammal assemblage is dominated by shaft fragments. This dominance remains, particularly in the middle-range size classes, even when all cancellous indeterminate material is included in the study. It therefore seems that an interpretation of the assemblage may still be possible despite the margin of error caused by the indeterminate cancellous material.

The land mammal shaft fragments have largely unfresh fracture and burning levels are relatively high in smaller size classes.

11.5 Interpretation and Discussion

11.5.1 Test Area 1

The land mammal assemblage from Test Area 1 does not appear to fit the expected pattern for the production of bone grease. The fragmentation is high, but the wrong type of bone appears to have been fragmented. Much of the grease-bearing cancellous bone remains in large pieces and has clearly not been comminuted for grease rendering. The fracture freshness index shows a mixture of fresh and unfresh breaks on the shaft fragments. Many of the shaft fragments bear some signs of original fresh fracture and there are a number of dynamic fracture scars which may indicate deliberate breakage. However, it is clear that much further, unfresh, fracture occurred at a later stage. The overall pattern for the land mammal bone suggests that pig bones may well have been cracked to exploit marrow but the cancellous bone was not exploited to any great extent for its grease content. The exploitation of pig bone marrow is also indicated by the aforementioned accessing of pig jaw cavities (see fig. 11.2). Further deliberate fragmentation of pig shaft bone may have resulted from craft activities. Bone tools made from pig shaft bone are present at the site (Storå pers. com.).

The level of fragmentation in seal bone is consistent with this overall interpretation. The seal bone is almost as fragmented as the land mammal bone. If grease rendering was taking place one would expect to find seal bone surviving in a much less fragmented state than the land mammal bone (see chapter 10). Since the level of fragmentation is similar it seems more likely that both seal and land mammal bone suffered the same attritional effects, most likely after deposition. The fact that the seal bone appears slightly less fragmented is easily explained by the fracturing of pig bones for marrow (which seal does not have) and the use of pig shaft bone for tools. Seal bone seems to have been less used for tool production at the site (Storå pers. com.), probably because it is less hard and dense.

There is a much higher level of burning in the upper layers of Test Area 1. This may not characterise the site as a whole, since the trench is a small one. The incidence of burning may be local. It is certainly likely, however, that the burning is the root cause of the higher level of fragmentation and less fresh fracture index scores observed in the upper layers. There is nothing to indicate that the pre-transgression layers should be interpreted differently to the post-transgression layers with regard to bone fat exploitation.

11.5.2 The "Black Layer"

The black layer presents more interpretational problems. The fragmentation level is very high and the assemblage is dominated by shaft fragments, particularly in the larger size classes. This pattern *is* characteristic of bone grease rendering where most cancellous has been comminuted, leaving just shaft fragments surviving to any great size. This is the case whether the indeterminate cancellous material is included in the count or not.

The fracture pattern in the assemblage, however, *is not* what one would expect for grease production or marrow extraction. Much of the fragmentation of the shaft appears to have occurred when the bone was no longer fresh. It is possible that bones could have originally been broken fresh during grease production and then have been subsequently broken again after deposition and loss of freshness. This should, however, lead to a mixture of fresh and unfresh features likely to lead to an index score not too far from three. The average score in the black layer is over four and many fragments have a virtual absence of fresh features. This tends to suggest that grease production an unlikely explanation for the heavy fragmentation of land mammal bone.

The fact that the seal bone is also very heavily fragmented suggests, as argued above, that some other cause of breakage is responsible for the fragmentation of both pig and seal bone. The burning level is quite high, which will have increased fragmentation and the incidence of unfresh fracture. The fragmentation is very heavy, however, and it is likely that there is another reason for high breakage levels which remains illusive. Such a pattern may well have resulted if the area was very well trampled at a time when the bones had been exposed for some time. It has been suggested that this area may have had ritual use (Burenhult, 1997), or the presence of much seal train oil in the soil (ibid.) might indicate a processing work area of some kind. Either possibility would result in much trampling.

11.5.3 Fat Exploitation in the Context of the Ajvide Seasonal Round

Rowley-Conwy and Storå (1997) have been able to narrow down the hunting of pigs and seal at Ajvide to particular seasons of the year. Regarding seals, two species must be considered. Metrical study of juvenile ringed seals shows little variation in size and, hence, a limited hunting season. If breeding habits were the same as current ringed seal, these specimens are likely to have been killed in the late winter/spring (ibid. p117). Study of the harp seal shows two possible hunting periods. Material from Test Area 1 indicates the same season as the ringed seal, but most of the material from the main area of the excavation indicates a autumn/early winter hunt. Animals hunted in the autumn will be in prime condition after summer feeding, but would have to be hunted in open waters (ibid.).

From the ageing of jaws and metrical study of long bones it seems that all the pigs present at the site could have been hunted between September and January (ibid. p120). This is the same autumn/winter pattern as displayed by some of the harp seals. The copious fish remains have not yet been fully analysed but it is possible fish formed the subsistence base during the summer months. It also seems likely that porpoise were hunted during the summer (ibid. p125).

This consideration of the Ajvide seasonal round is crucial if an understanding of this society's fat exploitation practices is to be gained. During the pig hunting season, in autumn and winter, food is likely to have been relatively plentiful. The pigs would be in good condition after the summer with good fat reserves. The meat would have some fat content which could be supplemented by breaking bones for marrow (and it seems that marrow was exploited). At this time there were also harp seal available on site that would provide meat and plentiful fat in the form of blubber. The blubber can be rendered into train oil for storage. There would be little need to attempt the very arduous process of rendering the pig bones for their grease content. The bones could, however, be saved up for processing later in the winter/spring as the Inuit do (see chapt. 1), for instance.

In the late winter/spring, however, ringed seal and harp seal were being hunted. These would provide a much easier source of fat than bone rendering would. By the summer months the rendering of bone fat would probably be unnecessary because of fishing and porpoise hunting. There would also be some difficulty in storing the bones until the summer. It therefore seems that there would be little need to render land mammal bones for their grease content since other, easier sources of fat appear to be available in most seasons and particularly in the winter/spring when bone rendering might normally be expected. The lack of evidence for the rendering of bones for fat at Ajvide seems to fit well with our overall understanding of the site's subsistence economics.

11.6 Conclusion

The study of bone fracture and fragmentation at Ajvide is an important one in the context of this overall study into bone fat exploitation. It is a good example of a heavily fragmented assemblage which appears *not* to indicate the exploitation of bone fat. In the case of Test Area 1 the fragmentation levels and fracture freshness score could be argued to be consistent with bone fat rendering, but the composition of the assemblage, in terms of bone type, clearly indicated otherwise. In the black layer fragmentation levels and composition were consistent with bone fat rendering, but the fracture scores were not. In both areas the fragmentation level in the seal bone assemblage formed a useful control. It is likely to indicate the background level of fragmentation as caused by other taphonomic processes, unrelated to grease rendering. The seal assemblage showed that the level of fragmentation at Ajvide was high and that the fragmentation level in the pig assemblage could therefore be explained by mechanisms other than grease rendering.

The methodology in use in this study is therefore shown to be a powerful one. It does not indicate that all heavily fragmented assemblages are the result of grease rendering. It is sensitive enough to assemblage composition and fracture type to indicate other taphonomic possibilities. In this instance, the interpretation was supported by other environmental and zooarchaeological evidence which indicates that bone grease rendering may not have been necessary in any given season of the year. In other words, bone grease is likely to fall outside the diet breadth model for this community, not being an efficient enough source of food by comparison to other resources available. It is possible that the smaller size of the land mammals in question (i.e. pigs in comparison with caribou and red deer) might have the effect of making bone grease rendering an even more inefficient process than normal, making it less likely to be considered as worth processing. The bones would contain less volume of cancellous bone by proportion to their surface area, making it harder work to produce the same quantity of comminuted fragments of grease-yielding bone. It seems likely that bone marrow, however, being relatively easily extracted, did fall within the diet breadth and was exploited.

Once again, dietary fat requirements have been closely tied to a community's seasonal round. In Greenland it was noted that there was a particular seasonal niche where the Medieval Norse would have found bone grease an invaluable resource (see chapt. 10). At Ajvide, however, the reverse is true. It is clear from this that palaeoeconomic studies and the use optimal foraging theory must be applied with season in mind.

Figure 11.1 - An average sample of highly fragmented indeterminate bone sherds from the "black Layer" at Ajvide (10cm scale)

Figure 11.2 - A pig jaw fom Ajvide displaying evidence of the extraction of marrow (10cm scale)

Figure 11.3 - A sample of the many fish bones found in Test Area 1 at Ajvide (10cm scale)

Figure 11.4 - A sample of identified pig bones from Layer 2,Test Area 1, Ajvide (10cm scale)

Figure 11.5 - Some examples of fresh-fractured land mammal shaft fragments from layer 2, Test Area 1, Ajvide (5cm scale)

Figure 11.6 - Some examples of identified pig elements which have survived relatively undamaged in layer 4, Test Area 1, Ajvide (10cm scale)

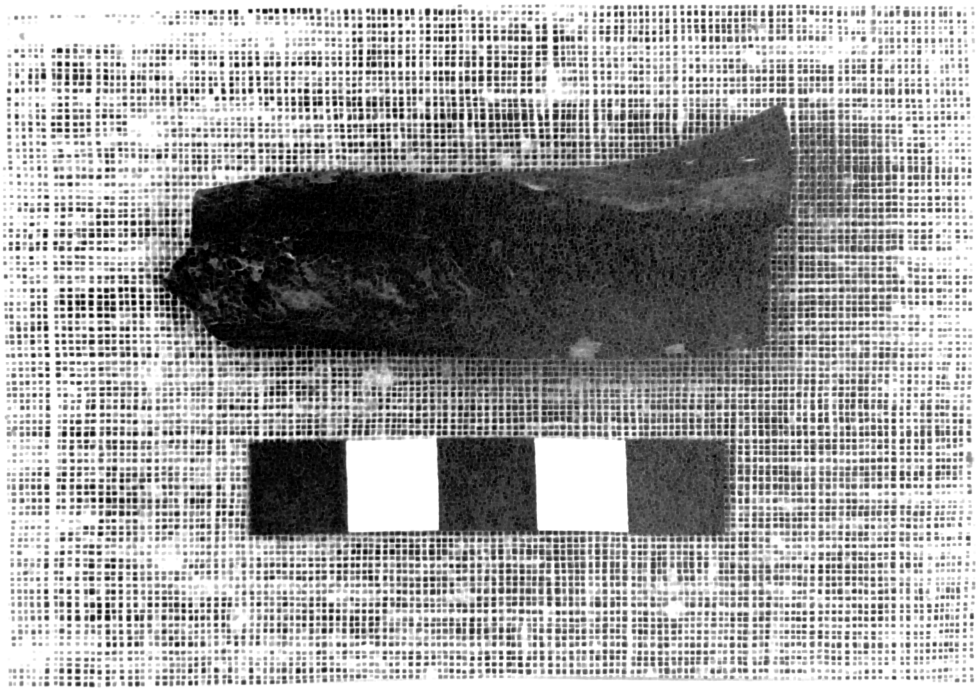


Figure 11.7 - A specimen of burnt bone from layer 1, Test Area 1, Ajvide. There are features of fresh fracture, but the transverse fracture to the right of the specimen is entirely unfresh in nature (5cm scale)

Figure 11.8 - A sample of identified seal bones from layer 2, Test Area 1, Ajvide (10cm scale)

Figure 11.9 - A sample of identified pig fragments from the "black layer", Ajvide (10cm scale)

Figure 11.10 - A sample of unidentified land mammal shaft fragments from the "black layer", Ajvide (10cm scale)

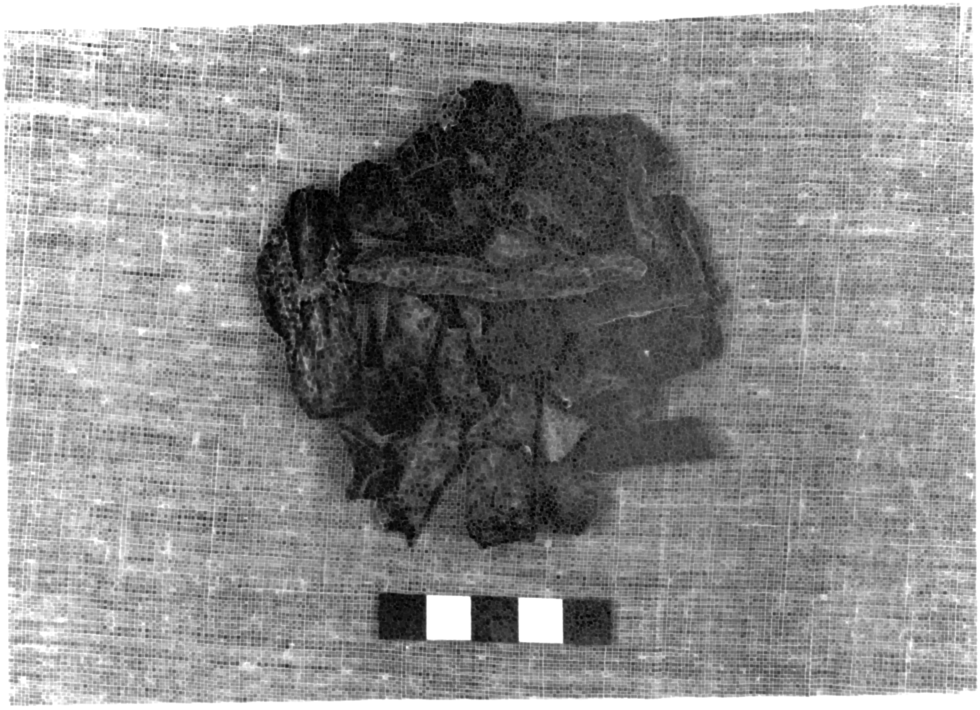


Figure 11.11 - A sample of identified seal bones from the "black layer", Ajvide (5cm scale)

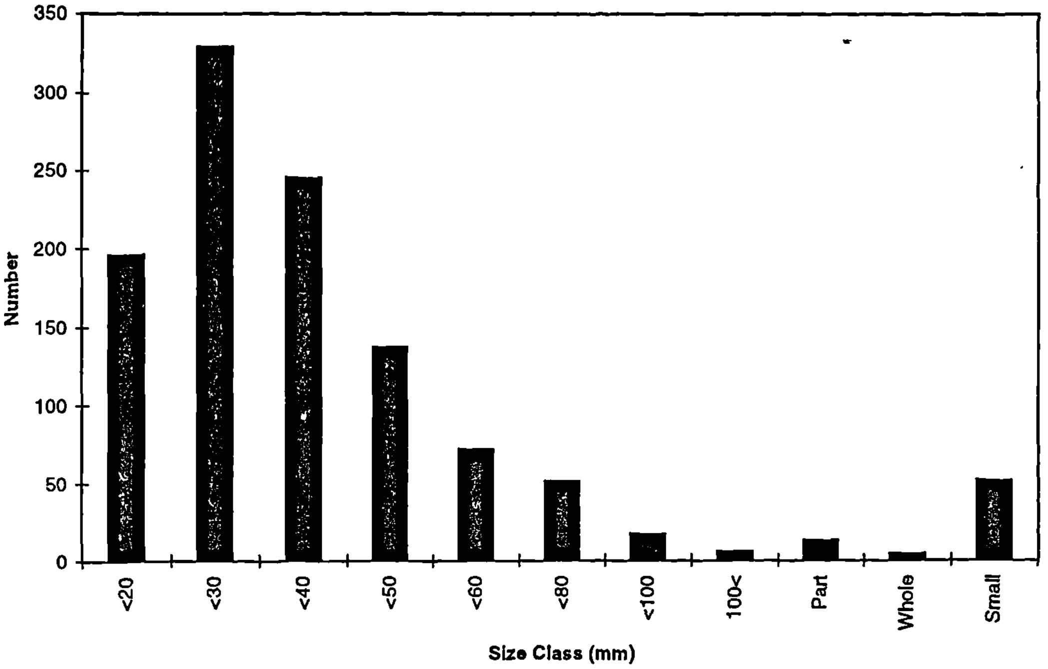


Figure 11.12 - A graph to show the number of fragments in different size classes for land mammals in Test Area 1, Ajvide

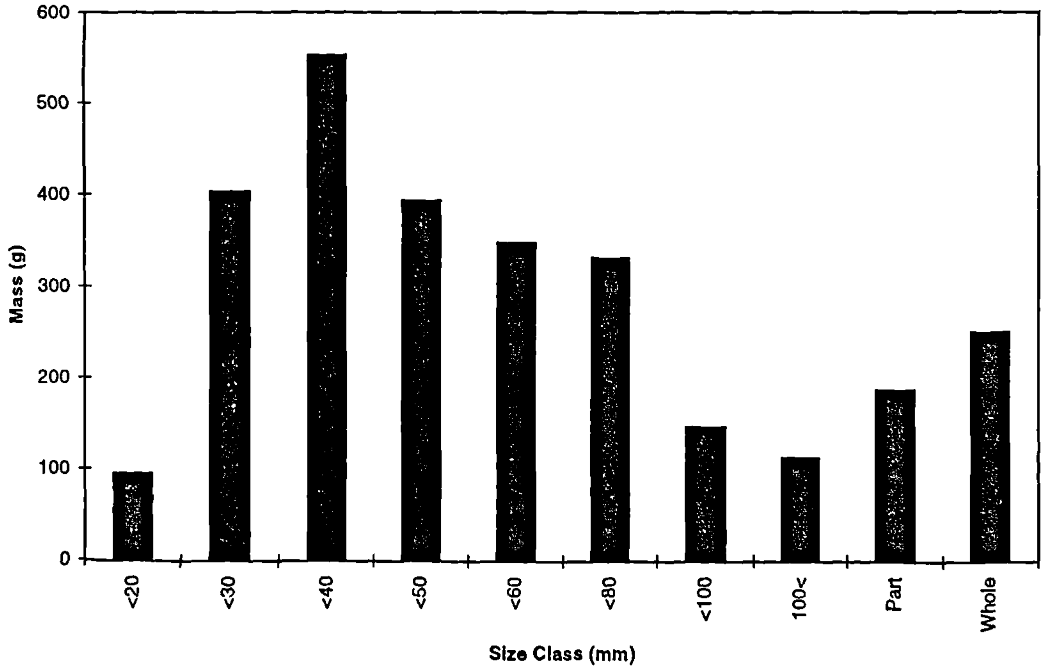


Figure 11.13 - A graph to show the mass of fragments in different size classes for land mammals in Test Area 1, Ajvide

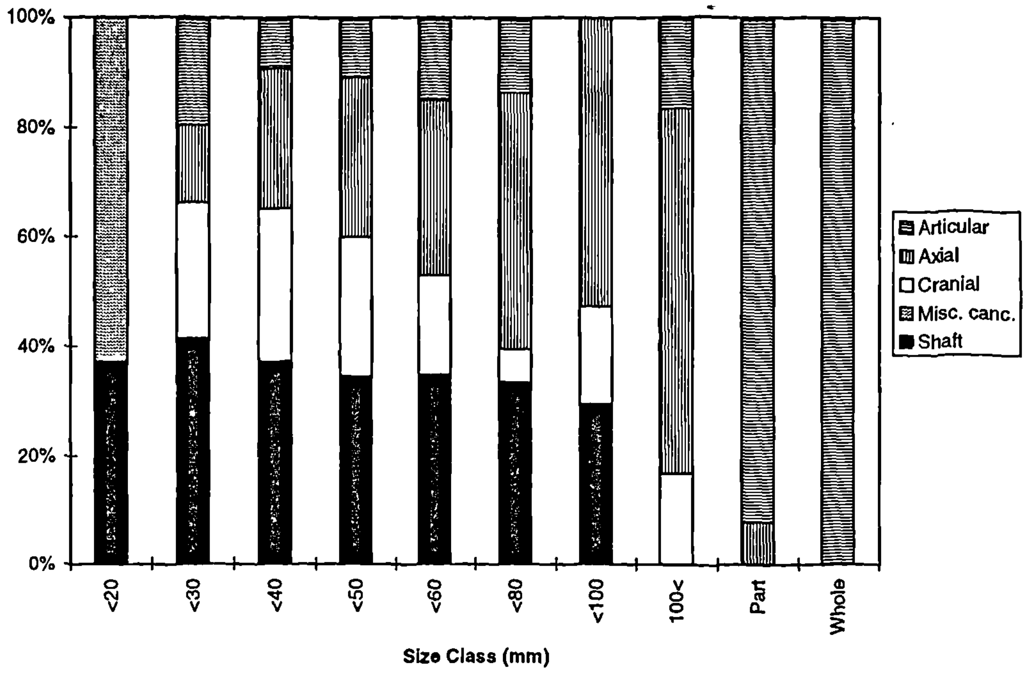


Figure 11.14 - A graph to show the percentage of different fragment types in different size classes for land mammals in Test Area 1, Ajvide

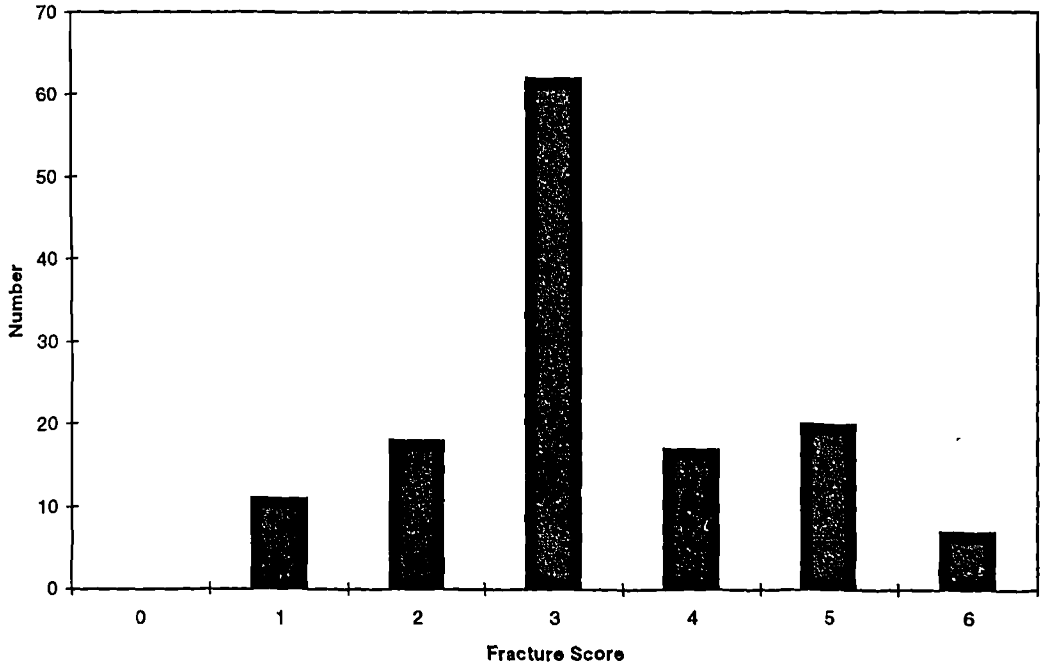


Figure 11.15 - A graph to show the numbers of different fracture freshness scores for land mammals in Test Area 1, Ajvide

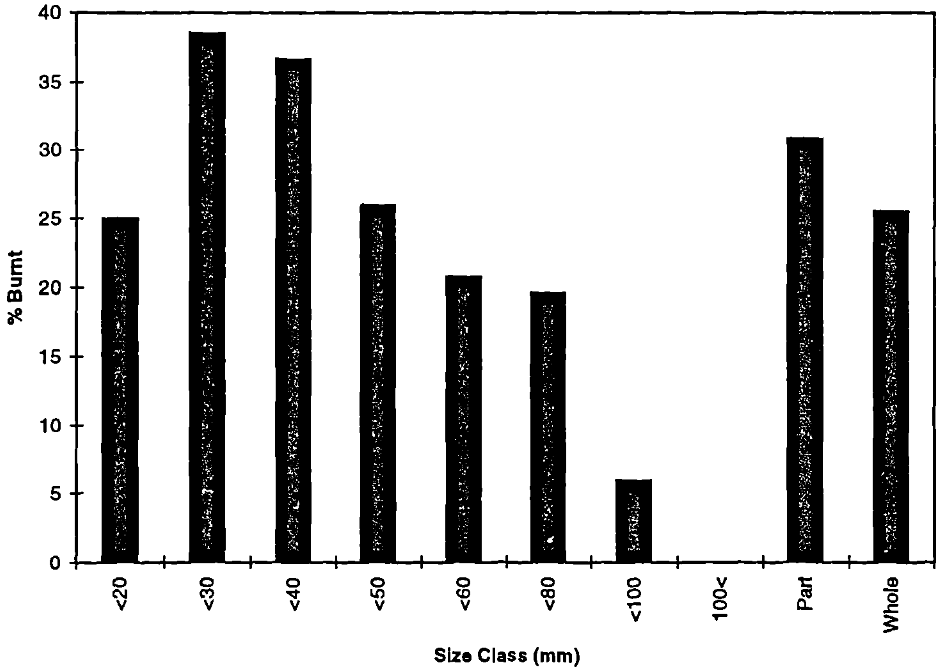


Figure 11.16 - A graph to show the proportion of burnt fragments in different size classes for land mammals in Test Area 1, Ajvide

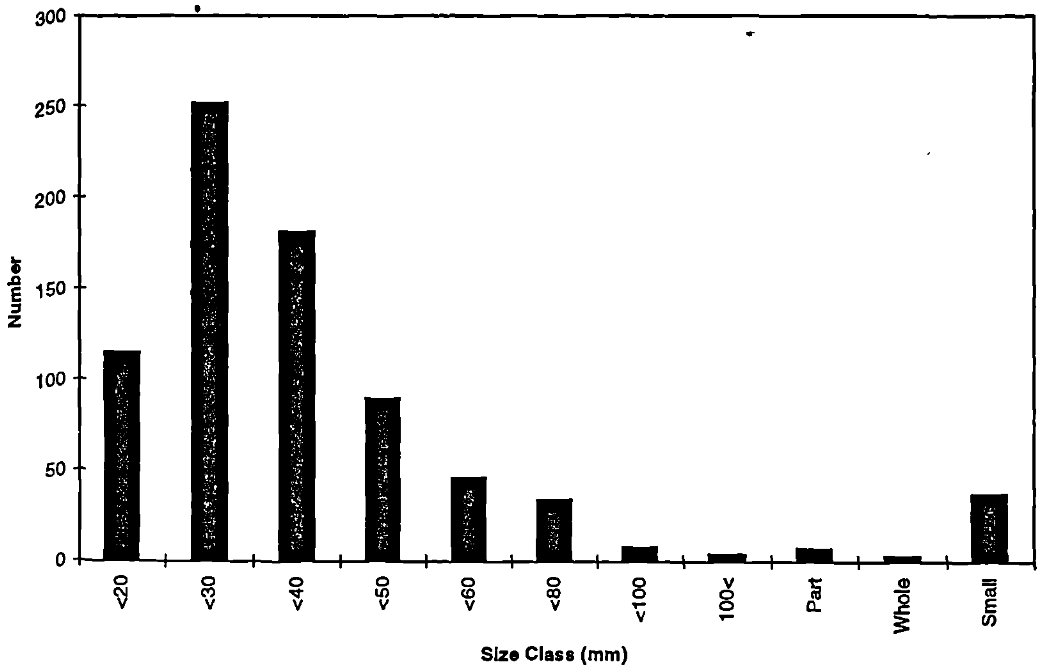


Figure 11.17 - A graph to show the number of fragments in different size classes for land mammals in layers 1 and 2, Test Area 1, Ajvide

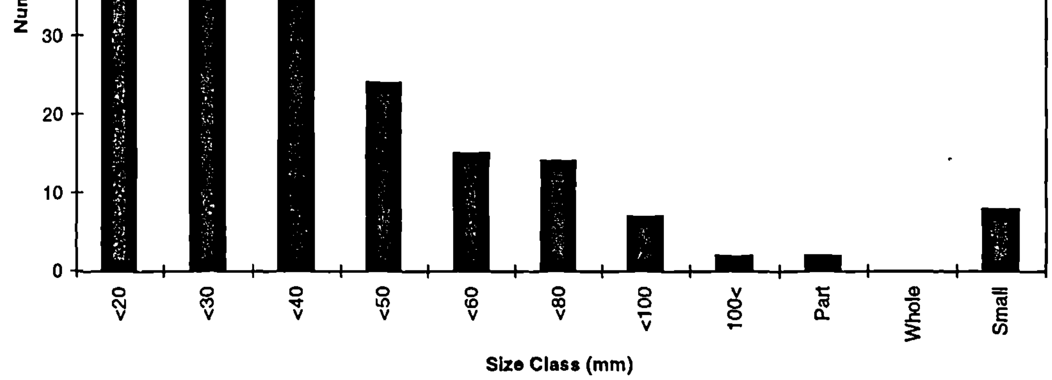


Figure 11.18 - A graph to show the number of fragments in different size classes for land mammals in layers 4,5 and 6, Test Area 1, Ajvide

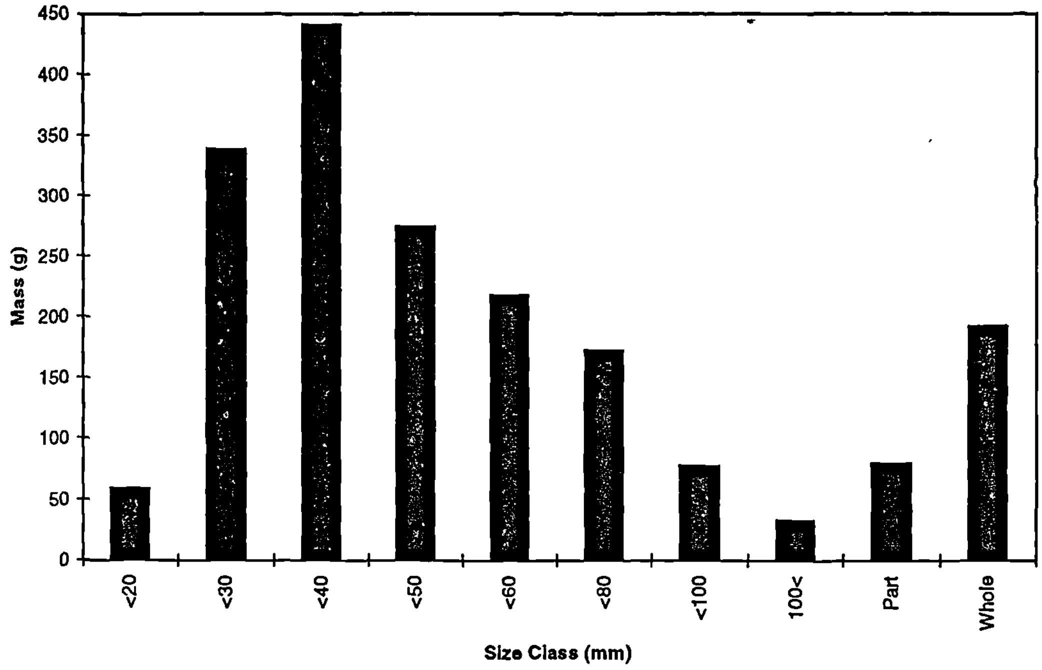


Figure 11.19 - A graph to show the mass of fragments in different size classes for land mammals in layers 1 and 2, Test Area 1, Ajvide

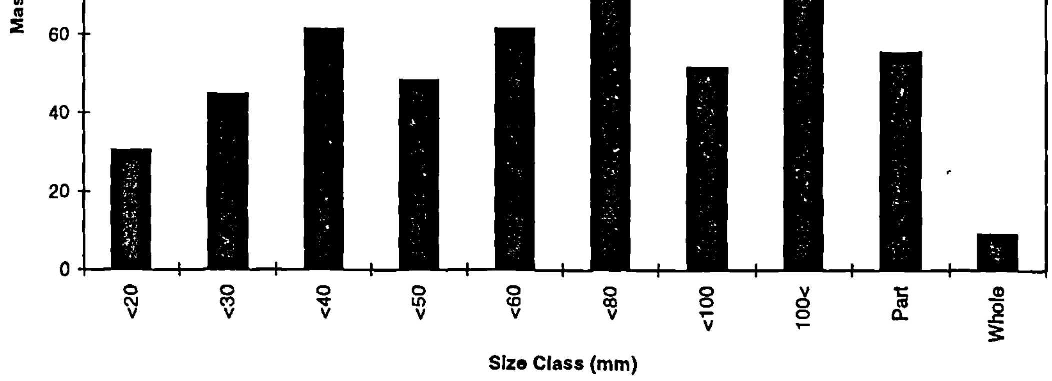


Figure 11.20 - A graph to show the mass of fragments in different size classes for land mammals in layers 4,5 and 6, Test Area 1, Ajvide

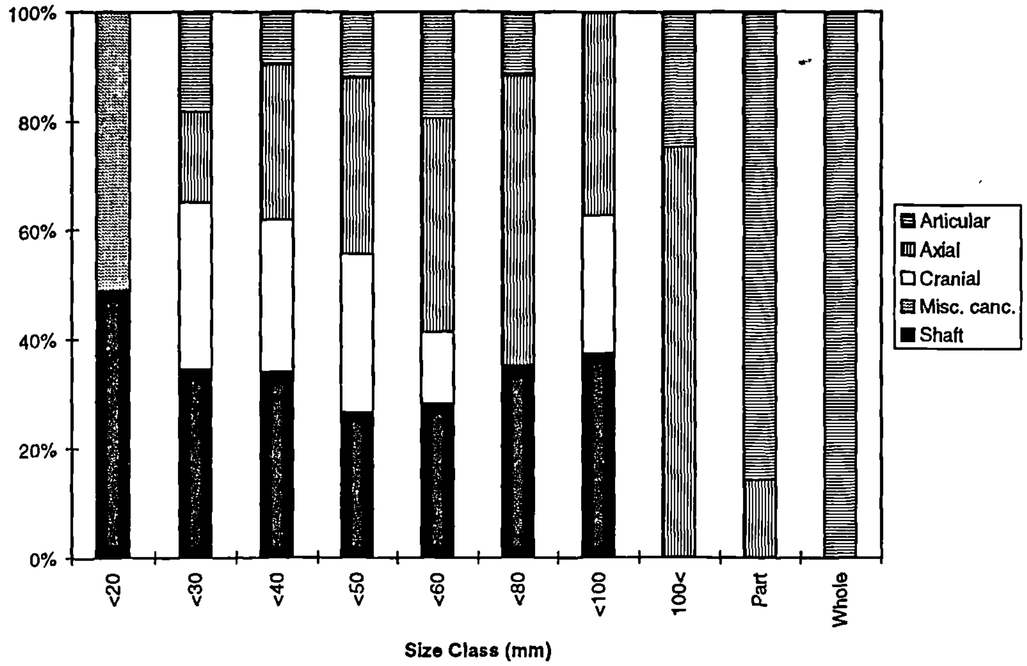


Figure 11.21 - A graph to show the percentages of different fragment types in different size classes for land mammals in layers 1 and 2, Test Area 1, Ajvide

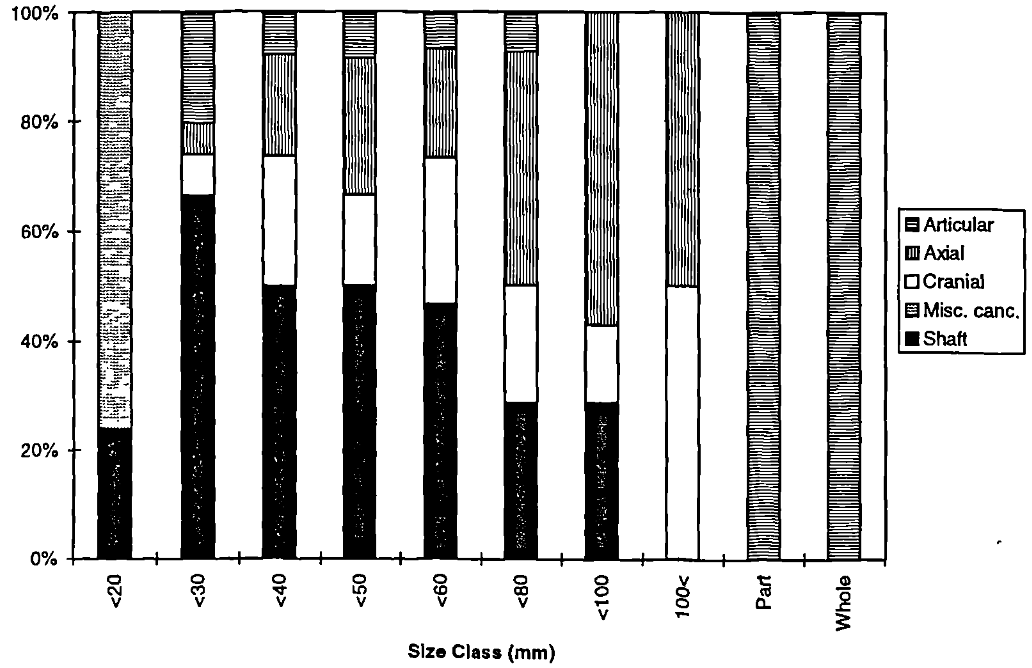


Figure 11.22 - A graph to show the percentage of different fragment types in different size classes for land mammals in layers 4, 5 and 6, Test Area 1, Ajvide

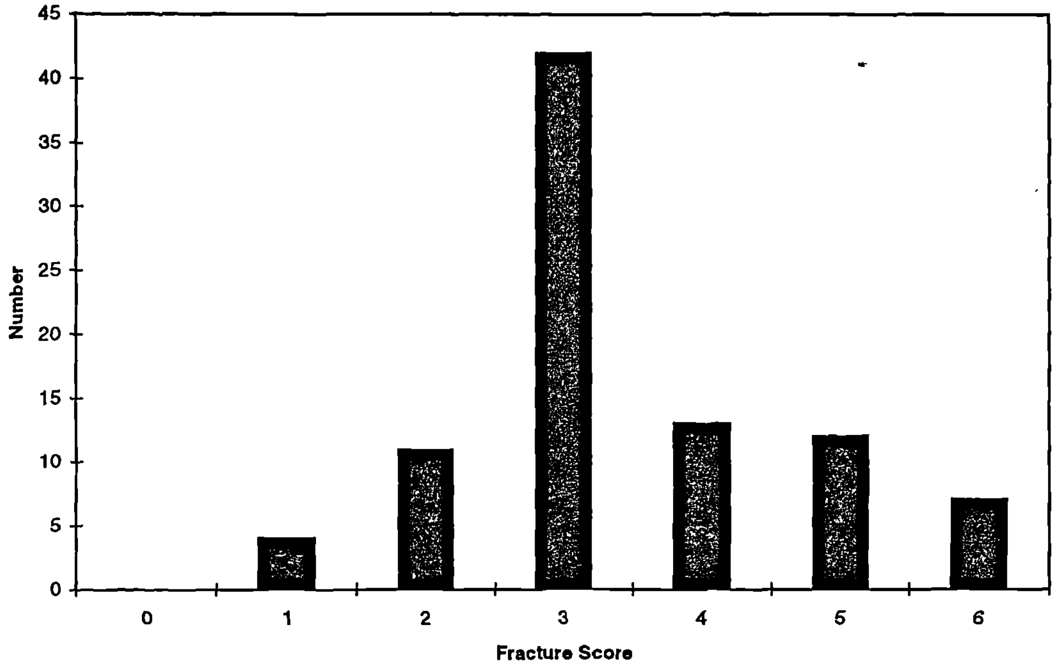


Figure 11.23 - A graph to show the number of different fracture freshness scores for land mammals in layers 1 and 2, Test Area 1, Ajvide

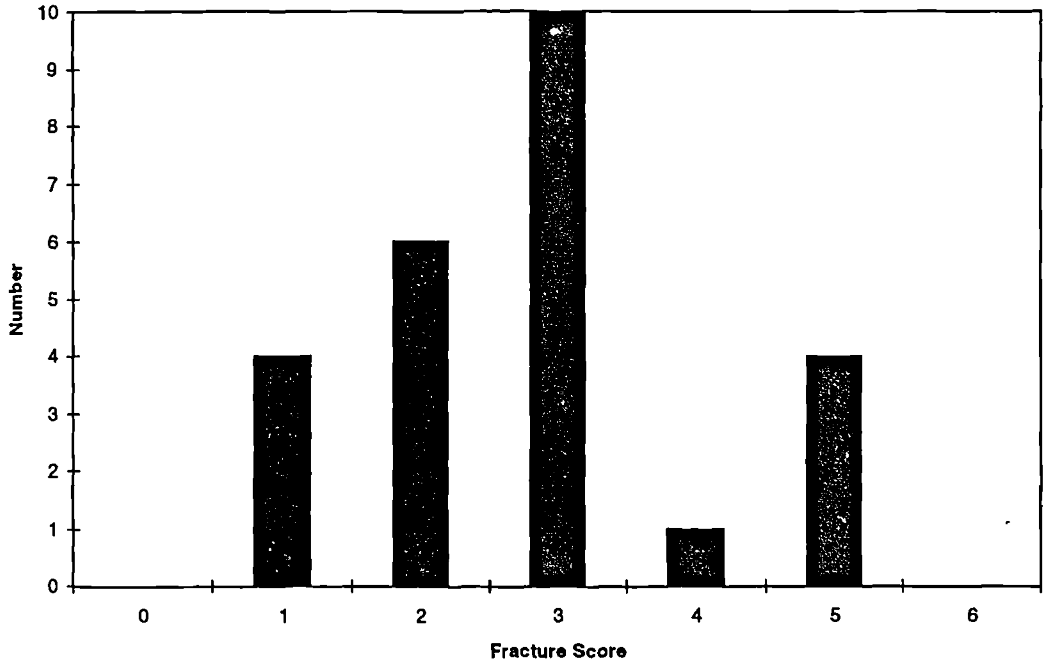


Figure 11.24 - A graph to show the number of different fracture freshness scores for land mammals in layers 4, 5 and 6, Test Area 1, Ajvide

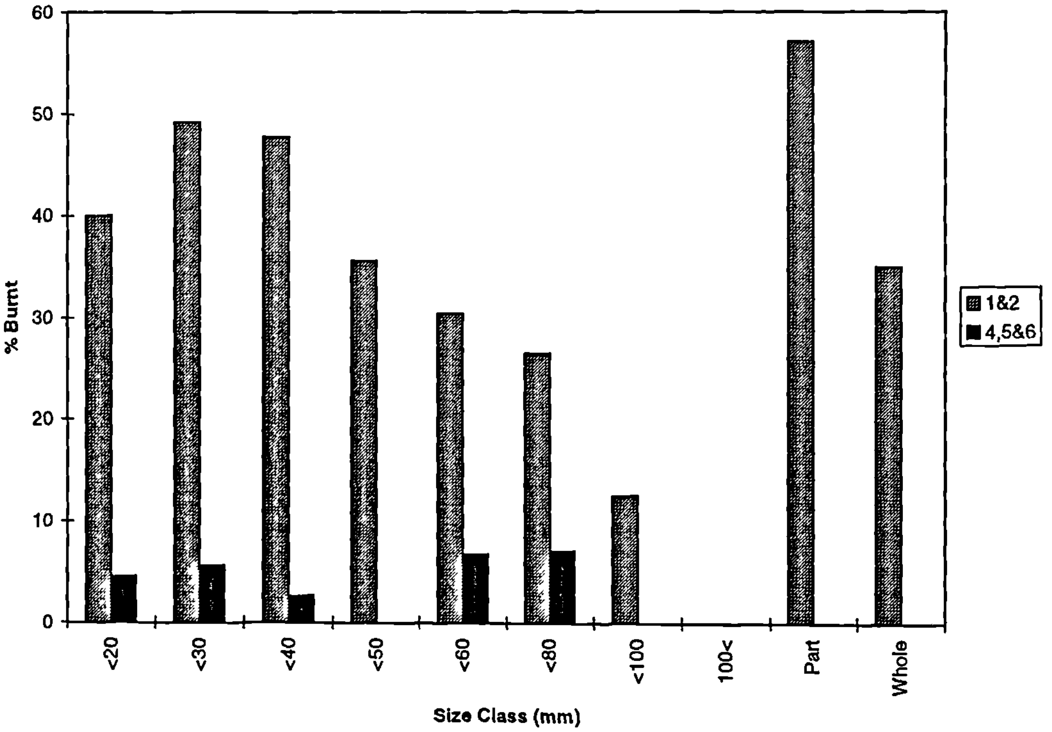


Figure 11.25 - A graph to compare the proportions of burnt fragments in different size classes for land mammals in layers 1 and 2 and layers 4, 5 and 6, Test Area 1, Ajvide

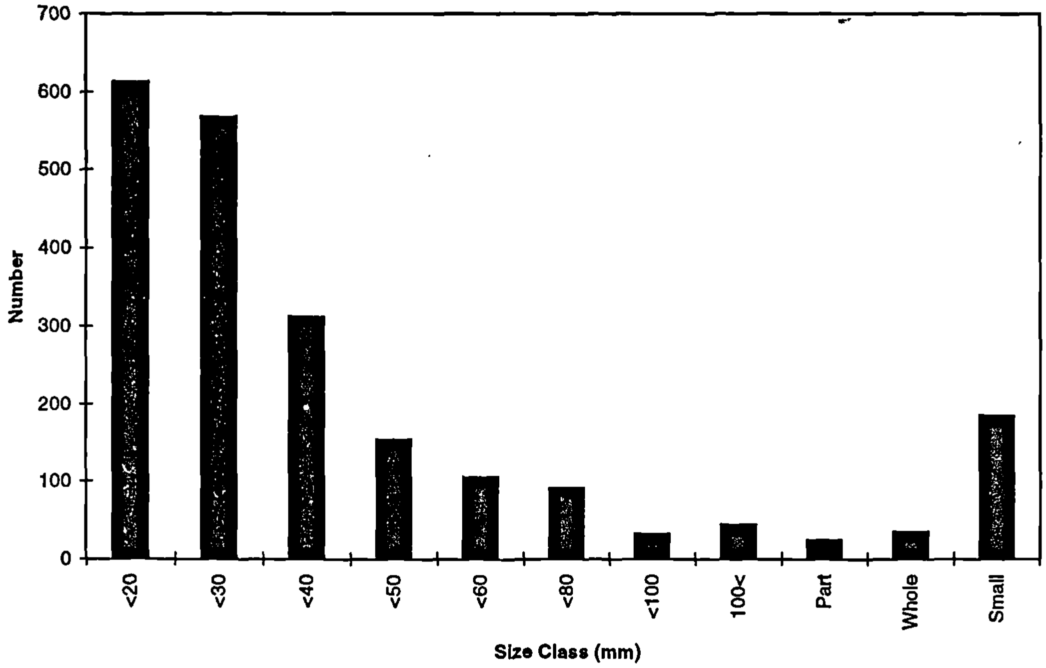


Figure 11.26 - A graph to show the number of fragments in different size classes for phocids in Test Area 1, Ajvide

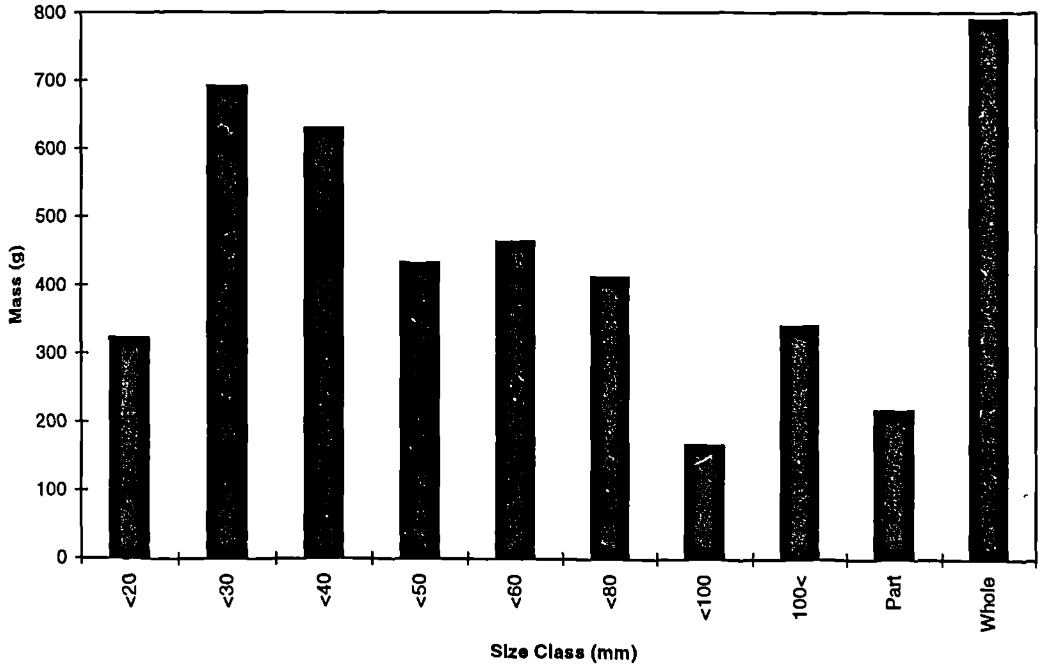


Figure 11.27 - A graph to show the mass of fragments in different size classes for phocids in Test Area 1, Ajvide

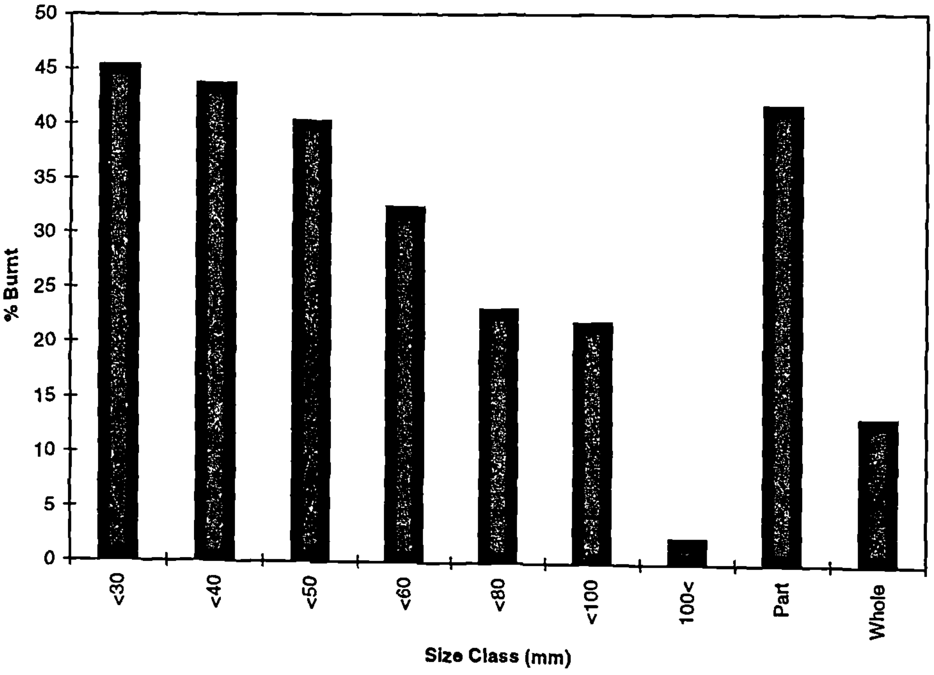


Figure 11.28 - A graph to show the proportion of burnt fragments in different size classes for phocids in Test Area 1, Ajvide

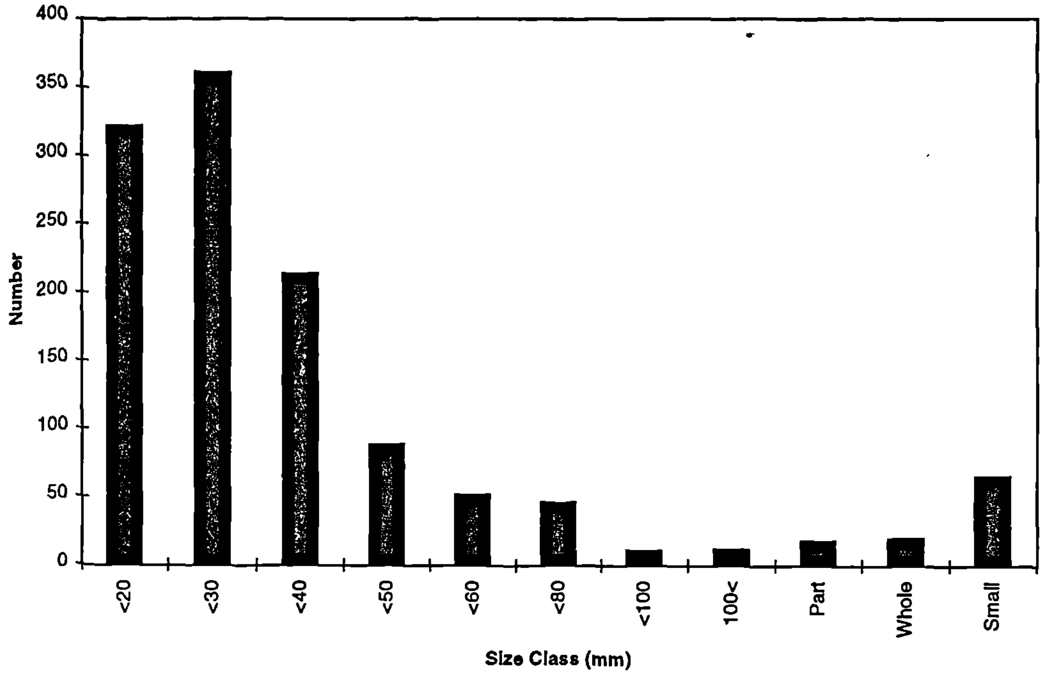


Figure 11.29 - A graph to show the number of fragments in different size classes for phocids in layers 1 and 2, Test Area 1, Ajvide

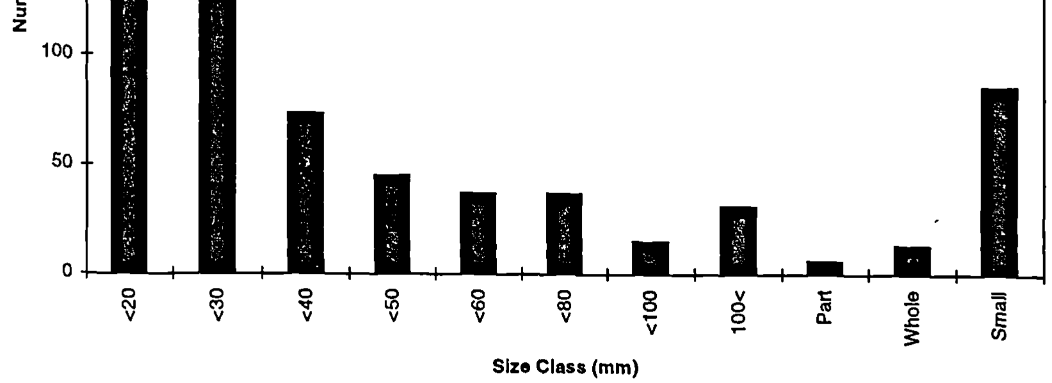


Figure 11.30 - A graph to show the number of fragments in different size classes for phocids in layers 4, 5 and 6, Test Area 1, Ajvide

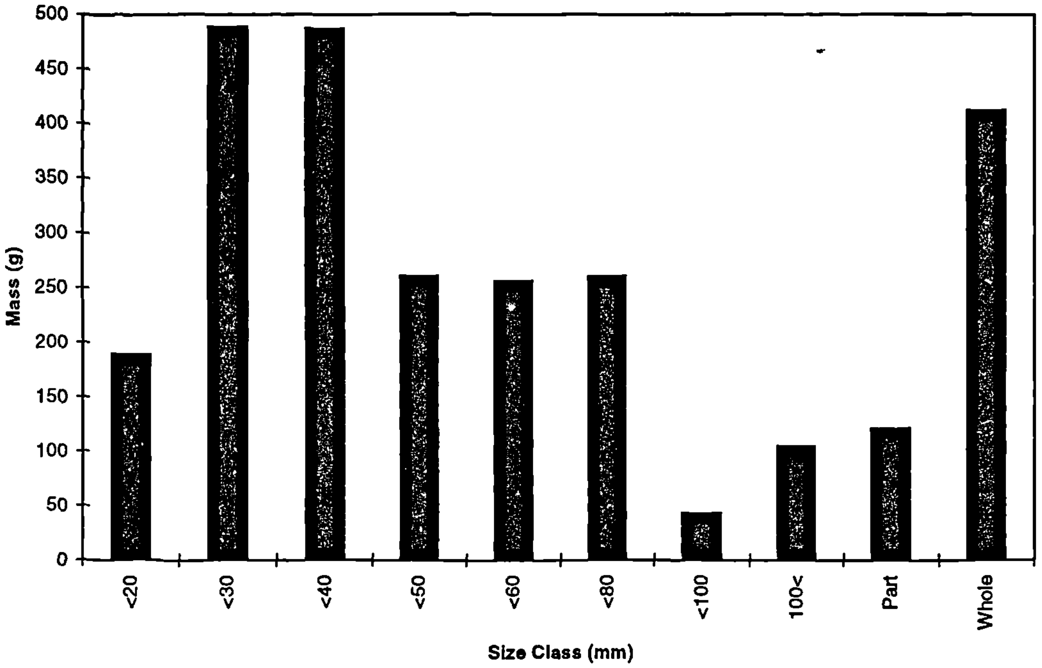


Figure 11.31 - A graph to show the mass of fragments in different size classes for phocids in layers 1 and 2, Test Area 1, Ajvide

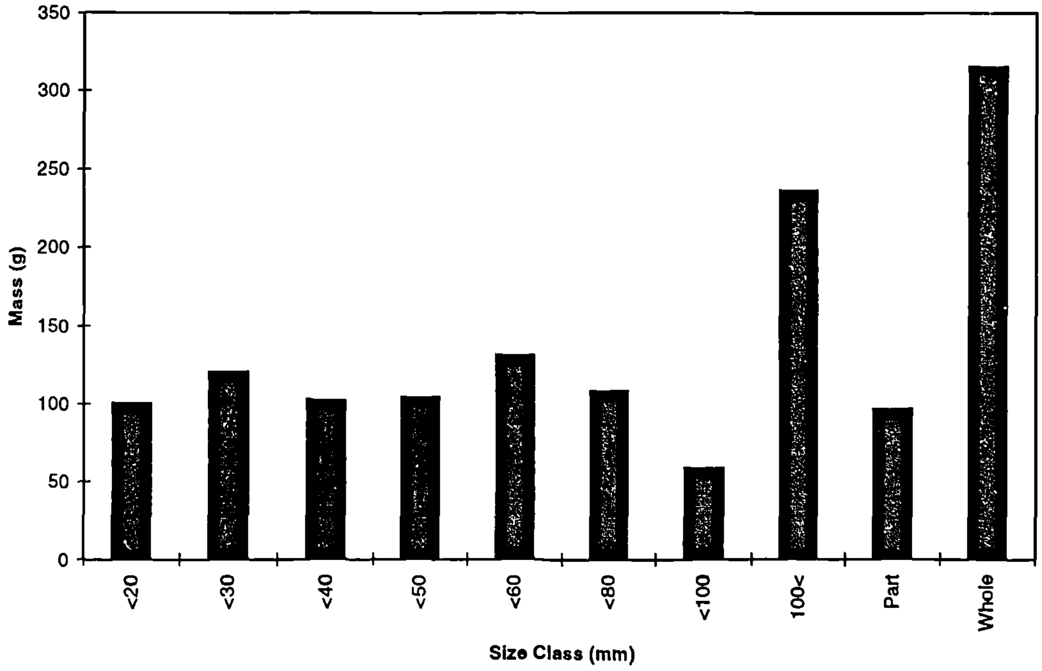


Figure 11.32 - A graph to show the mass of fragments in different size classes for phocids in layers 4, 5 and 6, Test Area 1, Ajvide

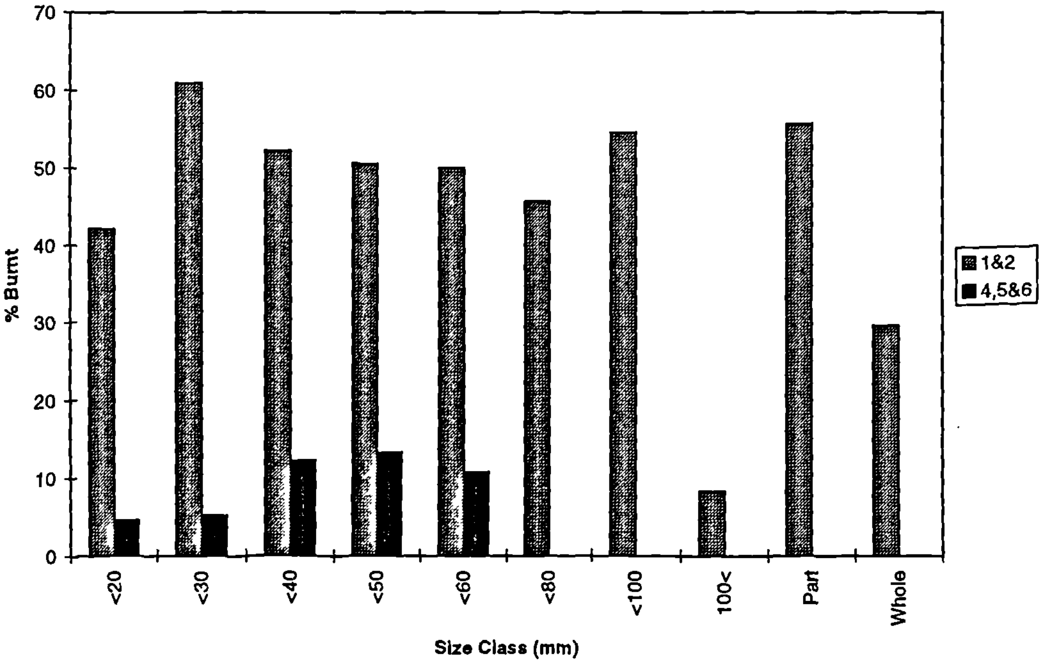


Figure 11.33 - A graph to compare the proportions of burnt fragments in different size classes for phocids in layers 1 and 2 and layers 4, 5 and 6, Test Area 1, Ajvide

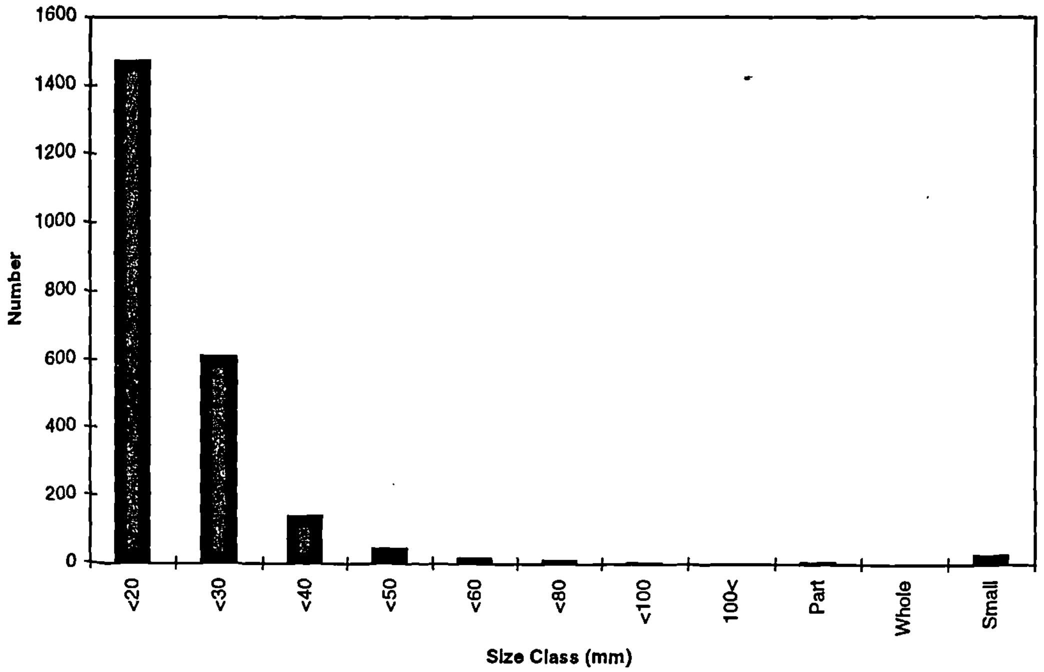


Figure 11.34 - A graph to show the number of fragments in different size classes for land mammals (just identified pig and shaft) in the "black layer", Ajvide

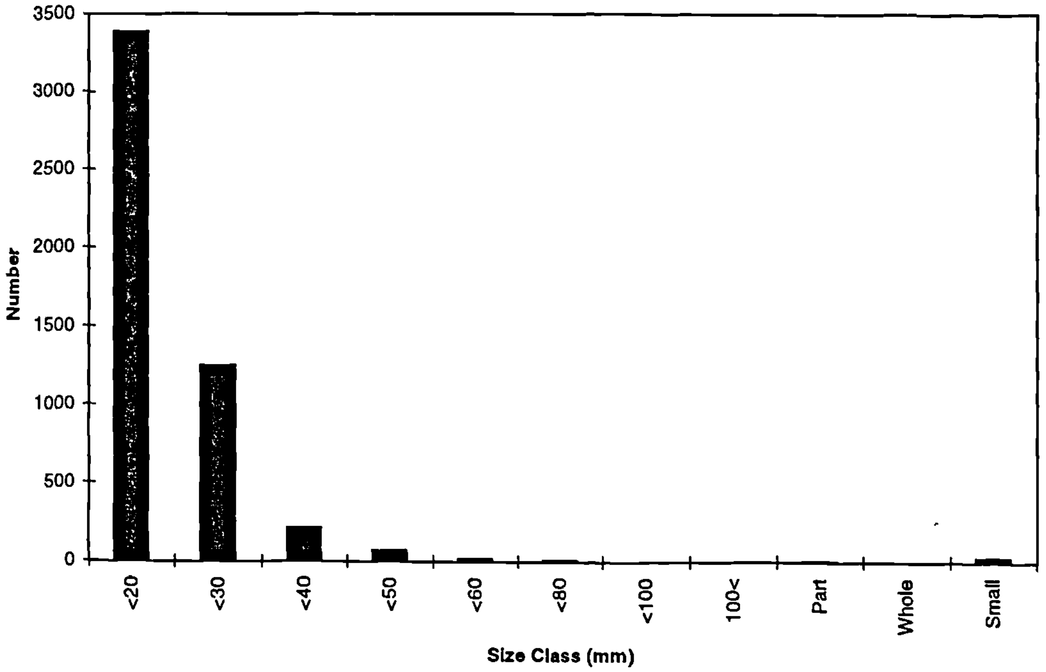


Figure 11.35 - A graph to show the number of fragments in different size classes for land mammals (including all indeterminate fragments) in the "black layer", Ajvide

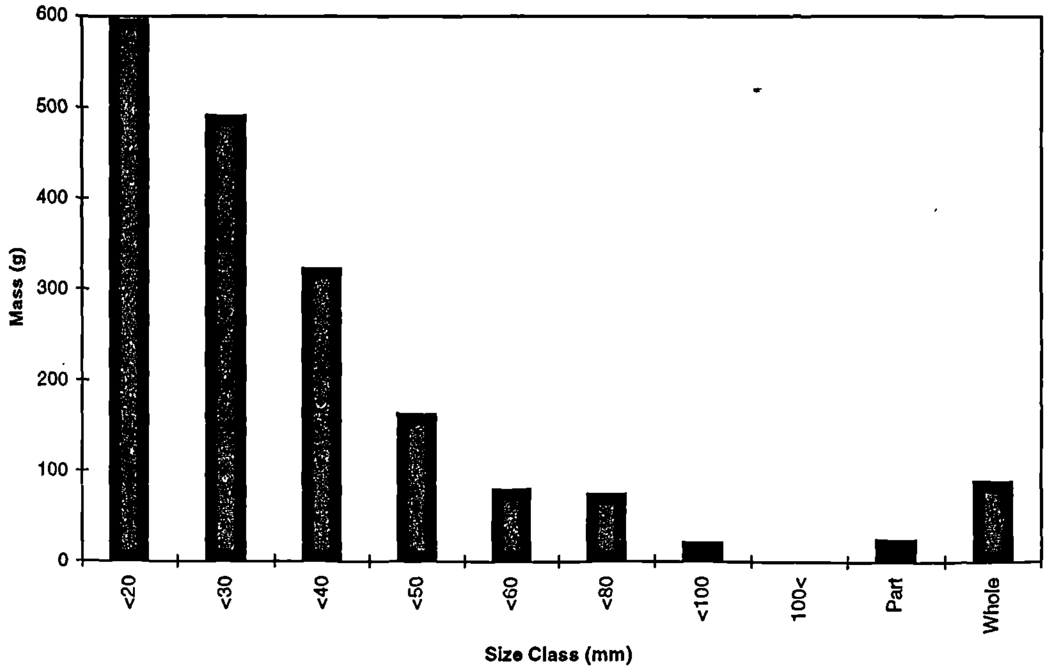


Figure 11.36 - A graph to show the mass of fragments in different size classes for land mammals (just identified pig and shaft) in the "black layer", Ajvide

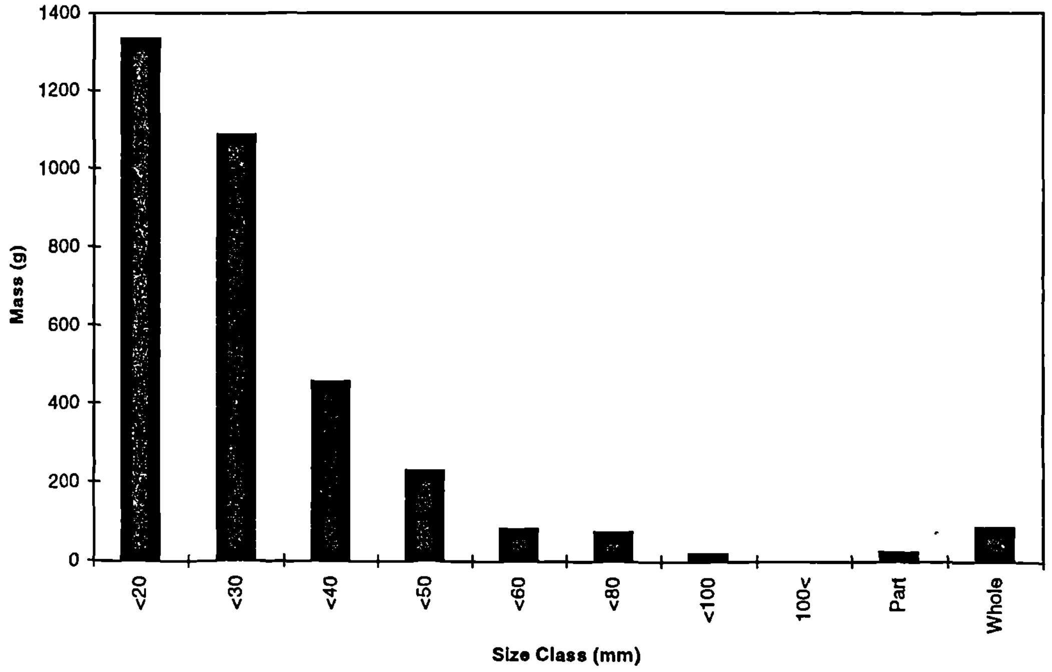


Figure 11.37 - A graph to show the mass of fragments in different size classes for land mammals (including all indeterminate fragments) in the "black layer", Ajvide

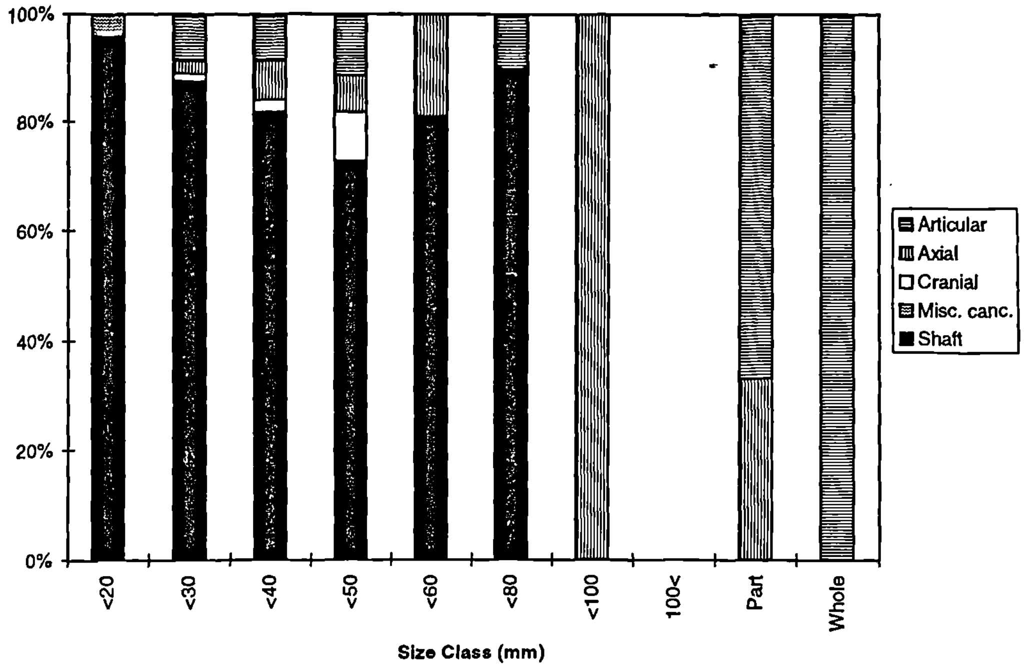


Figure 11.38 - A graph to show the percentages of different fragment types in different size classes for land mammals (just identified pig and shaft) in the "black layer", Ajvide

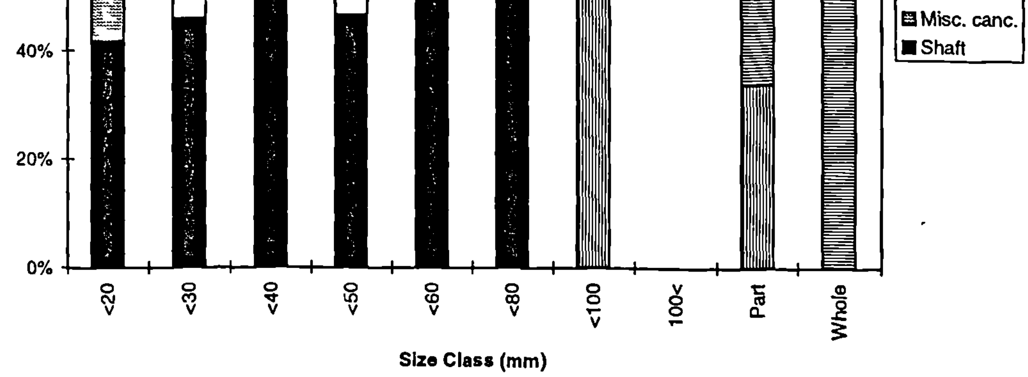


Figure 11.39 - A graph to show the percentages of different fragment types in different size classes for land mammals (including all indeterminate fragments) in the "black layer", Ajvide

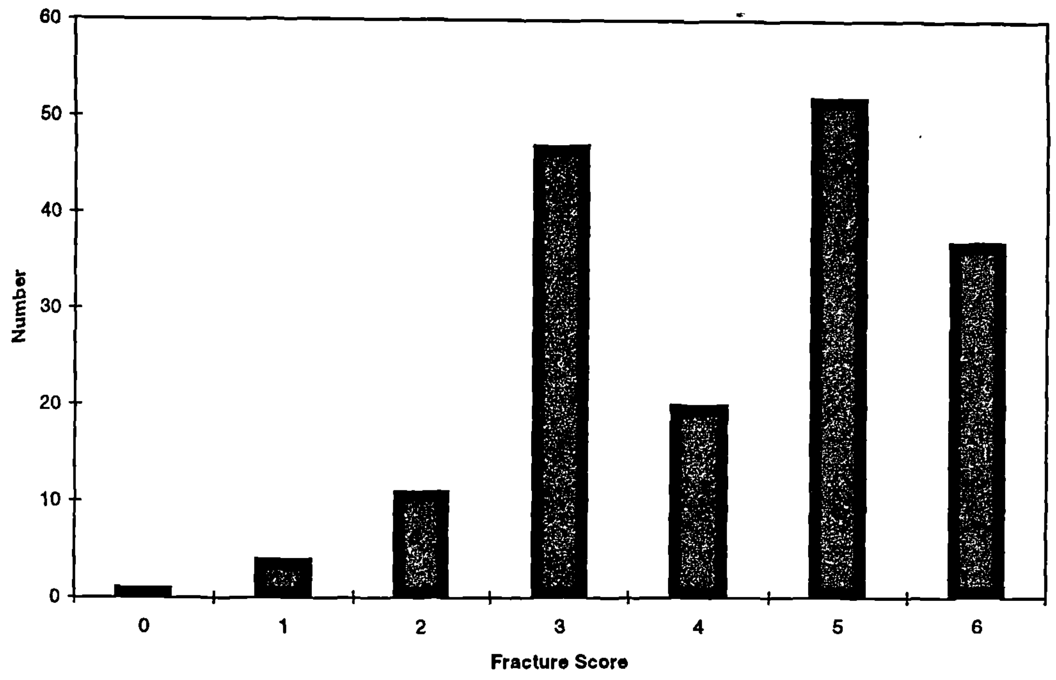


Figure 11.40 - A graph to show the numbers of different fracture freshness scores for land mammals in the "black layer", Ajvide

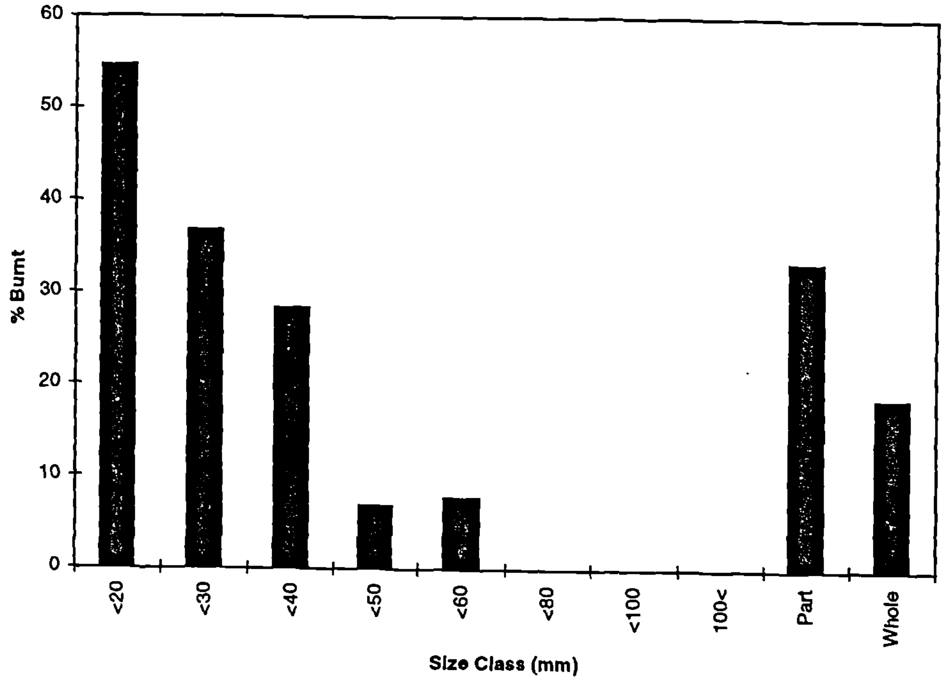


Figure 11.41 - A graph to show the proportion of burnt fragments in different size classes for land mammals (just identified pig and shaft) in the "black layer", Ajvide

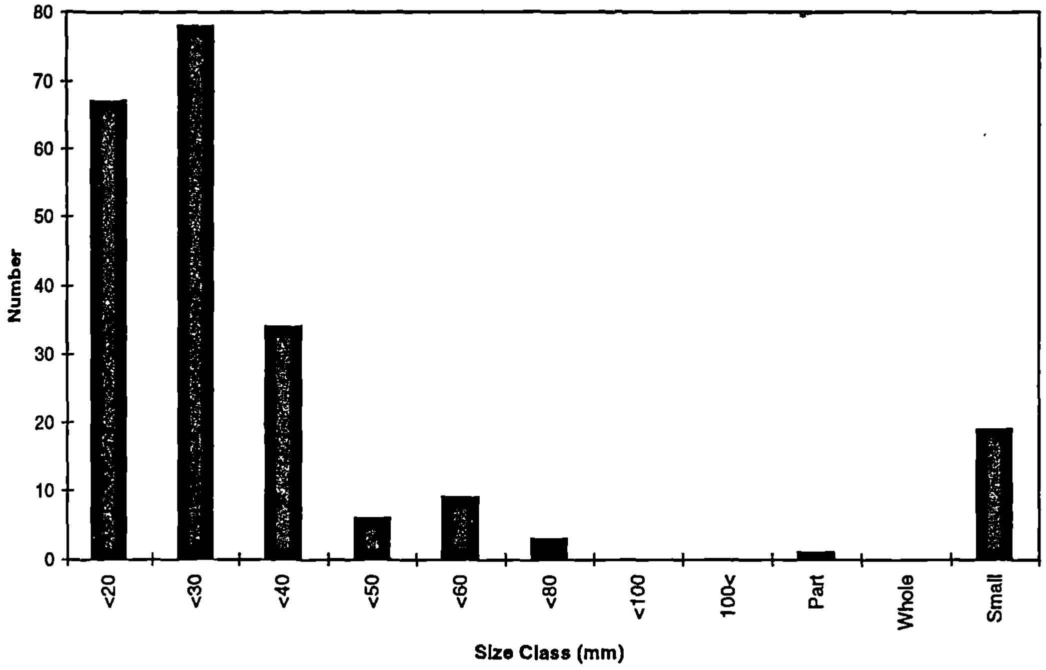


Figure 11.42 - A graph to show the number of fragments in different size classes for phocids in the "black layer", Ajvide

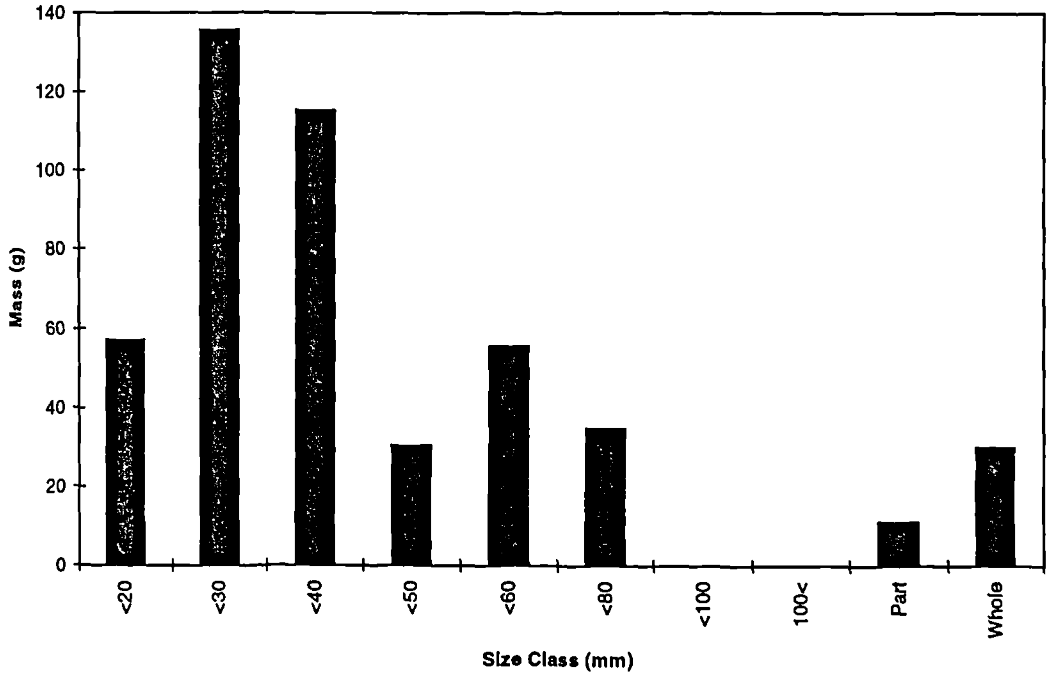


Figure 11.43 - A graph to show the mass of fragments in different size classes for phocids in the "black layer", Ajvide

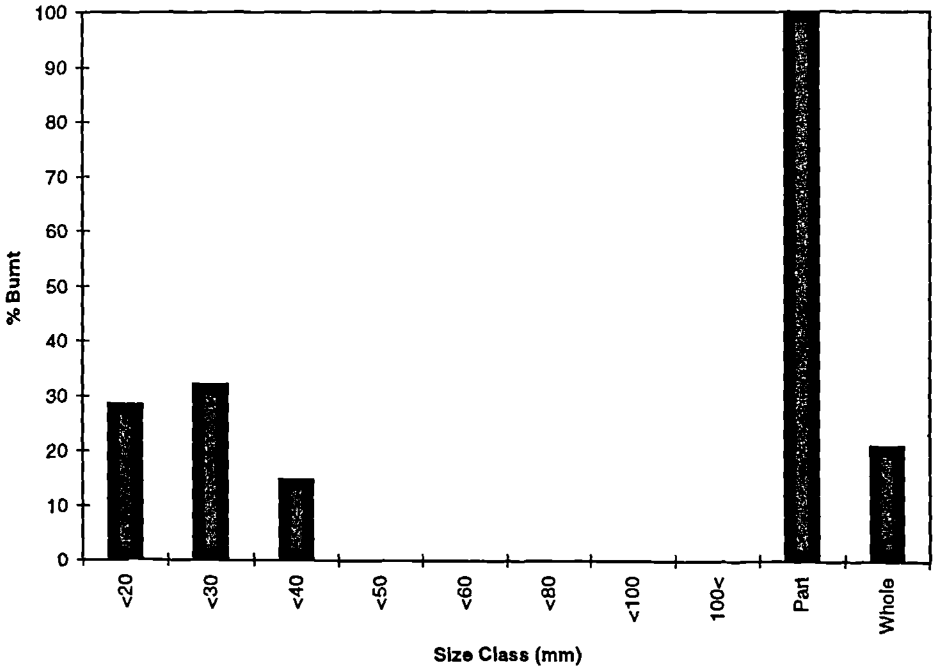


Figure 11.44 - A graph to show the proportions of burnt fragments in different size classes for phocids in the "black layer", Ajvide

CHAPTER TWELVE

CASE STUDY FOUR: THE ADDITION OF A SPATIAL ELEMENT TO FRACTURE AND FRAGMENTATION ANALYSIS OF AN EARLY POSTGLACIAL BONE SCATTER AT THREE WAYS WHARF, UXBRIDGE

12.1 Introduction

The site of Three Ways Wharf, which was excavated by the Museum of London between 1986 and 1988, is situated on low lying ground in the Colne Valley to the NW of Uxbridge (Lewis 1991, 246). There are two principal scatters of material. Scatter A is composed of flintwork and the bones of reindeer and horse and is dated to the late glacial. Scatter C, which is the subject of this study, consists mainly of red deer bones and Early Mesolithic flintwork (ibid.). From the flint scatter, which can be seen in figure 12.1 (hand recovered flints are plotted), c.7000 flints were recovered and preliminary work on refitting suggests that it represents a single phase of activity (ibid. 253). Over 37,000 bone fragments have been recovered and radiocarbon age determination of bone samples suggest a date range between 8840-8030 cal. BC (2σ) (Rackham, forthcoming). The position of more sizeable (as approximately judged by the excavators) bone fragments can be seen plotted in figure 12.2. This figure also shows the position of a burnt area (denoted by diagonal hatching) at approximately 17E, 3N. The linear feature which cuts the site on a

NE/SW alignment is a later feature, probably a Neolithic ditch (Rackham, pers. com.).

12.2 Previous Work on Scatter C Faunal Remains

The initial faunal analysis on Three Ways Wharf was carried out by Alan Pipe with further work being undertaken by James Rackham and is forthcoming in the site's excavation report. Scatter C consists largely of red deer fragments with a small number of roe deer present (Rackham, forthcoming). The position of bones was recorded to the nearest half metre square. Figure 12.3 shows Rackham's plot of the numbers of bone fragments per half metre square. It can be seen that the vast majority of bone fragments are to be found towards the centre of the excavated area, near to the burnt area. Significant numbers of fragments can also be seen to the East of the main group and in the NW corner, across the other side of the ditch. If the weight of bone fragments per half metre square is plotted (see fig. 12.4) we see the same pattern. Rackham notes the high level of fragmentation, and, as such, plots a spatial representation of mean weight per fragment by half metres squares (see fig. 12.5). This graph shows that most fragments weigh only a few grams. High average weights can only be found in the peripheral areas of the scatter and not where most of the bone is concentrated. This graph suggests that the central area is more fragmented than the rest.

The composition of the assemblage in terms of body part representation is also interesting. Rackham (pers. com.) notes that axial elements are almost entirely missing from the assemblage and that there are few appendicular articulations. Furthermore, only the articulations which contain little cancellous bone are present. The implication of having a highly fragmented site with the main sources of cancellous bone missing (or destroyed) is that bone marrow and grease were being exploited. Figure 12.6 shows Rackham's element abundance data for articulations (standardised) plotted against element volume. Brink (1997) demonstrated that there was a clear correlation between bone volume and grease content in his study of bison. In figure 12.6, bone volume measurements for caribou have been used (from Binford 1978, table 1.11) since it is the data most applicable to red deer, for which there is no existing study. It can be seen that the most represented elements, the proximal metapodials and distal tibia, have very low volumes (and grease value). Two exceptions to this trend are the distal humerus and the proximal radius/ulna. However, it is only the humerus which is genuinely anomalous since Binford (ibid.) only cites the proximal radius and ulna together (as radio-cubitus) in his volume figures, and it is the ulna which is most voluminous and the radius which is present at Uxbridge! Hence, there is a strong trend indicating that high grease-bearing bones do not survive on the site. One could interpret this data as suggesting that high grease-bearing elements were destroyed during rendering, leaving only articulations of lower value (i.e. in an optimal model there was a use cut-off at about the distal tibia, in terms of grease value). However, it is important to note that this pattern could have a post-depositional taphonomic cause. There is also a good correlation between carnivore selection of bones and grease content (Brink 1997) and these bones will also be open to more density-mediated attrition.

With regard to seasonality and occupation period, seasonal indicators at the site currently suggest a spring occupation (Rackham, pers. com.) and the size of the assemblage does not indicate long term use of the site (ibid.). The information from flint re-fitting corroborates this. The interpretation prior to the current study was that the site was used for a period of time in the springtime for the processing of hunted deer. Not all processing may have taken place there, as many elements are effectively missing. The axial skeleton may have been deposited elsewhere. It is likely that scatter C represents the processing of the appendicular skeleton for marrow and bone grease.

12.3 Questions to be Addressed

With reference to this current study of fracture and fragmentation at Uxbridge, Rackham raised a number of questions which ought to be addressed. These questions are demanding and push at the limits of the methodology put forward in this volume. In ascending order of difficulty, the questions posed were as follows:

- ⇒ Will the use of the fracture freshness index be able to provide further substantiating evidence that bone marrow and grease were being exploited at the site?
- ⇒ If fracture freshness index values are studied spatially, will it be possible to detect such features as areas of trampling (i.e. routes in and out of the site, or activity areas), that were created during the occupation of the site, or other spatial differences in fracture patterns?

⇒ Is it possible to tell for how long bones were stored before they were fractured and processed for their fat content?

Regarding the first question, it is certainly possible to ascertain whether fracture patterns are consistent with the practice of bone fat utilisation. With reference to the second question, there is every possibility that if there is a spatial pattern in fracture types that this would be picked up in a spatial study of index values. This is certainly problematic, however. If a site had been subjected to very little damage after it became disused, then there is every likelihood that spatial patterns in fracture type, relating to trampled patches and activity areas, would be detectable. However, the more post-abandonment damage there is, the more likely it becomes that any such detailed patterns would become masked by later taphonomy. Furthermore, such patterns would probably only be visible if almost all the deliberate human fracture was of fresh bones. In such a case, the bone scatter would, in its original form, consist of fragments scoring one or two on the fracture freshness index. Areas of trampling would then show as higher index values. If, however, the deposited bones already had high index values, such spatial patterns would be impossible to detect. On a supposed marrow and grease processing site, however, there is every possibility that index values will be uniformly low at the time the bones are deposited (like at some of the Greenlandic sites, chapt. 10). It is far from impossible that, on a well preserved site, with middens that demonstrate clearly the nature of bone processing at that site, patterns of site access, activity areas etc. will be visible in a spatial study of fracture freshness. Interpretation will be far from simple and will be seriously affected by the later taphonomy of the site.

The third question, assessing how long bones were stored before processing, is, however, an even more difficult issue. Telling the difference between completely fresh bones and bones which have been, for instance, stored over winter would certainly be possible under laboratory conditions, but the differences would be subtle. Only the slightest amount of post-depositional attrition would be likely to mask such a pattern. If a site had a very limited period of use and waste from processing was middened and not trampled or attacked by carnivores, and then that site was covered and preserved in excellent conditions (such as permafrost), it might be possible to answer this question with the methodology in this volume. Such sites may exist, but this author has not yet encountered one. With a glance at the Uxbridge material it is possible to say that it is not sufficiently well preserved. There will, therefore, be no attempt to answer the third of Rackham's questions, but there are definite possibilities for the first two.

A fourth question, that should certainly be addressed, can be added by the present author:

⇒ Is it possible to discern spatial patterns, in terms of the distribution of proportions of bone size classes and bone types (i.e. cancellous and diaphyseal), that may reflect the different processes taking place at the site?

12.4 Methodology

The methodology for this study is essentially the same as in previous studies, but with the addition of a spatial element. Studying each individual half metre square is extremely time consuming so the amount recorded for each fragment has been reduced.

With regard to fracture freshness, the half metre square and spit of origin, the index value of the fragment, the presence or absence of impact or rebound scars and the element of the skeleton (if known) were recorded. In order to make sample sizes as large as possible, attempts were made to give fracture freshness index values to all shaft fragments in excess of 35mm maximum dimension. A methodological problem was encountered because some conjoining fragments had been stuck together with glue. If this seriously interfered with the assessment of those fragments they were disregarded. If the amount of surface concealed was negligible, or would not affect the assessment, then assessment was made of the individual fragments.

In order to make classification by size class quicker, only three size classes were used: small (<20mm), medium (20 - 50mm) and large (>50mm) (by maximum dimension). Quantification by number only was carried out, since Rackham has already performed much work on spatial distribution by mass. Separation was also made between diaphyseal and cancellous bone within each size class. Bones that had been stuck together were assessed and measured separately.

Bone material from the residues of flotation sieving was available for study but was not studied for two reasons. There were many tiny fragments which could not be assessed sensibly and the sieving and sorting had not been carried out in a uniform manner across the site, making any spatial pattern questionable. The recovery on the site without sieving was, however, excellent and the omission of the residue samples is very unlikely to prejudice results.

The bone material had been stored by skeletal element not location. As a result the fragments were not recorded in an order relevant to their place of origin on the site. This had the advantage of making the author effectively blind to any pattern until the recording was completed, the data had been entered onto a computer database and sorted by squares of origin. The author was, therefore, less open to subconscious bias whilst assessing fragments.

12.5 Results

The raw data relating to this study can be seen in Appendix E. The results of this study have been plotted as three-dimensional histograms following Rackham's method. After some initial attempts at plotting the histograms by half metre squares it was decided that the sample sizes would not be large enough for this kind of study. Hence, the histograms referred to below were plotted by whole metre squares.

12.5.1 Number

Figure 12.7 shows the total number of bone fragments studied in each metre square (this is effectively the same plot as Rackham's in fig. 2.3, but at the lower resolution). This plot shows very clearly the big group of bone fragments near the centre of the site, adjacent to the area of burning (see fig. 2.2). Below, for simplicity's sake, this will be referred to as the main group. To the east of this is a further concentration of fragments (the eastern group) and there are also increased frequencies to the NW of the site (the NW group). The NW group is cut off from the main group by the later Neolithic ditch. Elsewhere, there are few, if any, fragments.

12.5.2 Size Class Distributions

Figure 12.8 shows the percentages of fragments which were classed as large (>50mm). This shows very much the same pattern as Rackham's plot of average fragment weight (fig. 12.5). There are apparently very few large fragments in the main group and more in the East and NW groups. The proportions of large fragments in the peripheral areas vary wildly. This is almost certainly due to the small sample size in those regions. The proportion of large fragments in square 23E, 5N is 100%, but this is because there is only one fragment in this square! This anomaly has the effect of depressing the heights of all other histogram bars and may obscure patterns. If the scale of the plot is clipped so that it only reads as far as 40% (see fig. 12.9) patterns in the rest of the site can be seen more clearly. In this graph one can see that there are indeed some large fragments in the main group, but it is almost certainly the case that there are more in the East and NW groups and very variable proportions elsewhere.

Figure 12.10 shows the proportions of medium sized fragments across the site. In the main group there are fairly uniform values of around 30% and much more variable values elsewhere on the site. This graph gives the impression that medium-sized fragments are more dominant outside the main group, but on close inspection one can also see many low values outside the main group. The pattern of the graph is probably more the result of smaller sample sizes (see fig. 12.7) in the periphery than any archaeological pattern.

Figure 12.11 shows the proportions of small fragments. This does not appear to show any pattern of great significance. In summary, it is clear that differences in sample sizes have a severe effect on these proportional histograms. One pattern that seems to hold up, however, is that the main group, by comparison to the other groups and periphery, has fewer large fragments in it. This pattern appears even more exaggerated when quantified in terms of mean fragment weight (fig. 12.5). That graph gave the impression that the main group was very much more fragmented. This is not the case, however, if one examines proportions of medium and small fragments. This pattern is the combined result of fewer very large fragments in the main group and small sample sizes in the periphery.

12.5.3 Distribution of Bone Types

Figure 12.12 shows the percentage of bone fragments which are cancellous. It is very clear from this that there is a significant pattern. There is very little cancellous material in the main group and considerably more in the East and NW groups. This cannot be the result of sample sizes. The samples are quite large for these groups and the pattern is very striking. In other, peripheral, areas cancellous levels are variable.

To investigate this pattern more closely, figures 12.13, 12.14 and 12.15 plot the absolute numbers of small, medium and large cancellous fragments respectively. Examining figure 12.13, it is clear that there are definite concentrations of small cancellous fragments in the East and NW groups. One must bear in mind, whilst viewing these absolute graphs, that the main group contains many more fragments than other areas, so apparently large absolute quantities may well represent quite small relative proportions. One must consider both figures 12.7 and 12.12 in conjunction with these absolute counts. Considering the dominance, in terms of fragment numbers, of the main group, it makes it even more impressive that the other two groups stand out so much on this graph. This is a very strong pattern.

Figure 12.14 shows the numbers of medium sized cancellous fragments. Again, there are peaks in the East and NW groups, with some representation in the main group (though a very small proportion of the total in that group). The pattern for the large fragments of cancellous bone is similar (see fig. 12.15). It is clear that the two smaller groups of bone have a very different composition in terms of bone type.

12.5.4 Fracture Freshness Index Scores

Figure 12.16 shows the number of fragments which were assessed for fracture freshness in each square. The vast majority were in the main group. Figure 12.17 shows the mean fracture freshness score for each square. It is just about perceivable that there is a shallow but consistent depression in fracture freshness values in the area of the main group. This is only a very slight trend and levels are quite variable in the peripheral areas where sample sizes are very small.

The overall index mean for the site is 3.31 (N=852) which indicates a relatively even mix of dry and fresh fracture features. There is certainly a fair amount of post-depositional damage to the bones on this site. If one takes the core of the main group to be the rectangle of squares bounded by 16E, 1N in the SW corner and 19E, 3N in the NE corner, then the mean index value for the main group is lower at 3.24 (N=527). The mean index value for the remainder of the site is 3.41 (N=325). This confirms the slight trend noticed visually from the graph, but is this just the effect of random variation or is it significant? A Two-Sample T-Test comparing the two means produces a T value of 1.87 (df = 850). Therefore, in a two-tailed test of significance, there is a confidence level of 93.79% that the two means are significantly different. The trend is very slight, but most likely to be genuine. There do not appear to be any other patterns with regard to freshness of fracture which cannot be accounted for by small sample sizes in the peripheral areas.

Impact scars were present in low numbers. There were 17 in total, which is 2.0% of the sample.

12.6 Discussion and Interpretation

Taking the assemblage in total, the general pattern is consistent with a site where both bone marrow and grease have been exploited. The assemblage is very fragmented with only a very small proportion of fragments being over 50mm maximum dimension. The overall mean fracture freshness index score is 3.31. This implies that there has been quite a substantial amount of unfresh fracture and post-depositional damage, as one might expect for an assemblage of this age. However, it also implies that there was also a fair proportion of fresh fracturing present on the site. The impact scars, though there are not a large number surviving, are an indication of deliberate fresh fracture. If this line of evidence is coupled with the very poor survival of cancellous material and the skeletal part abundance pattern for appendicular articulations, one has a pattern that fits bone marrow extraction followed by bone grease rendering rather well. This is supportive of Rackham's (pers. com.) interpretation of the site.

The spatial study revealed a very clear and interesting pattern with regard to the distribution of surviving cancellous material. Most of the cancellous material can be found in two distinct groups on the site. These are the two smaller groups of fragments to the East and NW of the main area of bone dumping. This main area of dumping consists almost entirely of shaft fragments. This pattern is very unlikely to be the result of random action and may well be related to the activities on the site. It is a distinct possibility that the two concentrations of cancellous material represent the output from the rendering of cancellous material for grease. The main concentration of shaft fragments could represent the waste material from the fracturing of diaphyses for marrow.

There is an ethnographically encountered pattern of bone deposition which fits the Uxbridge results rather well. Binford (1983, 153) describes the activities at the Anaktiqtauk Inuit hunting camp site in Alaska. At this site three hunters exploited bones for their fat content. This was not large scale production, but exploitation for their own immediate consumption. Two men sat round one hearth and cracked caribou bones for marrow. The broken shaft fragments fell to the ground where they were working. Larger waste fragments, which were not to be further processed were thrown behind them. The third man constructed a second hearth and produced bone juice which was drunk by all three men (ibid.). Bone juice is a fatty broth, which, although Binford is not specific, must have been made by boiling cancellous bone material (which contains the grease). This process is effectively the same as bone grease production, except the fat is not separated off for future use. The fat is consumed whilst still hot in the liquid. The bone juice waste, presumably consisting of broken up articulations, was dumped in two small piles. One pile was behind the man doing the processing, and the other was formed from material thrown across the other side of the fire (ibid.).

Binford drew a diagram of this pattern (Binford 1983, fig. 90). It can be seen redrawn and simplified in figure 12.18. In this figure the hearths are denoted by black areas. The lower of the two was the one used for bone juice production. The other was where bones were cracked for marrow. The two men sat to the right of it and dropped the broken splinters of shaft, from their marrow extraction, in what

Binford terms the "drop zone". They threw larger waste pieces into what he calls the "toss zone", which is the general area around them which is within casual throwing distance. This diagram also shows the two bone juice dumps; one either side of the bone juice processing hearth. The man engaged in this task sat to the lower right of this hearth, between the hearth and the bone juice dump (ibid.).

This pattern of bone disposal could work as a very good model for what is occurring at Scatter C, Uxbridge. The Anaktiqtauk case uses two hearths but Binford (1983, 155) notes that two hearths were not "...always felt to be necessary". Scatter C could be a very similar type of site working around a single hearth (i.e. the burnt area shown in figure 12.2).

Figure 12.19 is an interpretation of Scatter C which uses Binford's terminology. It is drawn to the same scale as figure 12.18 and is marked with Eastings and Northings at metre intervals. The main group of bones is situated next to the burnt area (hearth?) and consists mainly of shaft splinters. This could represent the "drop zone" where diaphyses were fractured for marrow and the splinters deposited. This may be the reason why the fracture freshness index scores were lower in this area. If this is the principal area where shafts were deliberately fractured, one might expect lower index scores. Almost all the bone fragments deposited in this area will have been freshly fractured, so, even if there is later unfresh breakage their index value will remain near three. In other areas, however, there may have been the disposal of unfractured bones which are later trampled etc. and bear no signs of fresh fracture. These fragments will lead to a higher average index score. Most of the flint debutage was also centred around the burnt area (see figure 12.1), which would make sense if people sat around the fire whilst working.

The two smaller dumps of bone in the East and NW, with their higher cancellous proportions, could represent the output from the production of bone juice. Round the outside of these dumps would be the "toss zone" where larger waste pieces might be thrown. It was the case that there were more fragments over 50mm in the peripheral areas (see fig. 12.8). The pattern we see at Uxbridge has probably been somewhat blurred and spread out over the 10,000 years since its formation. The difference in proportions of bone type remains fairly distinct, however, and patterns regarding bone size and fracture freshness are also consistent with the above interpretation, though these patterns are less distinct. Considering all the evidence together, a possible interpretation for Scatter C is that it represents a small seasonal hunting camp that was used on one occasion for a relatively short period (maybe a number of weeks). Primary butchery may well have taken place elsewhere, perhaps at the kill site, but the camp site was used for activities such as flint work, cooking and the processing of bones for marrow and bone juice. This bone fat was probably exploited to satisfy the immediate dietary needs of the hunters.

There are some potential problems with this scenario, however. As Rackham (pers. com.) points out, Binford's observations were of a hunting camp in an arctic region. The Uxbridge site is in a temperate region. There are at least 15 red deer represented at the site (Rackham, forthcoming). This number of animals would provide a large quantity of meat which could feed a large number of people. In an arctic climate, meat can be cached under the snow. This cannot be done on a temperate site for any lengthy period of time. If the Uxbridge site is a small hunting camp, one needs to consider how the hunters kept the meat from spoiling, during their stay at the camp, before transporting their kills back to a base camp. It is possible that some other preservation method was employed, such as drying the meat. Alternatively, the hunting stand may not have been far from the base camp and was used for a number of very short periods during the hunting season, with meat being regularly transported back to the base camp.

An alternative hypothesis is that this small scale spread of material is part of a much larger settlement which has yet to be located (the excavation area is not very extensive). Scatter C could represent a specialist processing area of such a site, where grease and marrow were extracted. This would explain the relatively large number of deer represented. Without further excavation in the immediate vicinity, it is impossible to tell which scenario is the more likely.

12.7 Conclusion

This case study has clearly demonstrated that spatial studies regarding fracture and fragmentation patterns can be very informative. The study into the distribution of bone type proved particularly interesting and revealed a very clear pattern. The study into fracture freshness index scores certainly provided evidence that the fracture patterns were consistent with exploitation of bone fat. There was only a modest pattern visible in spatial terms. This pattern was, however, statistically significant and is also consistent with the interpretation of the site. No areas of particular trampling were identified which might represent a site access or other feature. This does not necessarily represent a shortfall in methodology. It may be because no such features existed or because such patterns are obscured by other taphonomic factors. There is still every possibility that such features would show up on a better preserved site.

The spatial studies at Uxbridge were certainly affected by small sample sizes in the peripheral areas. It is clearly essential to consider carefully sample sizes before interpreting spatial studies based upon proportional or averaged data. Where necessary, trends should be tested for statistical significance.

This study represents a good illustration of the extra information that can be gained from the addition of a spatial element to zooarchaeological studies. The application of ethnographic models, such as those produced by Binford, is not possible without first carrying out this kind of detailed analysis.

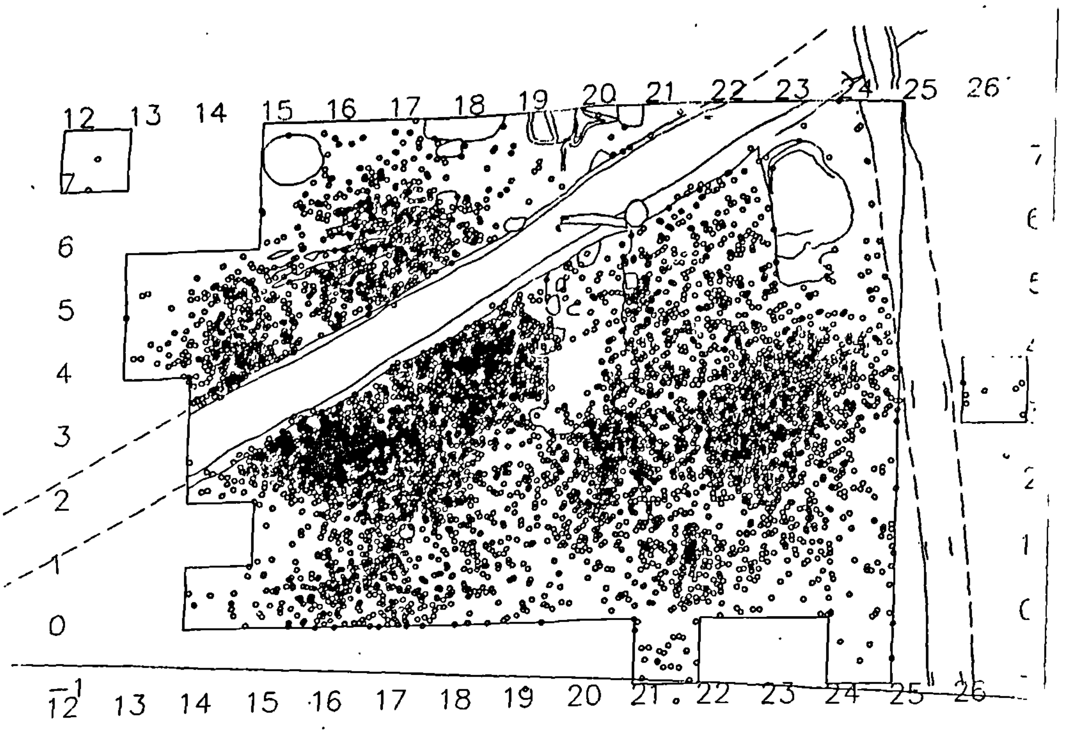


Figure 12.1 - A plan of Scatter C at Three Ways Wharf, Uxbridge, showing the distribution of larger flint finds (as plotted by the excavators)(reproduced courtesy of J. Lewis)

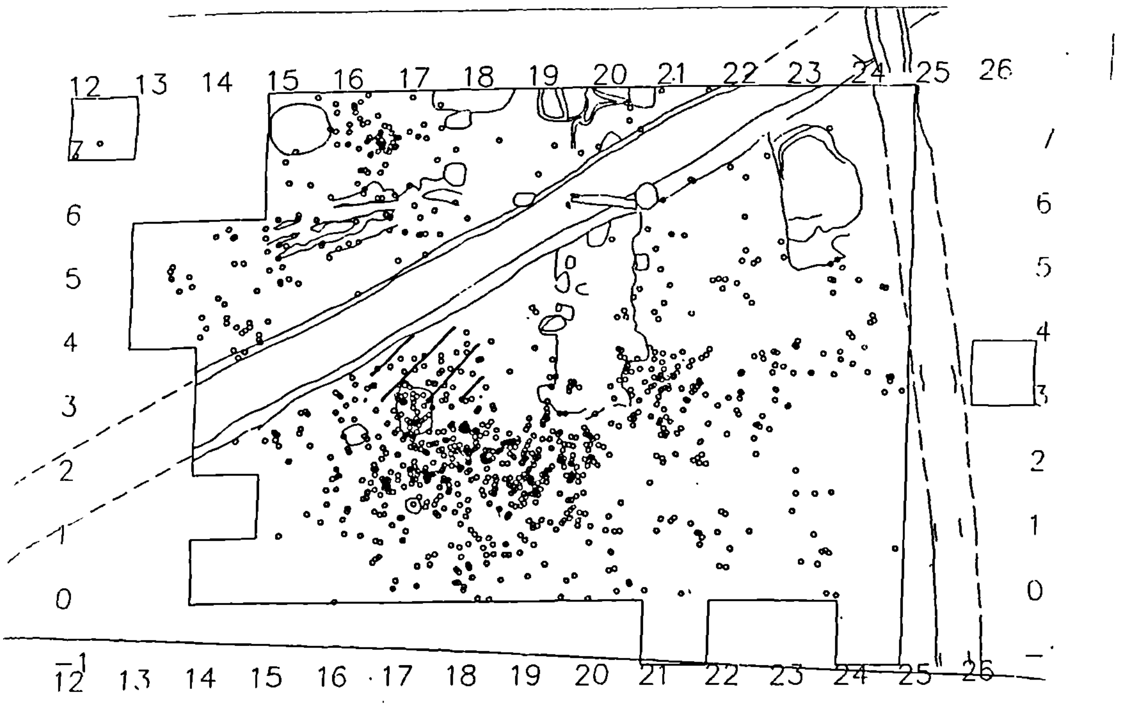


Figure 12.2 - A plan of Scatter C showing the distribution of larger bone fragments (as plotted by the excavators) and the position of an area of burning (hatched) (reproduced courtesy of J. Lewis)

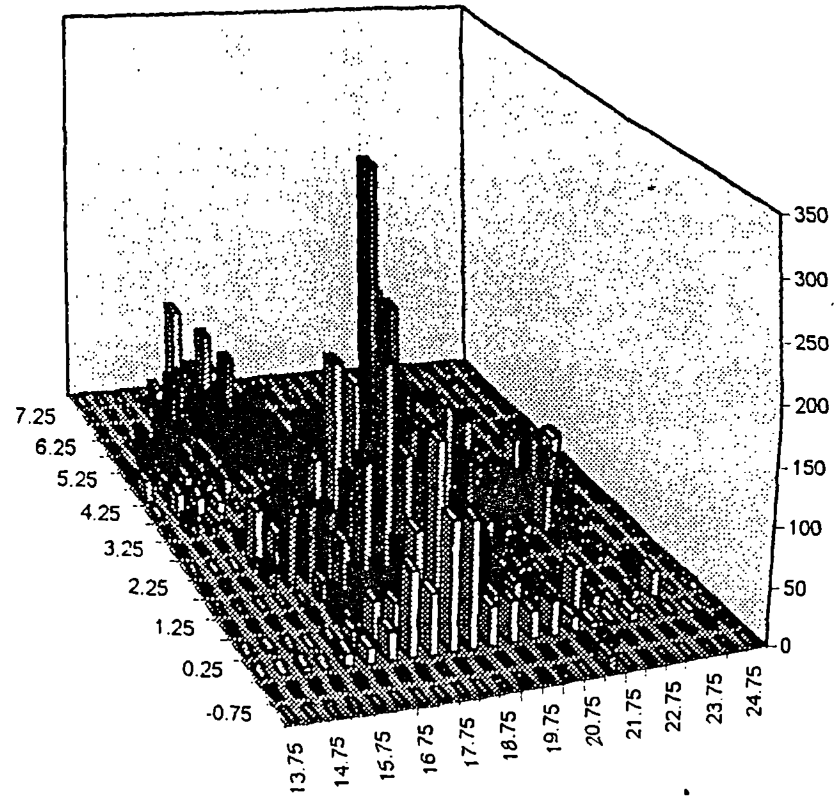


Figure 12.3 - A three dimensional histogram showing the number of bone fragments recovered from each half metre square in Scatter C (reproduced courtesy of J. Rackham)

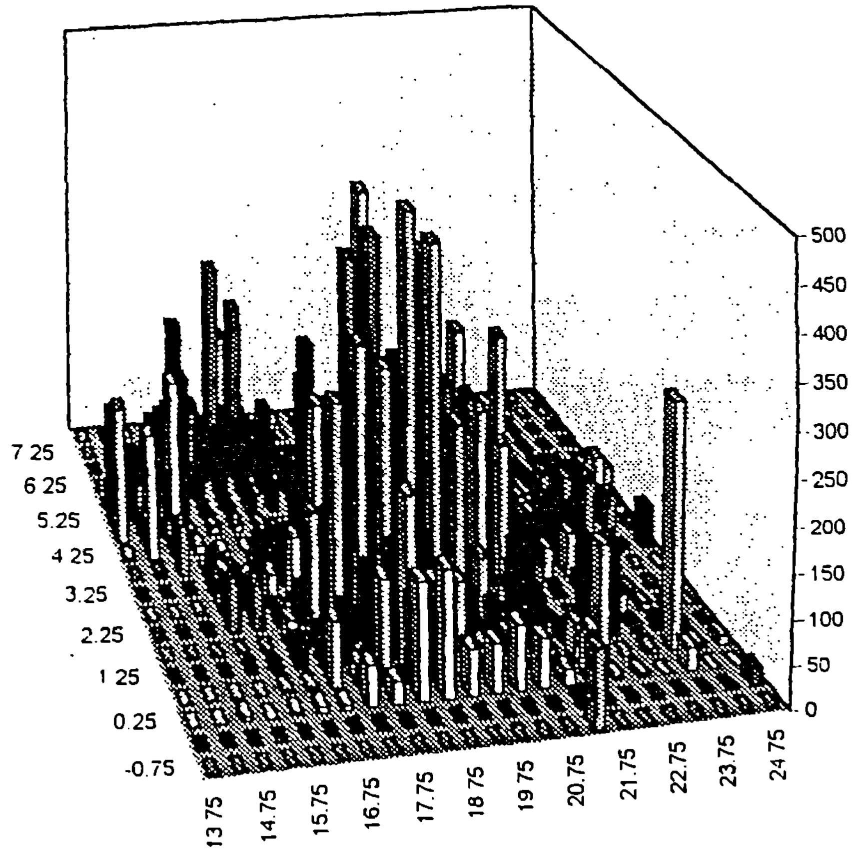


Figure 12.4 - A three dimensional histogram showing the weight of bone fragments in each half metre square in Scatter C (reproduced courtesy of J. Rackham)

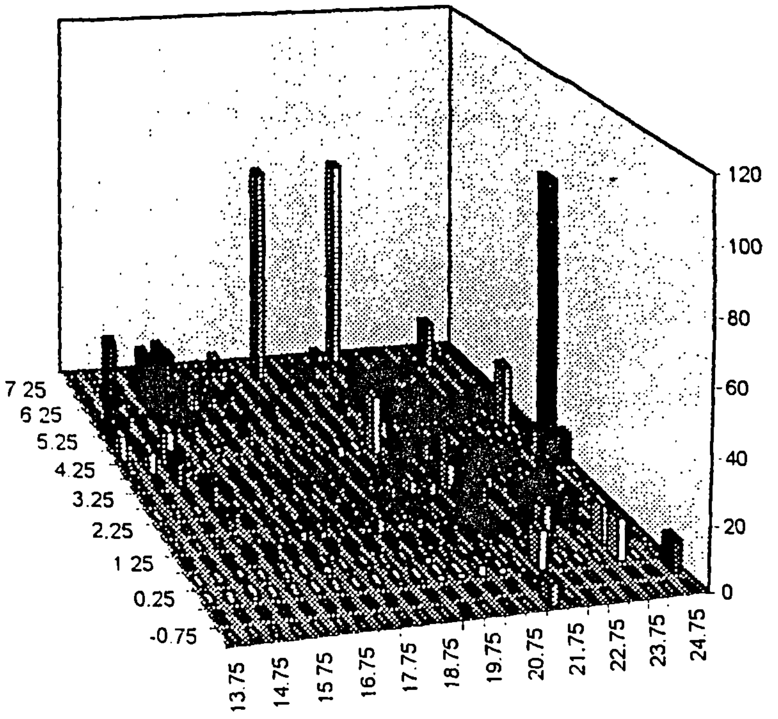


Figure 12.5 - A three dimensional histogram showing the average weight of bone fragments in different half metre squareds in Scatter C (reproduced courtesy of J. Rackham)

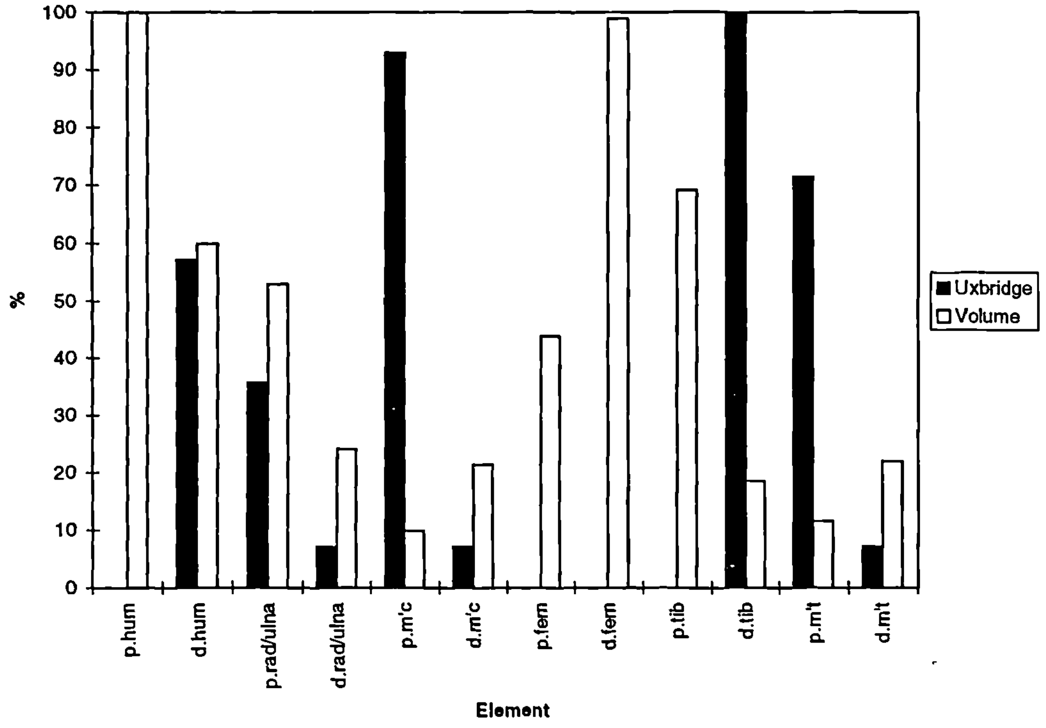


Figure 12.6 - A histogram comparing the volume of caribou elements (data derived from Binford 1978, table 1.11) and the abundance of articular elements in Scatter C at Uxbridge (unpublished data courtesy of J. Rackham)

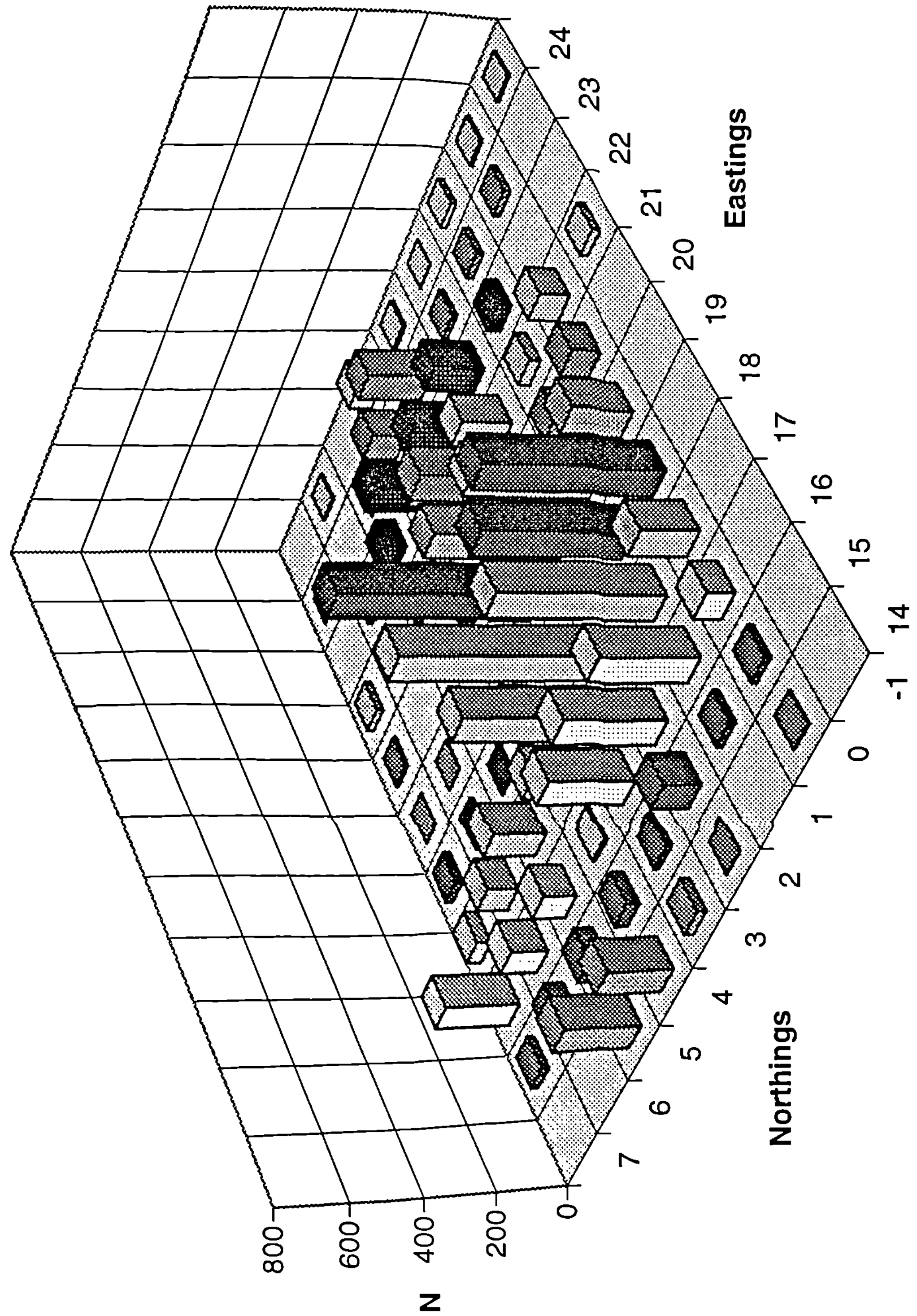


Figure 12.7 - A three dimensional histogram showing the number of bone fragments in each metre square in Scatter C

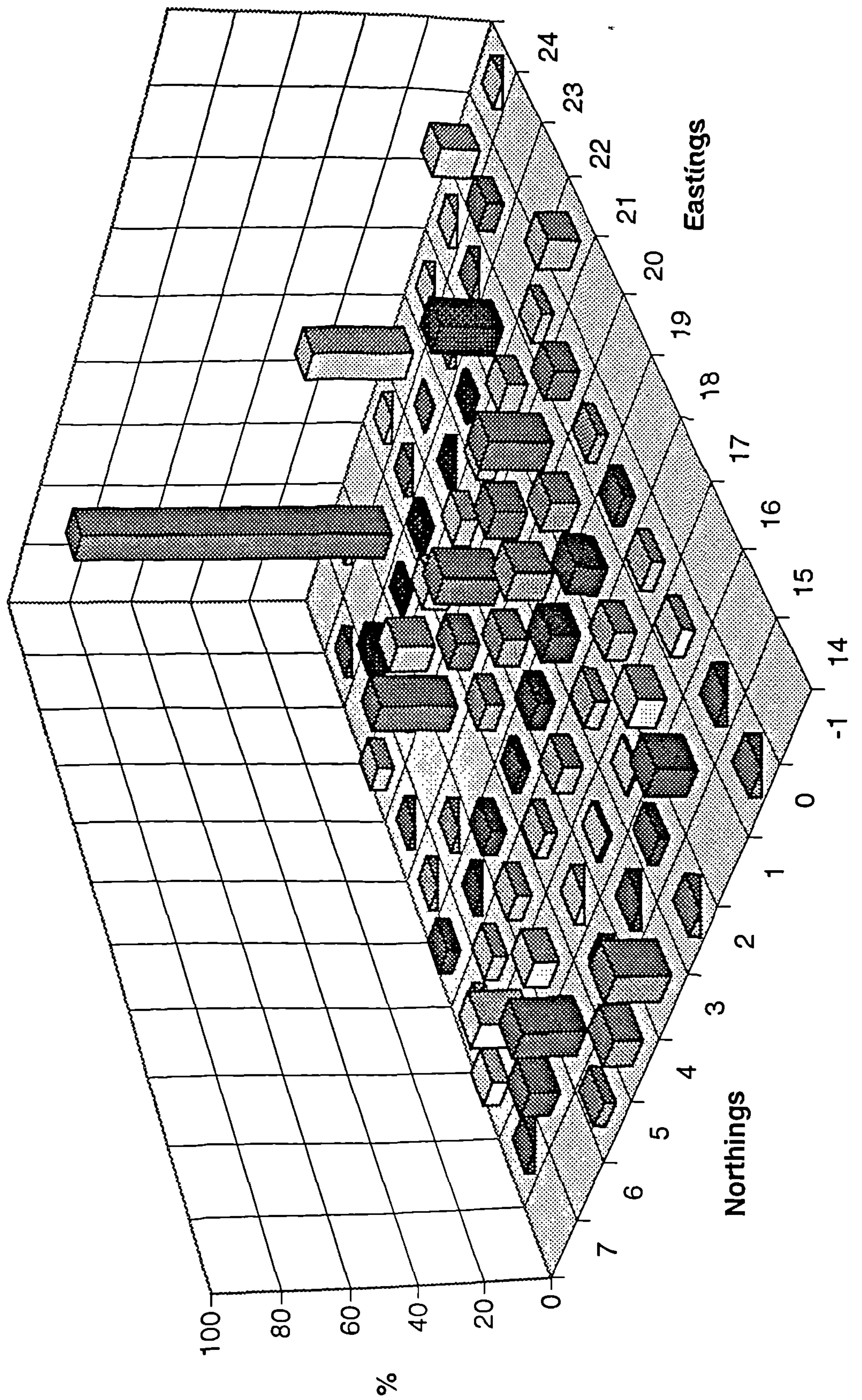


Figure 12.8 - A three dimensional histogram showing the proportions of fragments which were classed as large in each metre square in Scatter C

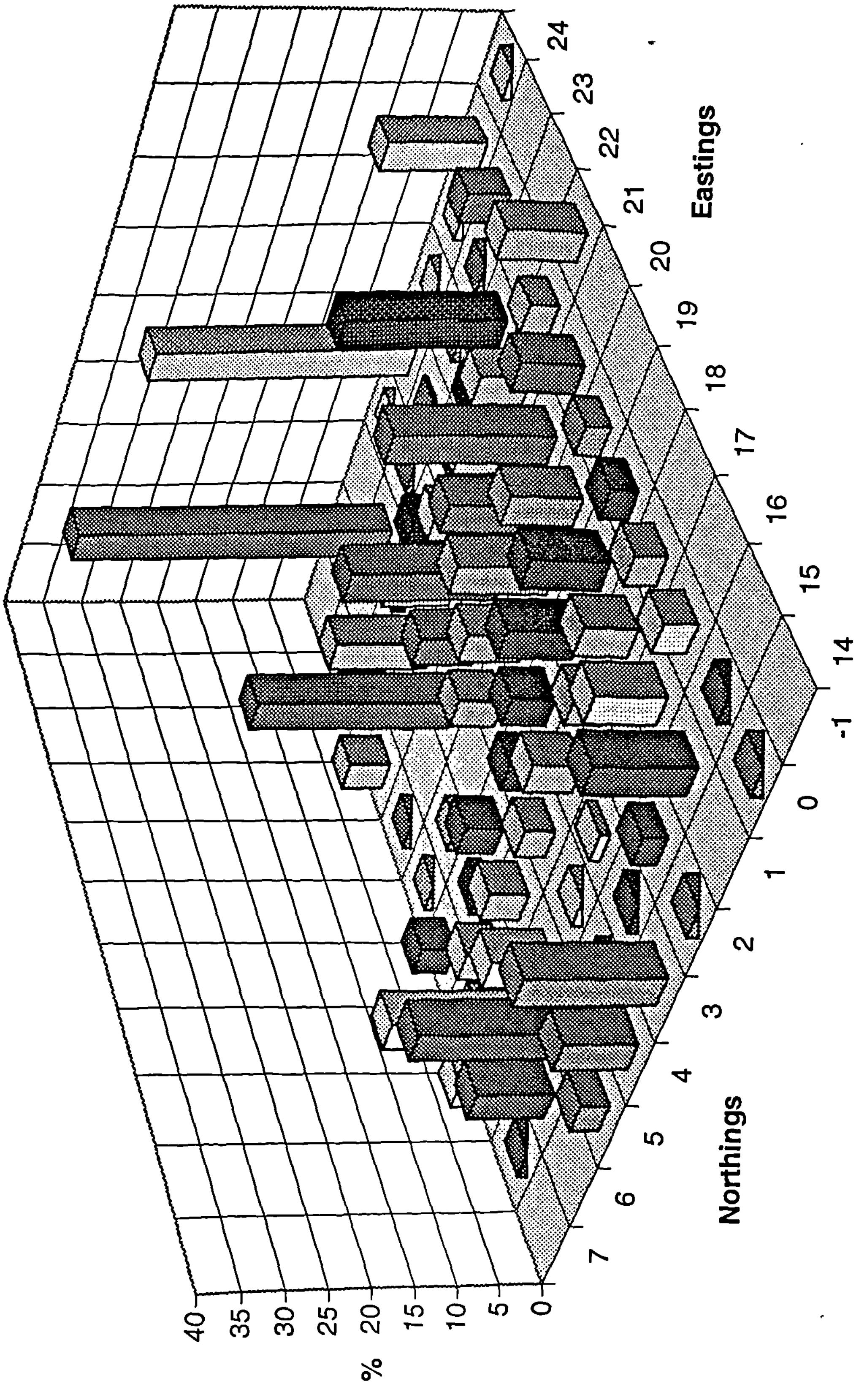


Figure 12.9 - A three dimensional histogram showing the proportions of fragments classed as large in each metre square in Scatter C (with the scale clipped to a maximum of 40%)

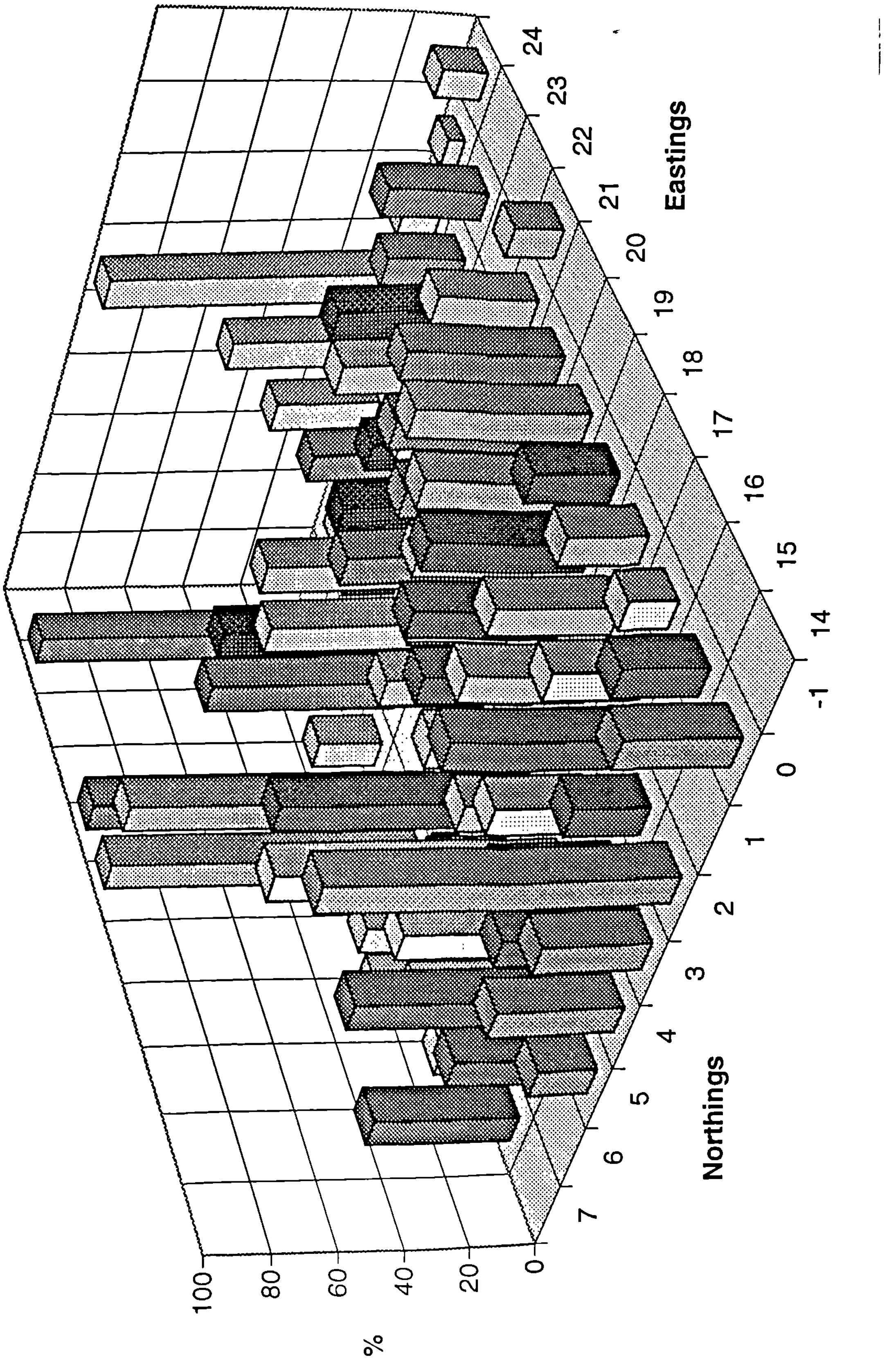


Figure 12.10 - A three dimensional histogram showing the proportions of fragments classed as medium sized in each metre square in Scatter C

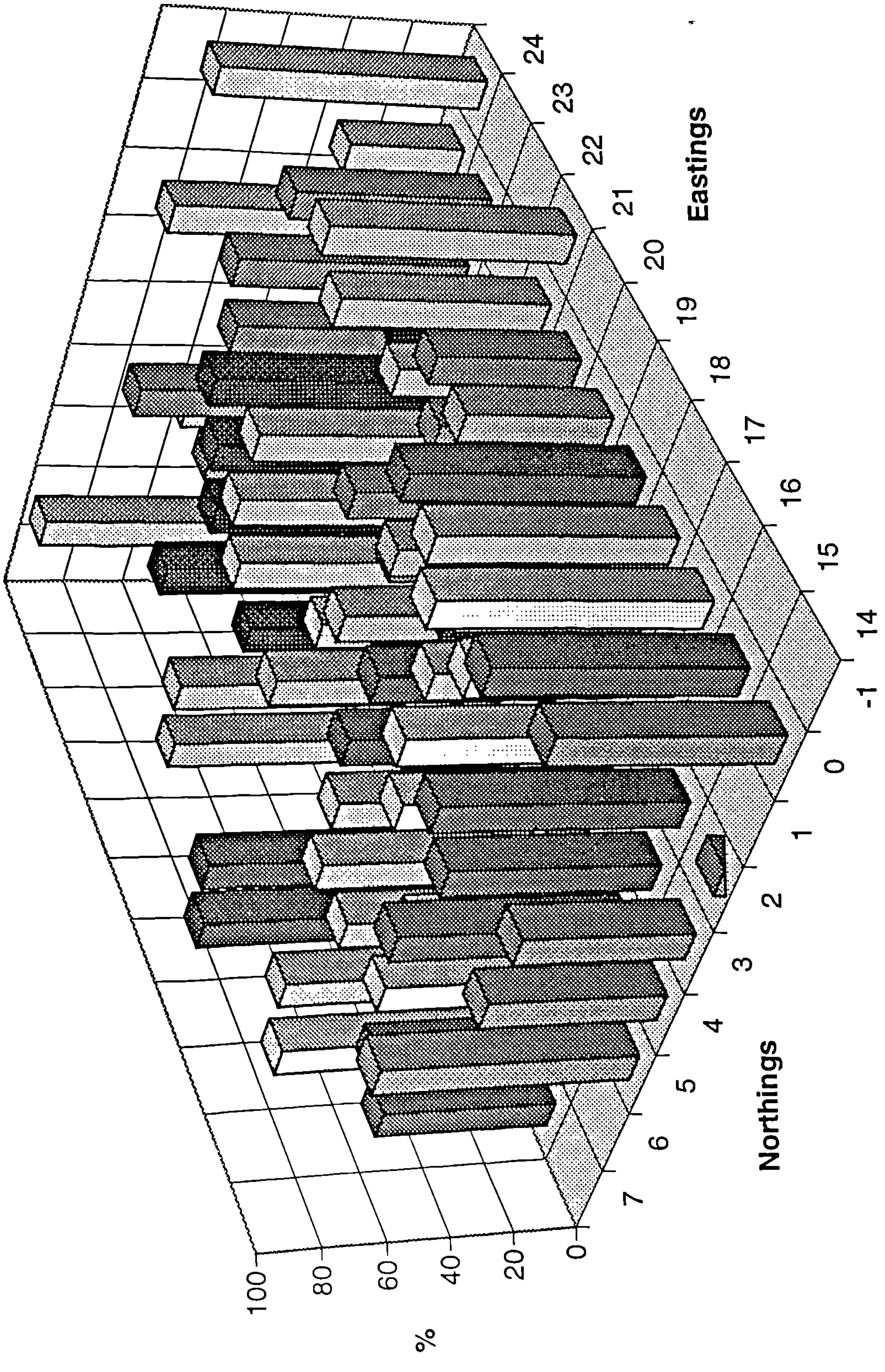


Figure 12.11 - A three dimensional histogram showing the proportions of fragments classed as small in each metre square in Scatter C

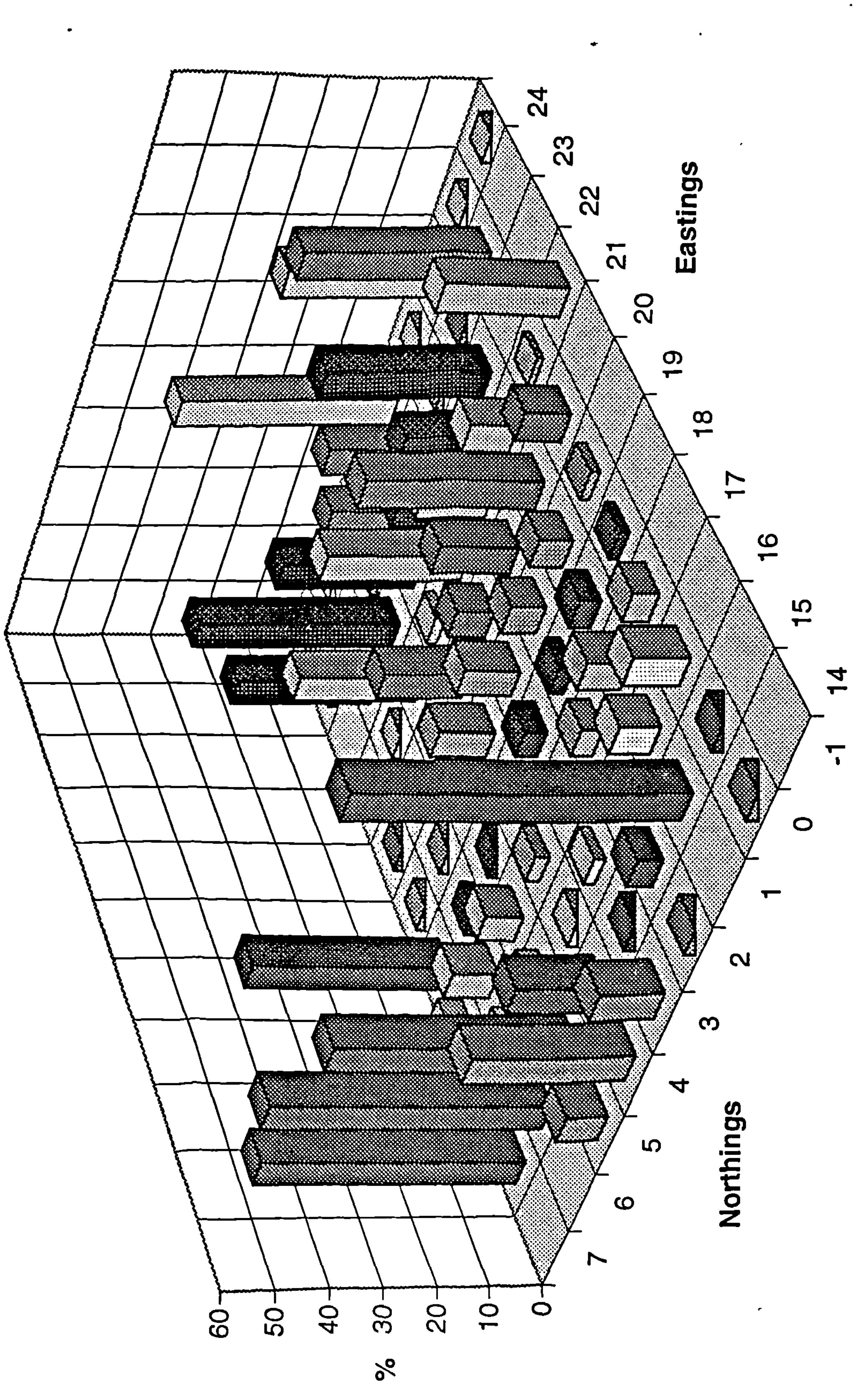


Figure 12.12 - A three dimensional histogram showing the proportions of fragments classed as being cancellous in each metre square in Scatter C

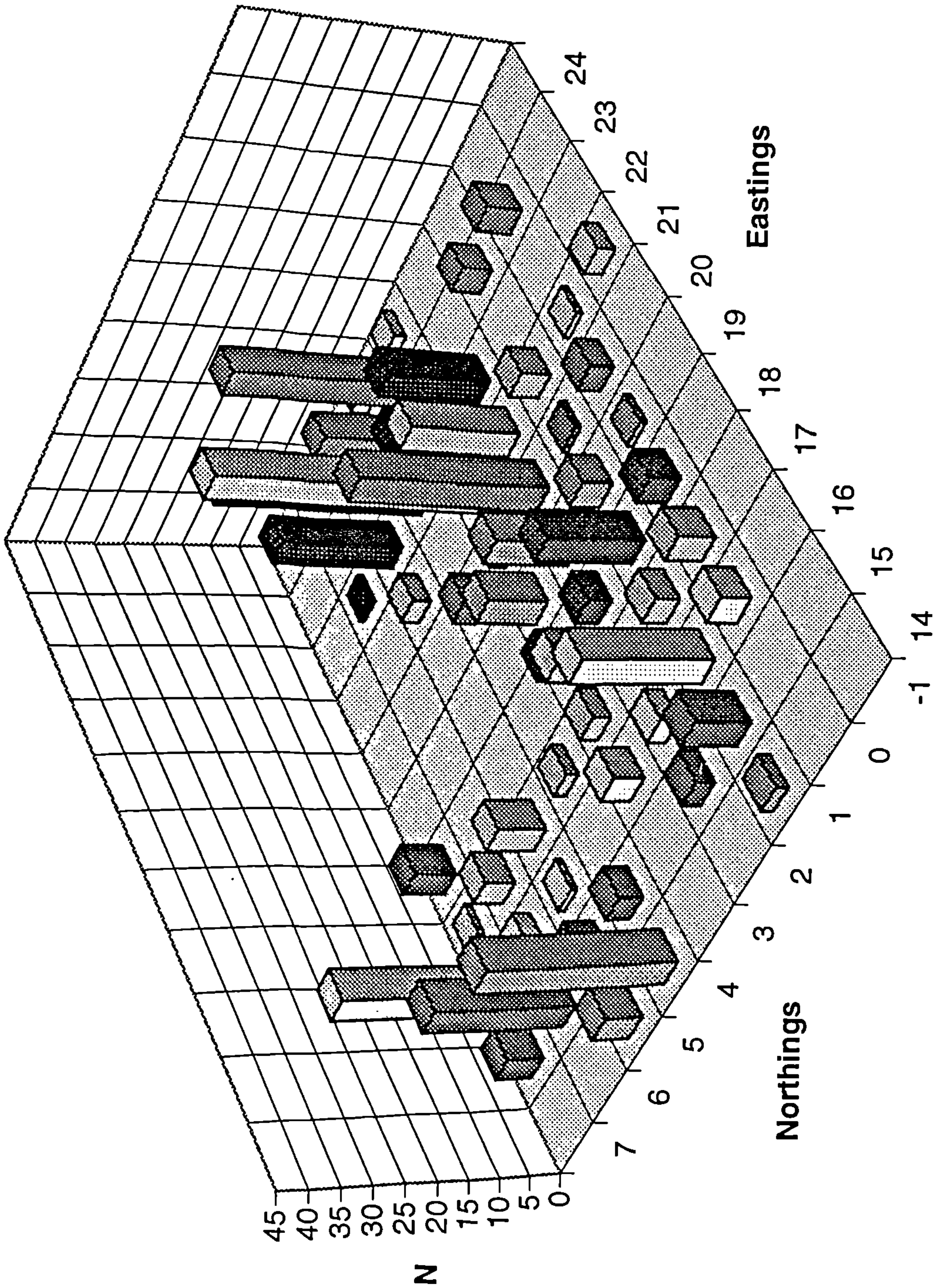


Figure 12.13 - A three dimensional histogram showing the number of small cancellous fragments in each metre square in Scatter C

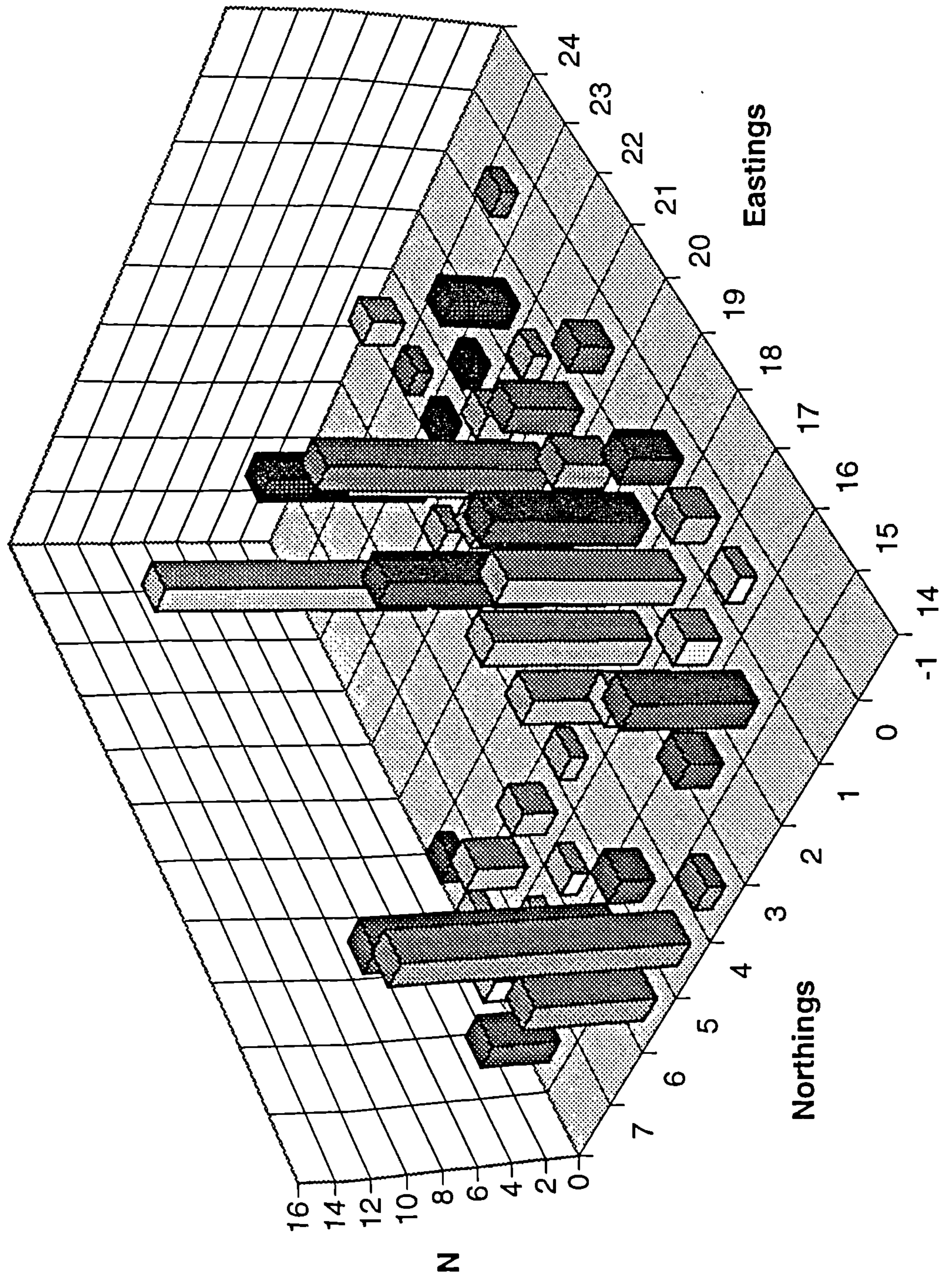


Figure 12.14 - A three dimensional histogram showing the number of medium sized cancellous fragments in each metre square in Scatter C

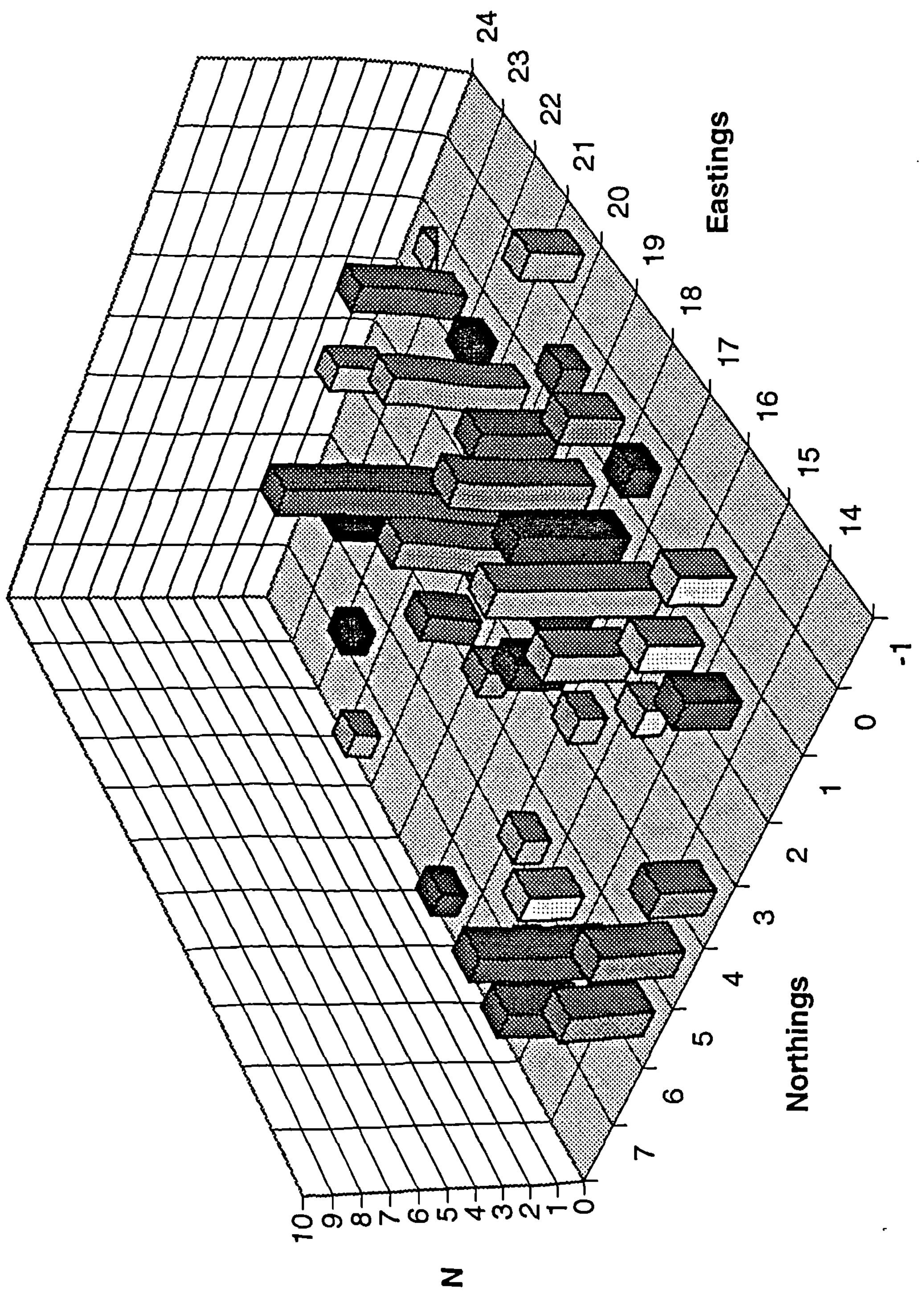


Figure 12.15 - A three dimensional histogram showing the number of large cancellous fragments in each metre square in Scatter C

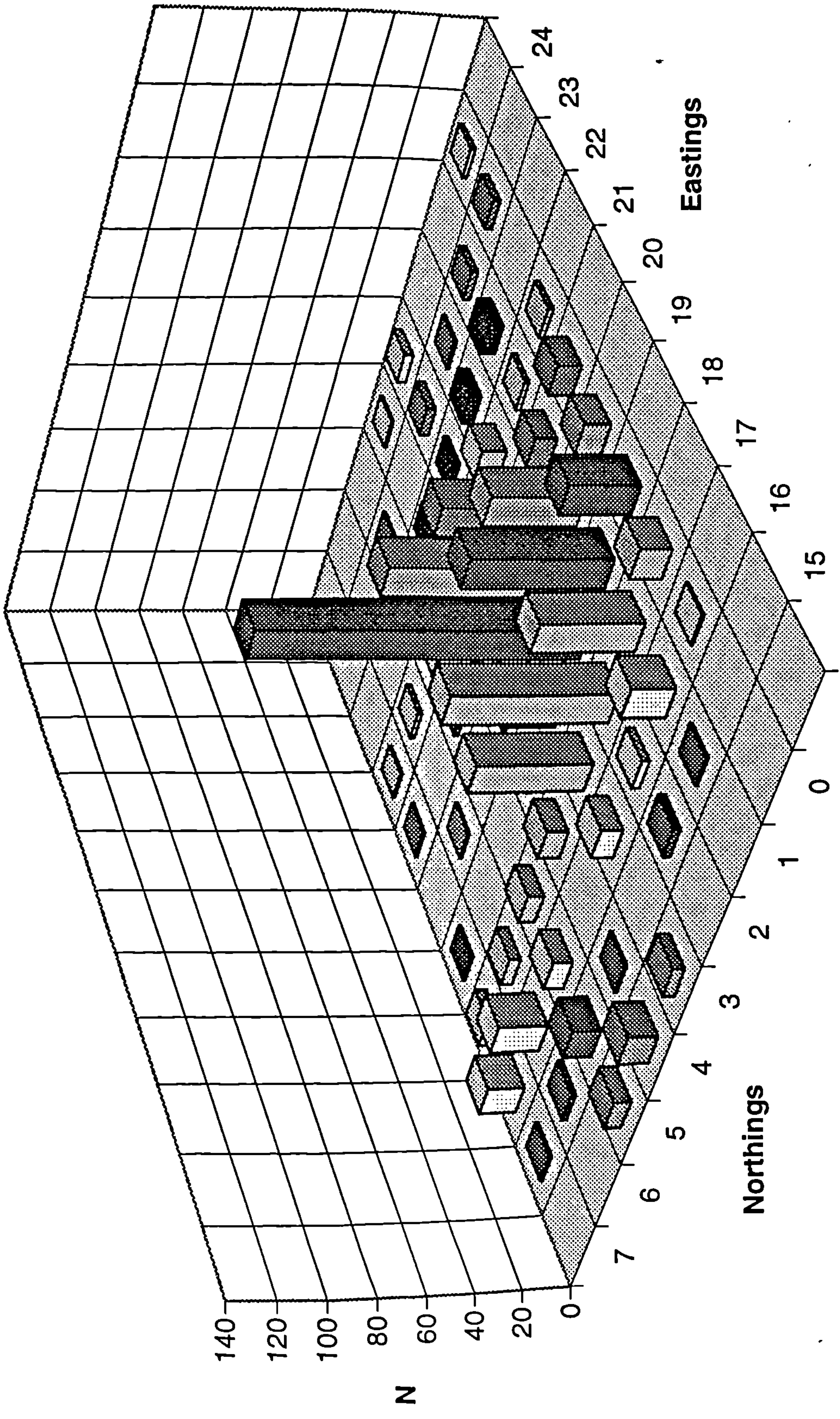


Figure 12.16 - A three dimensional histogram showing the number of fragments studied for fracture freshness in each metre square in Scatter C

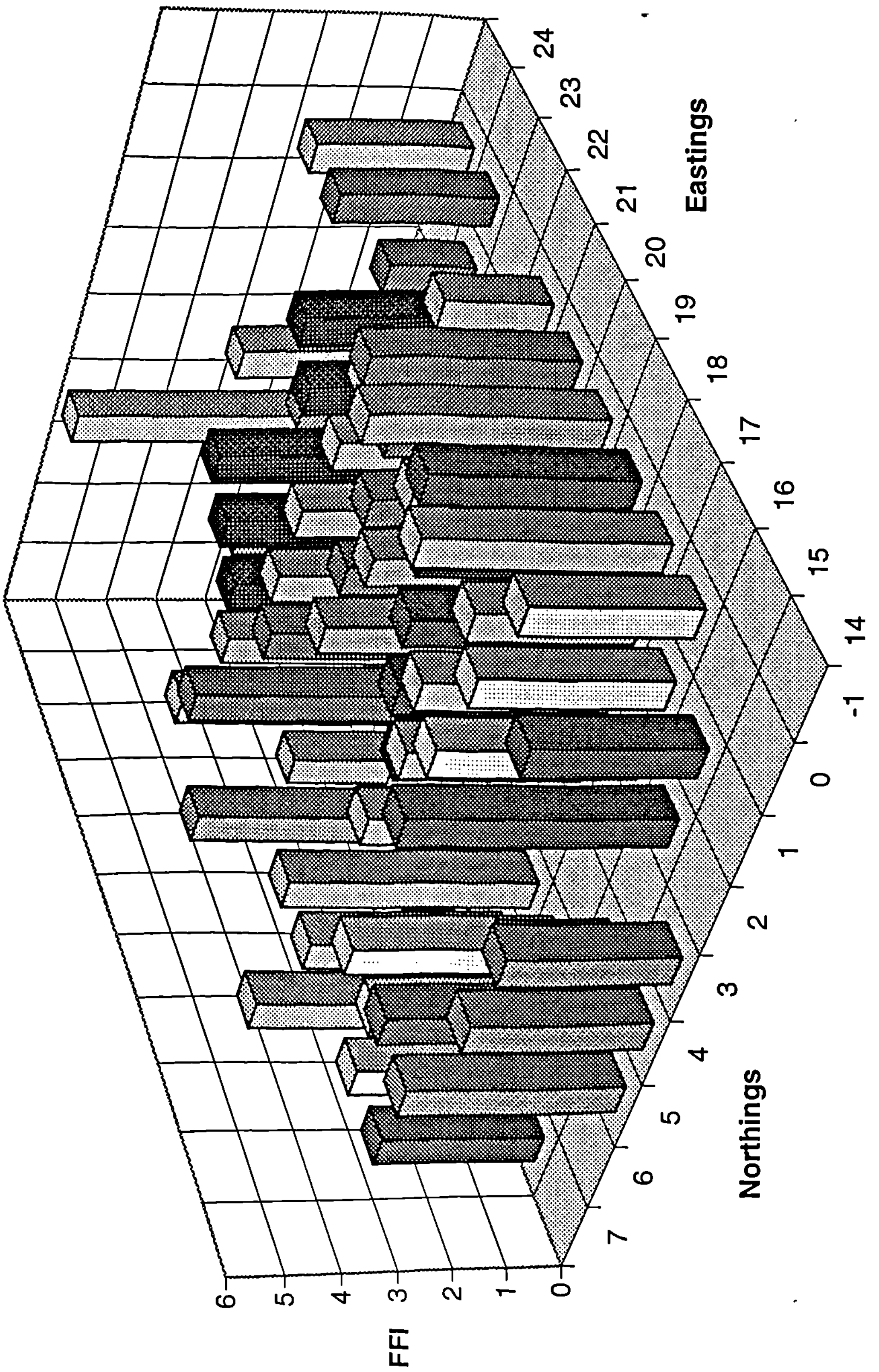


Figure 12.17 - A three dimensional histogram showing the average fracture freshness index score in each metre square in Scatter C

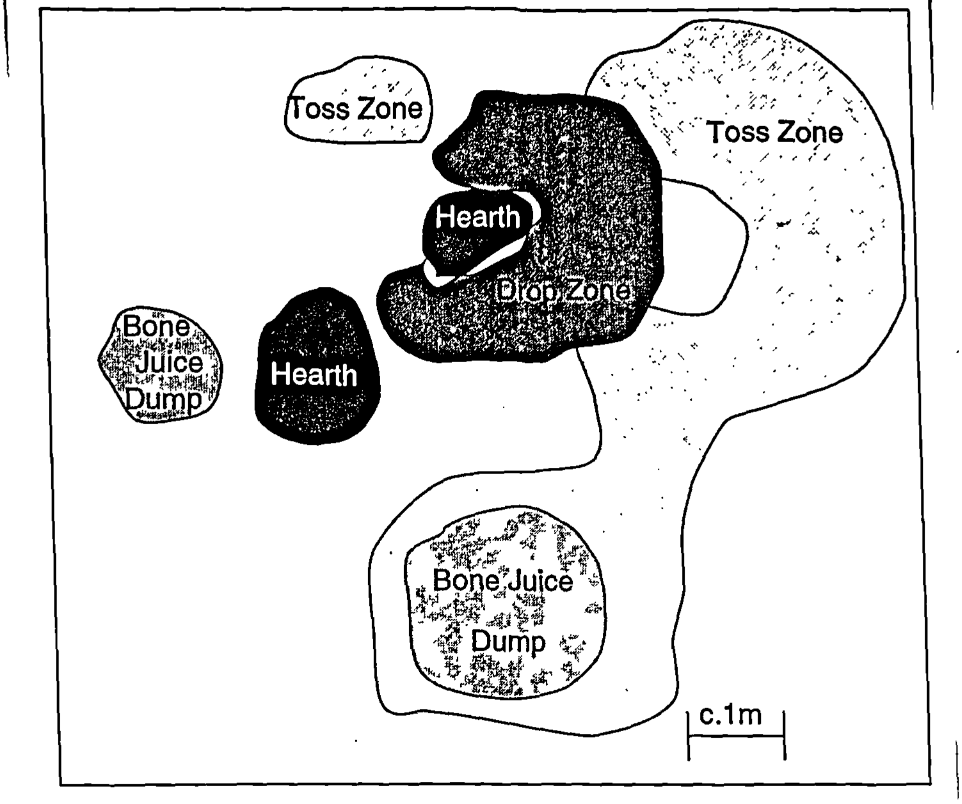


Figure 12.18 - A plan showing the pattern of bone deposition at a Anaktiqtauk hunting camp in Alaska (redrawn from Binford 1983, figure 90)

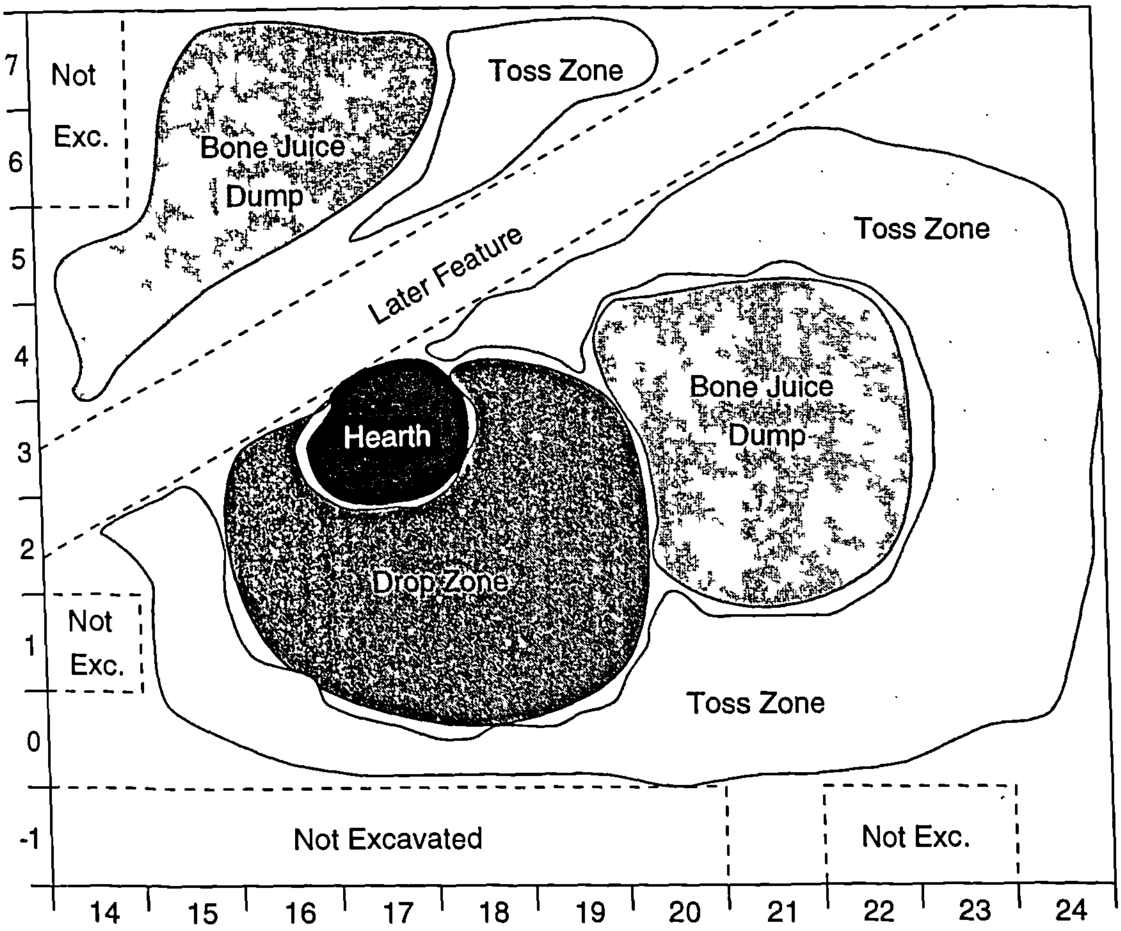


Figure 12.19 - A drawing interpreting Scatter C at Uxbridge in similar terms to Binford's (1983) illustration of an Anaktiqtauk hunting camp (Eastings on the x-axis, Northings on the y-axis)

CHAPTER THIRTEEN

DISCUSSION AND CONCLUSION

This volume has been concerned with the methodology of the identification and interpretation of bone marrow and grease exploitation, but, in the course of testing this methodology in various case studies, there has also been the opportunity to arrive at some interesting archaeological conclusions. Below, the methodological aspects of the study will be reviewed first and then some of the archaeological conclusions will be discussed. Following this, there are some suggestions for future research possibilities and some concluding comments. Table 13.1 provides a summary of the various sites studied and highlights the principal features of the bone assemblages, with regard to fracture and fragmentation, and gives the final interpretation regarding bone marrow and grease use at that site. Reference to this table will prove useful during the following discussion.

13.1 Methodology

13.1.1 The Fracture Freshness Index

Based upon existing knowledge of bone fracture, summarised in chapter 4, a method of indexing fracture freshness was developed in chapter 5. This index was tested against laboratory generated fractures. It was concluded that the indexing method was sufficiently sensitive to identify when bones were freshly fractured. Importantly, it also seemed possible to tell the difference between bones which had suffered ethnographically described pre-marrow extraction treatments, and bones which had been subjected to harsher cooking methods, unlikely to be associated with marrow extraction.

The index also appeared to be successful in its application to real archaeological assemblages. Taking all the case studies into consideration, the lowest index average for a sample came from the Palaeo-Eskimo site of Itivnera, which had a mean score of just 0.36 (N=544). The highest average came from the black layer at Ajvide which scored 4.24 (N=172). Studies on different samples, all of substantial size, produced quite different results. In almost all cases, the results from the fracture freshness index were consistent with the interpretation suggested by other lines of evidence. For instance, at the Greenlandic sites, it was clear that preservation was excellent and there was much circumstantial evidence to suggest widespread deliberate bone breakage for fat extraction. These sites produced the lowest index values, as one would expect. The two Mesolithic sites, Mondeval and Uxbridge, produced index values generally in the region of three. It was clear, from impact scars, that there had been deliberate breakage and there were many individual fragments with low scores. However, the middle-ranging index average was a reflection of considerable levels of post-depositional damage. This was to be expected for sites where much of the material came from occupation floors and activity areas, where trampling would have occurred, and the bones had to suffer many thousands of years of taphonomic activity. In contrast, the black layer at Ajvide never really fitted well with an interpretation of bone fat rendering. The layer was in the middle of a cemetery, had been given ritual connotations by the excavators, and had a high level of burning. Furthermore, our knowledge of that community's seasonal round did not suggest the need for high levels of fat exploitation. The much higher fracture freshness index did not come as a surprise.

There was, therefore, every reason to believe that the index was working correctly. It could diagnose sites where bones had been subjected to much fresh fracturing. Of course, preservation levels must always be considered and sites suffering much post-depositional damage will have higher index values, even though there was much original fresh fracturing. It is always likely, however, that one will be able to distinguish between sites which had much fresh fracture, followed by post-depositional damage, from ones which have only had the latter. If one starts out with fresh bone splinters, scoring near zero on the index, and these splinters are later broken when dry, the resultant index value is likely to be close to three. Despite the later breaks, there will be fresh fracture edge remaining. The mixture of fresh and unfresh features should result in a score of one for each criterion and, therefore, an index value near three. However, if whole bones are broken after they are beginning to dry, say by trampling, they will start with an index value of three and later breakage will tend to make the score higher. In any case, such bones will not display impact scars or any surfaces which follow the fresh pattern.

It should be stressed that, whilst the index did the job it was designed to, namely identifying general levels of fresh breakage in averaged samples, it should not be used for characterising individual specimens. The experimental series suggested that the index did not always characterise individual bones perfectly. It was the average result that seemed to be correct. It should also be pointed out that, although bones were subjected to many different treatments in the experiments, the index is not designed to identify such treatments. Those experiments were only conducted to demonstrate that the index could identify *general* levels of fracture freshness, and nothing more.

If one wished to create an index aimed at identifying particular treatments on individual elements, one would need to carry out many more experiments, both in terms of the treatments applied and the sample sizes. Furthermore, for such detailed work, it would be wise to use a number of different analysts and blind testing (as suggested to this author by M. Levine, pers. com.). Such detailed work, however, was beyond the needs and aims of this study.

With regard to spatial analysis of fracture type, the principal problem encountered at Uxbridge was that sample sizes were often too low in some areas of the site. This tended to result in very variable index levels in those areas. There is every reason to believe that spatial analysis would work better on a site where sample sizes were more uniformly high. Uxbridge had probably rather poor preservation levels for this type of study and better results would be obtained on a better preserved site. Given the nature and age of the Uxbridge site, however, the results are still very interesting.

The indexing method, as outlined in chapter 5 and employed in the case studies, was relatively quick to apply and provided many useful and interesting results. Index results, however, should always be considered in conjunction with other taphonomic evidence, such as the observation of impact scars, burning levels, obvious modern breakage, carnivore damage etc.

13.1.2 Fragmentation Levels and Fragment Type

The combined study of fragment sizes and fragment types (i.e. cancellous or shaft etc.) proved a most powerful tool. Assessing whether an assemblage is very fragmented or not, however one does it, is not really enough to identify patterns of bone fat exploitation. One needs to know what has been highly fragmented. Bone fragments were basically divided into two types: cancellous bone (spongy bone with high grease content) and diaphyseal bone (dense shaft bone with less grease content). In some studies more detail was attempted (i.e. the separation of axial bone, cranial bone etc.).

The model used in this study, based on ethnographic examples, was that, where bone grease was being heavily exploited, most of the cancellous bone would be comminuted. There would, therefore, be a pattern where most large fragments would be shaft and the smaller categories would contain what was left of the cancellous material. This pattern was found at Mondeval, the Greenland sites and Uxbridge. A contrary pattern was found at the control study site of Wallsend (chapt. 7), where large scale grease production was an unlikely prospect. This confirmed that the model was likely to be valid. It was principally the high proportions of cancellous material in Test Area 1 at Ajvide which indicated that grease from pig bones was probably not being extensively exploited.

Both fragment size and type can be assessed relatively quickly. It is not essential that every judgement of size and type is accurate to a high degree. It is more important that the analytical method is fast enough to allow sizeable samples to be sorted. Occasional errors will have little relevance to the overall proportions. If methods are not sufficiently easy and quick to carry out, they will almost certainly not be commonly incorporated into site analyses. There is no suggestion that such a study should be carried out on all faunal assemblages but there is no reason why selected samples should not be analysed in this way on sites where grease and marrow exploitation is a possibility or fragmentation levels are, for some other reason, an issue.

It is necessary to stress the importance of carrying out fragmentation studies which are quantified both by weight as well as number. Both methods are heavily biased in their own way (number is biased towards small fragments and weight is biased towards large pieces) and the true picture is perhaps best viewed through the consideration of both. This is amply illustrated in the case studies.

13.1.3 Ethnography, Chemistry, Utility Indices and Optimality

The first three chapters were dedicated to putting bone fat use into its ethnographic and palaeoeconomic context. They summarise important issues relating to the nature of fats, their nutritional value, the uses they are put to and the methods used by humans to exploit them, in both observed and theoretical terms. Not all the specific data and methods referred to in this section are employed in the case studies (which were principally carried out to test fracture and fragmentation methodology), but the issues highlighted in the first part of this volume provide the theoretical underpinning for the rest of the work.

The basic models used to identify bone fat exploitation are derived from detailed ethnographic work. Without such high quality ethnoarchaeology as that carried out by Binford and others, it would not be possible to carry out a study like this one. As mentioned in chapter one, there does not yet appear to be a study of this variety that has been carried out on a subsistence agricultural community. This would certainly be of interest, particularly if the Neolithic was to be studied using this methodology.

One cannot properly understand bone fat utilisation without having an understanding of the anatomy and physiology of the animals that are its source. That is the purpose of discussing chemical assays, fat mobilisation sequences and economic utility indices. The example of the horse fat utility index made the point well. It showed that assumptions should not be applied across different species. No one would suspect from looking at a horse that its large limb bones would contain relatively little marrow by comparison to similarly sized animals, and that its marrow would be very different in its nature due to different body chemistry. Horse fat use was not encountered in the case studies, but the same principles that were highlighted in that chapter were. In the Greenland study it was essential to be aware of the absence of marrow cavities in seal bones and the different chemical constituents in its grease that would make it hard to exploit. One needs to apply the right data for the right species being exploited, wherever this is possible.

Unfortunately, there was no red deer index that could be used for bone volume (used as an index of grease value) in application to the Uxbridge element abundances. The use of the equivalent caribou index demonstrated the use of applying economic indices quite well, however. During the case studies there was no real opportunity to apply optimal models to the data, but such models were the foundation of interpretations. It appeared that at Uxbridge the lesser grease bearing articulations, such as tibia and proximal metapodials, were not considered worth using (i.e. fell outside the hunters' perceived optimal diet breadth). At the Norse Greenlandic sites, it seemed that a bulk strategy was employed. All the grease bearing bones of land mammals, apart from ribs, were utilised. At Itivnera, however, it seemed that the Palaeo-Eskimos had an earlier cut-off point, allowing them to ignore some more major sources of grease like appendicular articulations.

So, although the case studies were not specifically intended to investigate the use of chemical or utility indices and optimality, such considerations played a part in the interpretation of all of the sites.

13.2 Archaeology

This study has illustrated the importance of fat procurement to peoples in marginal environments. The Greenlandic sites and Mondeval are certainly examples of marginal environments, Greenland being subarctic and Mondeval being above the Alpine tree line (at 2100m and frequently snow covered). At all these sites much fat was exploited. In the case of the Norse settlers in Greenland and the Mesolithic hunters at Mondeval, it seems that almost all fat resources were exploited. Fat was clearly of importance to the Palaeo-Eskimo inhabitants of Itivnera, but not to the same level as it was at the Norse Greenlandic sites. This pattern was almost certainly due to the different degrees to which these two sets of people were adapted to living in that environment.

Putting these findings in terms of optimal foraging theory, one could say that the lesser fat-bearing bones fell outside the optimal diet breadth of the Paleo-Eskimos, but within the diet-breadth of Norse inhabitants. In this instance, it is not the environment which is the variable that alters optimal cut-off points, it is the actual range of dietary items under consideration that is different. The indigenous Palaeo-Eskimos had all the naturally occurring Greenlandic food species open to them and optimal foraging theory can be applied in the normal way (i.e. with consideration of resource distribution within the landscape and rates of energetic return for different exploitation scenarios). Matters are far more complex when considering the Norse. Their economy was not a closed subsistence economy (see chapt. 10). There was trade of items such as furs and walrus tusks with Scandinavia in return for status items. Such activities interfere with any simple optimal model for subsistence. For the Norse, the time lost in pursuing trade activities almost certainly limited their potential diet breadth. They attempted to live off a pastoral economy subsidised with limited hunting. Their *choice* to pursue the economic path they did almost certainly meant that some valuable food species had to be ignored. Hence, they were forced to exploit the resources they did have to a greater extent. Their cut-off, with regard to which bones to process for fat, was lower than that of the Palaeo-Eskimos. The economic path the Norse chose led to their eventual failure on Greenland; as trade with Scandinavia was not sustained, worsening climate made pastoralism more difficult. Having a closed subsistence economy, however, the Palaeo-Eskimos had less potential choice in economic strategy. Their only option was to be fully adapted to their environment.

The Greenlandic case study not only illustrated how levels of bone fat exploitation might be indicators of levels of subsistence resource stress, but also showed how bone grease use may well be tied to seasonal patterns of resource availability. The need to process bones for fat, on the Norse sites, was almost certainly greatest in winter. Seal hunting would provide fat in spring, dairy products would be available in summer and domestic animals were probably culled in Autumn prior to overwintering. Winter would be a lean time. Seasonality was also an issue at Ajvide. It seems that pigs were hunted in the autumn, but seals were hunted through the winter and spring providing a rich source of fat. There would be no time of great need for extra fat. Marrow from pigs was probably exploited, as this would require little effort, but the time consuming process of grease extraction was probably not worth the return, considering the alternatives. So pig marrow fell within the diet breadth, whilst grease did not. It should also be noted that Ajvide's climate would have been more temperate than Greenland's and its resources less marginal than Mondeval's.

Exploitation of the Uxbridge site was probably also seasonal; in springtime. In this instance, the exploitation of fat was probably just to fulfil the immediate needs of a small group of hunters (although it is possible that this was part of a larger site). The animals they were hunting would probably not have been in excellent condition after winter and would most probably have had lean meat. The exploitation of marrow and bone juice would have formed a useful supplement to the hunters' diet. At Uxbridge, the use of spatial studies presented the potential to understand the site in more detail than at the other sites. Something of the actual arrangements of site activities seemed to be visible as a result of differential deposition of bone and flint waste across the site.

In summary, the examination of bone fat exploitation at these sites solved some important issues regarding subsistence economics in terms of levels of marginality, environment, seasonality and the effects of outside economic influence. It also seems possible to make inferences regarding the layout of site activities. It is clear that fat can be an important element in interpreting the palaeoeconomics of archaeological sites.

13.3 Future Possibilities

Taking the above points into account, there is considerable scope for future work in this field. Some interesting areas of research would be:

- ⇒ Comparing contemporary hunter/gatherer sites within a region to assess whether there is a relationship between levels of bone fat use and the marginality and seasonality of the site in question.
- ⇒ Comparing contemporary hunter/gather sites within a region with a view to assessing whether different types of sites can be identified by their bone

processing activities (i.e. is the scale and nature of exploitation of bones for fat different at hunting camps and base camps etc.)

⇒ Comparing sites in some more climatic regions. What differences are there in bone fat exploitation if, for example, arctic, temperate, Mediterranean, tropical and hot desert hunter/gatherer groups are compared?

⇒ Comparing the use of bone fats over time on sites with a long time span or on a group of nearby sites of different date. Is there a change in fat exploitation patterns over time? In particular, what effect does the arrival of agriculture and domestic animals have on bone fat use?

⇒ Comparing the exploitation of fat with regard to different species of animal. For example, comparing fat exploitation by people with a horse hunting economy with that of reindeer hunters would be interesting, because of these species different anatomy and physiology.

With regard to methodology it would be useful if studies were carried out to:

⇒ Gain more detailed information regarding bone fracture under different conditions. This would require a larger scale study with larger sample sizes.

⇒ Carry out more studies of economic anatomy on species for which indices do not yet exist.

13.4 Conclusion

The use of bone fat as a resource is an important issue in archaeology and one which should be addressed routinely in site interpretations. The theory and methods of analysis outlined in this volume have been successful in illustrating this point and can be applied to assemblages quite quickly and easily. There is much scope for future research in this area using the methodology in this volume. There is also scope for improving the methodology through further experimental work.

Subject	**Fragment-ation Level**	**Fragment Type**	**Fracture Freshness (*FFI mean*)**	**Comments**	**Interpret-ation**
Mondeval (all Layers) (Red Deer and Ibex)	extremely fragmented	shaft dominates	mixed (*2.31-3.00*)	significant post-depositional damage, some burning	intense exploitation of grease and marrow
Wallsend (domestic animals)	moderate (many large frags. survive)	much cancellous bone	mixed (*3.16*)	much modern damage	no grease use, perhaps some marrow use
Sandnes (Land Mammal)	fragmented	mainy shaft and rib	mainly fresh (*0.83*)	little post-depositional damage or burning	heavy grease exploitation (not ribs) and marrow extraction
Sandnes (Seal)	moderate (some large frags. survive)	cancellous	N/A		not exploited for fat
Niaquussat (Land Mammal)	fragmented	mainy shaft and rib	mainly fresh (*1.11*)	little post-depositional damage or burning	heavy grease exploitation (not ribs) and marrow extraction
Niaquussat (Seal)	moderate (many whole bones survive)	cancellous	N/A		not exploited for fat
Qeqertasussuk (Seal)	moderate (many whole bones survive)	cancellous	N/A	very well preserved	not exploited for fat
Itivnera (Caribou)	moderate (some whole bones survive)	mainly shaft	very fresh (*0.36*)	little post-depositional damage or burning	marrow and grease exploited but some good sources ignored
Ajvide (TA1 Pig)	fragmented	much cancellous	mixed (*3.28*)	much burning	grease not exploited, marrow exploited
Ajvide (Black Layer Pig)	very fragmented	mainly shaft	many unfresh (*4.24*)	much burning	grease probably not exploited
Ajvide (all Seal)	quite fragmented	cancellous	N/A	much burning	not exploited for fat
Uxbridge (Red Deer)	fragmented	mainly shaft	mixed (*3.31*)	preservation not good	exploited for marrow and bone juice

Table 13.1 - A summary of the main features of the assemblages studied, regarding bone fracture and fragmentation, and interpretation of those assemblages with regard to bone fat exploitation

APPENDIX A

MONDEVAL DE SORA DATA

Table A.1 - Numbers of fragments in each size and bone type class, and numbers of burnt fragments in each size class, for each bag of fragments studied in context 8i

Table A.2 - Numbers of fragments in each size and bone type class, and numbers of burnt fragments in each size class, for each bag of fragments studied in context 8ii

Table A.3 - Numbers of fragments in each size and bone type class, and numbers of burnt fragments in each size class, for each bag of fragments studied in context 3

Table A.4 - Numbers of fragments in each size and bone type class, and numbers of burnt fragments in each size class, for each bag of fragments studied in context 4

Table A.5 - Numbers of fragments in each size and bone type class, and numbers of burnt fragments in each size class, for each bag of fragments studied in context 20

Table A.6 - Numbers of fragments in each size and bone type class, and numbers of burnt fragments in each size class, for each bag of fragments studied in context 21

Table A.7 - Numbers of fragments in each size and bone type class, and numbers of burnt fragments in each size class, for each bag of fragments studied in context 3

Table A.8 - Numbers of fragments in each size and bone type class, and numbers of burnt fragments in each size class, for each bag of fragments studied in context 7

Table A.9 - Mass of fragments in each size class for each bag of fragments studied in context 8i

Table A.10 - Mass of fragments in each size class for each bag of fragments studied in context 8ii

Table A.11 - Mass of fragments in each size class for each bag of fragments studied in context 31

Table A.12 - Mass of fragments in each size class for each bag of fragments studied in context 4

Table A.13 - Mass of fragments in each size class for each bag of fragments studied in context 20

Table A.14 - Mass of fragments in each size class for each bag of fragments studied in context 21

Table A.15 - Mass of fragments in each size class for each bag of fragments studied in context 3

Table A.16 - Mass of fragments in each size class for each bag of fragments studied in context 7

Table A.17 - The frequencies of fracture freshness scores given in the contexts studied

Table A.1

Layer	8i																												
Class	<20		<30			<40			<50			<60				<80			<100			>100			part			whole	
Type	Indet.	Burnt	Canc	Shaft	Burnt	Canc	Shaft	Burnt	Canc	Shaft	Burnt	Axial	Artic.	Shaft	Burnt	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	App.
bag1	899	242	6	21	0	2	5	0	1	3	0	0	0	5	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
2	192	17	2	12	2	3	3	0	0	1	0	0	0	2	0	0	0	3	0	0	0	0	0	0	0	1	0	0	0
3	1455	316	13	24	7	4	4	0	1	5	0	0	0	3	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0
4	193	37	2	15	1	0	0	0	2	1	0	1	0	1	0	1	0	1	0	0	2	0	0	0	0	0	0	0	0
5	613	319	1	8	0	1	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	1	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0
7	727	195	11	24	6	1	15	0	0	3	0	0	0	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
8	4	0	4	6	0	3	10	0	3	7	0	3	0	4	0	0	0	5	0	0	1	0	0	0	0	0	0	0	0
9	3	0	0	4	0	1	9	0	0	6	0	0	0	3	0	0	0	3	0	0	0	0	0	1	0	0	0	0	0
10	330	53	1	4	1	0	3	0	0	1	0	0	0	2	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0
11	870	162	7	21	5	4	6	0	1	3	0	0	0	1	0	1	0	3	0	0	0	0	0	0	0	0	0	0	0
12	339	45	1	15	2	0	2	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	1062	359	5	23	10	1	5	2	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	409	120	2	22	3	1	9	0	0	4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	179	14	3	22	1	0	8	1	0	7	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
16	145	28	2	7	0	0	2	0	1	3	0	0	0	1	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
17	427	102	1	2	0	0	2	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	19	9	1	7	3	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	655	201	5	28	1	2	8	2	0	7	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
20	185	11	4	9	0	3	5	0	0	2	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
21	5	0	1	1	0	4	7	0	1	7	0	0	2	5	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
22	1071	275	4	34	19	0	8	0	0	3	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
23	806	191	6	15	2	0	11	0	0	2	0	0	1	1	0	0	3	3	0	0	0	0	0	0	0	0	0	0	0
24	561	167	7	12	8	1	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	713	168	8	24	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	285	69	3	9	0	6	2	0	0	2	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	743	126	4	18	3	1	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	160	35	5	6	2	3	3	0	0	0	0	1	0	1	0	1	0	0	0	0	1	2	0	1	0	0	0	0	0
29	828	123	6	27	4	3	11	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	492	108	6	17	1	2	10	1	0	5	0	0	0	1	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0

Table A.1 cont.

31	419	115	7	24	1	2	9	0	1	2	0	0	0	1	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
32	850	207	7	14	7	2	0	0	1	1	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	21	0	0	0	0	2	1	0	2	1	0	0	0	2	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
34	112	31	3	14	4	0	3	0	1	4	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
35	416	107	4	22	3	0	8	0	1	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	545	217	14	16	5	0	3	0	2	4	0	0	0	3	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
37	155	54	1	11	2	0	3	0	1	0	0	0	0	3	0	0	0	4	0	0	1	0	0	0	0	0	0	0	0
38	3	0	0	1	0	2	1	0	0	3	0	0	1	1	0	1	0	2	1	0	0	0	0	0	1	0	0	0	0
39	413	155	8	4	1	3	3	1	0	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
40	140	5	5	2	0	4	1	0	2	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0
41	542	58	12	22	3	0	6	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
42	280	54	7	12	2	1	7	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
43	289	71	7	15	3	0	4	0	0	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
44	457	168	2	6	2	1	4	1	0	4	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
45	577	144	6	18	0	1	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46	507	85	7	12	2	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
47	1	0	2	3	0	0	3	0	0	4	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
48	407	114	6	11	7	0	4	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
49	421	126	4	14	7	0	3	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50	213	47	4	4	1	0	5	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51	513	127	3	17	3	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
52	260	62	3	13	2	4	1	1	1	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
53	8	0	14	9	2	7	2	0	1	5	0	0	0	2	0	1	0	2	0	0	1	0	0	0	0	0	0	0	0
54	436	65	13	12	2	3	5	0	2	2	0	0	1	4	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0
55	624	137	4	23	5	2	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
56	0	0	1	1	0	3	5	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
57	230	83	4	5	2	2	2	1	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
58	28	14	3	4	1	1	1	1	0	1	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
	<20		<30			<40			<50			<60				<80			<100			>100			part			whole	
	Indet.	Burnt	Canc	Shaft	Burnt	Canc	Shaft	Burnt	Canc	Shaft	Burnt	Axial	Artic.	Shaft	Burnt	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	App.
Totals	27930	5738	272	747	149	88	264	13	26	126	0	8	6	77	0	9	4	55	3	0	8	3	1	4	2	5	0	0	0
Grand Totals	27930		1019			352			152			91				68			11			8			7			0	

Table A.2

Layer	8ii																												
Class	<20		<30			<40			<50			<60				<80			<100			>100			part			whole	
Type	Indet.	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Axial	Artic.	Shaft	Burnt	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	App.
bag1	203	16	6	8	0	5	5	1	0	5	0	1	0	2	0	2	0	2	0	0	1	0	0	1	0	0	0	0	0
2	821	95	16	22	0	1	12	0	3	5	0	0	0	3	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0
3	538	77	1	22	1	2	4	1	0	3	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
4	16	0	6	17	0	3	12	0	0	7	0	0	1	5	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
5	432	64	5	9	0	5	5	0	0	3	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
6	379	8	9	8	0	3	8	0	0	4	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
7	756	116	17	18	4	1	4	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	252	15	11	19	1	4	12	1	0	2	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
9	172	12	2	5	1	0	5	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
11	178	31	2	8	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	819	81	9	31	1	4	15	1	2	8	0	0	0	3	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
13	126	24	0	9	0	2	2	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0
14	144	59	11	1	1	2	1	1	3	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
15	283	61	8	18	3	0	11	1	0	5	0	0	1	1	0	0	1	3	0	0	2	0	0	1	0	0	0	0	0
16	747	118	10	28	3	0	4	0	0	8	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
17	525	153	5	13	3	2	8	0	1	3	0	0	1	4	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0
18	488	122	8	11	1	0	7	0	0	6	0	0	0	2	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
19	257	49	9	16	0	1	6	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
20	495	149	10	12	1	2	7	1	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0
21	3	0	2	4	0	1	8	0	0	4	0	0	0	2	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
22	469	92	4	8	1	2	2	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
23	418	50	11	15	2	2	18	1	2	5	0	0	0	3	0	0	1	4	0	0	2	0	0	0	0	0	0	0	0
24	222	6	7	25	2	1	5	0	1	1	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
25	679	162	6	18	5	1	6	0	0	3	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
26	425	58	2	21	3	1	11	3	0	3	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0
27	377	95	3	14	2	3	8	0	2	6	0	2	1	3	1	0	0	1	0	0	1	0	0	0	0	1	0	0	0
28	649	136	9	22	8	0	10	3	1	6	0	0	0	0	0	2	0	4	0	0	0	0	0	0	0	0	0	0	0
29	500	150	8	10	4	3	1	1	2	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	263	32	9	17	4	6	7	0	3	3	0	0	0	4	0	1	0	7	0	0	0	0	0	0	0	0	0	0	0

Table A.2 cont.

31	366	44	3	5	0	0	4	0	0	3	0	1	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
32	231	25	2	19	0	1	11	0	1	11	0	2	0	4	0	0	0	3	0	0	4	0	0	0	0	0	0	0	0
33	266	43	4	13	1	4	6	0	0	2	0	3	0	1	0	0	0	0	0	0	2	0	0	1	0	0	0	0	0
34	243	66	7	15	3	1	3	0	1	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
35	367	69	6	11	3	4	2	0	1	0	0	2	0	1	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0
36	451	91	8	22	2	2	2	0	0	2	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
37	1	0	5	0	0	3	5	0	0	1	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0
38	3	0	4	5	0	2	2	0	4	3	0	2	0	1	0	0	0	3	0	0	0	0	0	0	0	1	0	0	0
39	151	9	6	10	0	3	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40	704	75	19	23	2	6	10	1	1	5	0	0	0	2	0	1	0	2	0	0	3	1	0	0	0	0	0	0	0
41	0	0	0	0	0	0	5	0	0	2	0	0	0	1	0	0	1	2	0	0	1	0	0	0	0	0	0	0	0
42	988	180	7	40	15	0	10	2	0	2	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
43	1168	288	15	35	5	3	11	1	1	6	0	0	0	2	0	0	0	3	0	0	2	0	0	0	0	0	0	0	0
44	519	85	4	14	1	1	4	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
45	0	0	1	4	0	0	4	0	2	3	0	0	1	3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
46	742	114	9	26	13	2	16	1	1	10	0	0	0	4	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
47	558	207	3	12	2	0	6	0	1	4	1	0	0	6	0	0	0	1	0	0	2	0	0	0	0	0	0	0	0
48	601	158	5	20	4	1	7	0	0	2	0	0	1	5	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0
49	215	8	6	11	0	0	5	0	0	2	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
50	331	69	2	16	0	0	6	0	1	1	0	0	0	2	0	0	0	1	0	0	2	0	0	0	0	0	0	0	0
	<20		<30			<40			<50			<60				<80			<100			>100			part			whole	
	Indet.	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Axial	Artic.	Shaft	Burnt	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	App.
Totals	19374	3562	322	730	103	90	325	20	37	156	2	14	9	88	1	7	5	66	1	0	29	1	0	6	1	6	0	2	0'
Grand Totals	19374		1052			415			193			111				78			30			7			7			2	

Table A.3

Layer	31																												
Class	<20		<30			<40			<50			<60				<80			<100			>100			part			whole	
Type	Indet.	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Axial	Artic.	Shaft	Burnt	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	App.
bag1	500	42	12	30	0	5	12	0	0	3	0	0	0	3	0	0	0	4	1	0	1	0	0	0	0	0	0	0	0
2	273	75	5	13	0	1	5	0	1	2	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
3	206	9	11	12	0	4	1	0	1	3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	282	48	6	11	1	1	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	394	84	5	10	1	0	5	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	2	1	0	0	0	0	1	3	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
7	128	15	2	6	0	0	1	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	97	8	1	6	0	0	3	0	0	1	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
9	44	7	0	3	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	48	6	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
11	84	31	3	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	60	38	1	4	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	49	8	3	3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	40	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	125	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	85	29	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	11	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	12	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	10	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	<20		<30			<40			<50			<60				<80			<100			>100			part			whole	
	Indet.	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Axial	Artic.	Shaft	Burnt	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	App.
Totals	3115	444	51	111	5	15	31	1	4	17	0	0	1	6	0	0	0	9	1	0	1	0	0	0	0	0	0	0	0
Grand Totals	3115		162			46			21			7				9			2			0			0			0	

Table A.4

Layer	4																												
Class	<20		<30			<40			<50			<60				<80			<100			>100			part			whole	
Type	Indet.	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Axial	Artic.	Shaft	Burnt	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	App.
1	3156	635	26	95	45	2	18	4	1	12	0	0	0	2	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
2	2	2	2	0	1	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	418	80	6	8	4	0	6	1	1	1	0	0	0	0	0	1	0	3	0	0	0	0	0	0	0	0	0	0	0
4	882	193	1	21	10	0	9	2	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	239	62	2	6	4	1	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
6	1449	425	12	22	16	3	3	2	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
7	4204	585	38	121	43	7	32	9	0	15	1	0	0	5	1	0	0	5	0	0	1	0	0	0	0	0	0	0	0
8	2612	526	22	100	36	5	29	7	4	18	2	0	1	5	0	0	1	9	0	0	4	0	0	0	0	0	0	0	0
9	3767	845	17	98	63	6	22	7	0	5	0	0	0	4	0	0	0	4	0	0	0	0	0	1	0	0	0	0	0
10	3612	676	33	137	82	6	40	11	3	11	3	1	0	6	0	1	0	6	0	0	1	0	0	0	0	0	0	0	0
11	71	44	4	8	2	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	<20		<30			<40			<50			<60				<80			<100			>100			part			whole	
	Indet.	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Axial	Artic.	Shaft	Burnt	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	App.
Totals	9240	4073	163	616	306	32	160	43	9	67	7	2	1	25	1	2	1	32	0	0	6	1	0	1	0	0	0	0	0
Grand Totals	9240		779			192			76			28				35			6			2			0			0	

Table A.5

Layer	20																												
Class	<20		<30			<40			<50			<60				<80			<100			>100			part			whole	
Type	Indet.	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Axial	Artic.	Shaft	Burnt	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	App.
bag1	167	155	1	2	3	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	177	167	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	294	286	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	122	107	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	43	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	155	145	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	161	153	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	162	157	0	3	3	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	162	142	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	89	79	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	47	44	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	213	195	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	97	94	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	107	94	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	76	73	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	105	95	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	39	36	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	126	119	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	23	21	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	196	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	402	395	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	53	51	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	179	162	0	1	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	136	124	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	<20		<30			<40			<50			<60				<80			<100			>100			part			whole	
	Indet.	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Axial	Artic.	Shaft	Burnt	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	App.
Totals	3331	2917	3	28	22	3	3	4	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Grand Totals	3331		31			6			3			0				0			0			0			0			0	

Table A.6

Layer	21																												
Class	<20		<30			<40			<50			<60				<80			<100			>100			part			whole	
Type	Indet.	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Axial	Artic.	Shaft	Burnt	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	App.
1	690	597	0	10	8	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	299	261	6	3	7	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	177	161	3	15	14	0	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	323	289	1	6	5	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	409	400	0	6	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	294	278	4	8	10	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	246	191	2	5	4	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	359	337	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	293	245	0	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	67	62	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	120	97	0	0	0	0	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	94	78	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	106	97	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	37	35	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	60	53	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	77	66	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	40	37	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	32	24	3	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	57	46	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	27	21	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	101	88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	15	10	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	42	37	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	12	12	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	58	44	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	25	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	48	41	0	1	1	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	33	27	1	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	9	9	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	9	9	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A.6 cont.

	<20		<30			<40			<50			<60				<80			<100			>100			part			whole	
	Indet.	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Axial	Artic.	Shaft	Burnt	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	App.
31	21	12	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	82	71	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	14	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	27	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	54	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	25	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	24	20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	23	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39	113	98	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Totals	4542	3989	32	71	75	3	15	10	1	2	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Grand Totals	4542		103			18			3			1				0			0			0			0			0	

Table A.7

Layer	3																												
Class	<20		<30			<40			<50			<60				<80			<100			>100			part			whole	
Type	Indet.	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Axial	Artic.	Shaft	Burnt	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	App.
bag1	915	833	0	13	4	0	5	3	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	59	44	3	37	36	0	13	5	0	4	3	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
3	194	135	10	63	46	4	24	10	2	7	4	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
4	360	186	3	26	9	0	6	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	1210	1082	7	66	46	2	9	6	0	1	0	1	0	2	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
6	184	144	14	69	50	1	13	11	1	3	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	344	200	11	14	7	2	6	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	222	149	6	15	3	1	6	2	0	1	1	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0	0	0	0
9	724	606	14	84	49	4	19	11	1	7	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	520	345	5	4	2	2	2	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0
11	620	613	3	18	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	31	12	0	8	4	0	3	0	0	4	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	216	205	2	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	360	330	1	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	178	134	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	230	212	0	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	4	4	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	181	167	2	4	3	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	110	98	2	5	4	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	147	128	1	5	2	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	75	52	4	10	11	2	3	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
23	70	65	1	4	1	2	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	244	221	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	445	270	1	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	155	155	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	314	253	6	54	39	0	10	3	0	1	0	0	0	6	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	107	93	0	12	9	1	2	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	306	249	3	8	4	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	296	265	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A.7 cont.

	<20		<30			<40			<50			<60				<80			<100			>100			part			whole	
	Indet.	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Axial	Artic.	Shaft	Burnt	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	App.
31	284	202	1	4	4	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	68	58	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	153	120	0	4	2	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	289	264	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	239	210	1	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	120	101	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Totals	9971	8201	103	545	366	21	129	59	8	34	15	1	2	17	4	0	0	9	0	0	3	0	1	0	0	1	0	0	0
Grand Totals	9971		648			150			42			20				9			3			1			1			0	

Table A.8

Layer	7																												
Class	<20		<30			<40			<50			<60				<80			<100			>100			part			whole	
Type	Indet.	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Axial	Artic.	Shaft	Burnt	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	App.
bag1	1850	325	11	46	16	5	14	1	3	8	2	0	0	3	0	0	0	2	0	0	2	0	0	0	0	0	0	0	0
2	713	106	22	27	4	9	10	0	7	8	1	1	0	3	0	1	0	3	1	0	0	0	0	0	0	0	0	0	0
3	1237	349	22	28	17	3	13	2	4	1	1	0	0	5	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
4	373	76	9	17	2	1	8	2	1	0	0	0	0	4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
5	215	29	5	9	1	1	15	0	1	5	0	1	0	3	0	0	0	4	1	0	1	0	0	0	0	0	0	0	0
6	1077	168	18	40	6	2	15	2	2	4	0	0	0	3	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
7	501	21	12	27	5	6	13	1	1	4	0	0	0	5	0	0	0	5	0	0	1	0	0	0	0	0	0	0	0
8	397	102	4	11	3	2	4	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
9	1046	346	13	19	9	6	5	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	554	75	12	24	12	0	14	0	0	2	1	1	0	3	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0
11	774	289	5	20	8	3	5	0	0	2	0	0	0	3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
12	740	291	5	18	7	1	3	0	0	0	0	0	0	3	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
13	474	309	3	16	6	2	3	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	212	96	1	6	1	1	5	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	227	64	1	15	9	2	7	0	0	2	0	0	0	4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
16	1968	523	11	24	10	1	5	0	0	1	0	0	1	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
17	667	259	3	7	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	366	166	6	9	4	0	2	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	1340	315	18	21	9	5	12	2	1	3	0	0	0	4	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
20	789	151	6	25	9	3	7	2	1	2	1	0	0	3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
21	977	260	8	28	13	1	5	1	0	4	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
22	503	173	5	16	4	1	5	2	0	1	1	0	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0
23	524	142	1	14	3	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
24	533	9	21	5	5	2	0	0	5	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
25	246	72	4	11	0	0	4	0	0	1	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	440	44	6	23	6	2	9	0	0	3	0	2	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
27	703	219	8	15	3	3	10	2	0	3	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
28	674	129	10	19	8	3	11	2	0	4	0	0	0	1	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0
29	858	323	10	24	7	0	3	0	0	4	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	479	201	2	9	8	3	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0

Table A.8 cont.

31	558	71	14	31	9	3	7	0	0	2	0	0	0	4	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0
32	488	88	2	15	3	2	8	0	0	6	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	630	126	7	31	16	0	11	1	1	3	0	0	0	2	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0
34	927	379	3	12	1	1	6	0	0	1	0	0	0	1	0	0	0	4	0	0	1	0	0	0	0	0	0	0	0
35	248	32	2	13	3	1	3	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
36	331	84	2	17	2	0	7	1	0	2	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
37	491	136	6	10	1	2	6	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	627	178	3	15	9	2	3	0	0	1	0	0	0	1	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0
39	263	46	2	14	5	0	7	0	0	0	0	0	0	4	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
40	246	56	1	8	2	2	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
41	880	161	3	15	5	2	6	2	0	3	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
42	1021	446	2	22	11	0	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
43	316	58	6	12	5	1	4	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
44	349	43	14	21	4	4	7	0	0	1	0	0	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0
45	443	89	5	12	6	1	2	0	0	3	0	0	0	2	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
	<20		<30			<40			<50			<60				<80			<100			>100			part			whole	
	Indet.	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Axial	Artic.	Shaft	Burnt	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	App.
Totals	19895	7625	334	821	277	89	292	28	29	98	7	7	3	83	2	3	1	47	2	0	15	1	0	4	0	2	0	0	0
Grand Totals	19895		1155			381			127			93				51			17			5			2			0	

Table A.9

Mass	(g)	Layer	8i							
Class	<20	<30	<40	<50	<60	<80	<100	>100	Part	Whole
bag1	38.9	19.5	11.1	10.5	15.8	9.1	0	0	0	0
2	18.6	9	5.5	2.5	9	14.1	0	0	3	0
3	69.5	24.5	11.1	15.8	10.4	3.4	0	0	10.6	0
4	12.8	12.1	0	6.5	5.6	8.3	14.4	0	0	0
5	42.6	6	21	0	0	0	0	0	0	0
6	0.1	0.6	0.4	5.7	0	0	17.7	0	68.4	0
7	48.7	25.7	23.2	9.3	6.2	11.2	0	0	0	0
8	0.1	9.4	23.6	34.9	27.4	37	3.9	0	0	0
9	0.1	5	18.9	13.6	16.1	14.2	0	10.1	0	0
10	22.1	2.5	3.9	1.4	9.1	5.8	0	0	27	0
11	58.3	18.3	11.6	10.4	3.1	24.2	0	0	0	0
12	22.7	15.8	1.8	8.5	0	0	0	0	0	0
13	71.2	19.9	6.2	5.6	1.9	0	0	0	0	0
14	27.4	12.4	13.9	9	1.7	0	0	0	0	0
15	12	14.2	7.9	14.4	1.3	2.1	0	0	0	0
16	9.7	7.5	3.2	19.1	4.2	15.6	0	0	0	0
17	28.6	1.7	4.7	3.3	2.7	0	0	0	0	0
18	3.3	7.6	2.9	0	0	0	0	0	0	0
19	43.9	17.8	12	13.5	2.1	6.3	0	0	0	0
20	12.4	9.2	7.5	6	4.9	6	0	0	0	0
21	0.1	3.6	24.5	19.3	31.5	16.3	0	0	0	0
22	71.8	26.3	9.9	8.5	5.6	0	0	22.8	0	0
23	54	14.3	13.1	3.5	5.8	40.8	0	0	0	0
24	37.6	13.2	3	4.9	0	0	0	0	0	0
25	47.8	17.5	3.2	0	0	0	0	0	0	0
26	19.1	7.2	25.2	4.6	15.9	0	0	0	0	0
27	49.8	14	8.9	0	0	0	0	0	0	0
28	10.7	4.5	4.4	0	6.4	2.1	9.1	46.9	0	0
29	55.5	21.5	14.8	3.1	0	0	0	0	0	0
30	33	14.2	18.2	13.3	4.8	13.8	0	17.5	0	0
31	28.1	20	13.1	6.4	5.6	13.6	0	0	0	0
32	57	13.2	5.1	4.3	8	0	0	0	0	0
33	1.2	0	4.2	15.3	11	12.5	0	0	0	0
34	7.5	7.4	2.8	10.9	10.4	8	0	0	0	0
35	27.9	14.8	8.7	4.5	2.3	0	0	0	0	0
36	36.5	21.1	3.3	12.9	12.9	8.4	0	0	0	0
37	10.4	6.6	3.4	0.6	10.3	27.3	11.6	0	0	0
38	0.1	1.3	3.3	5.6	5.9	10.4	6.1	0	21.1	0
39	27.7	5.8	11.5	0	3.5	14	0	0	0	0
40	9.4	4.1	9.9	9.7	3.4	5.3	0	0	7.1	0
41	36.3	25.5	6.9	1.9	0	0	0	0	0	0
42	18.8	10.8	10	0	3.2	0	0	0	0	0
43	19.4	13	4.5	6.5	8.1	0	0	0	0	0
44	30.6	6.5	7.1	12.7	1.6	11.4	0	0	0	0
45	38.7	13.7	3.6	1.1	0	0	0	0	0	0
46	34	10.2	5	0	0	0	0	0	0	0
47	0.8	6.6	3.8	8.2	6.5	7.8	0	0	0	0
48	27.3	11.1	5.3	3.4	2.6	0	0	0	0	0
49	28.2	13.6	2.9	3.5	2.6	0	0	0	0	0
50	14.3	3.7	9.7	3.3	0	0	0	0	0	0

51	34.4	11.6	2.2	4.2	0	0	0	0	0	0
52	17.4	8.3	14.3	1.4	8.4	0	0	31.8	0	0
53	1	13.8	13.4	10.7	6.1	17.1	6.2	0	0	0
54	29.2	18.7	12.3	10.9	10.5	10.8	4.6	0	0	0
55	41.8	14.7	5.4	1	0	0	0	0	0	0
56	0	2.2	16.4	3.2	12.2	3.8	0	0	0	0
57	15.4	4.5	9.1	0.4	1.3	0	4.3	15.3	0	0
58	4.6	7.6	5.8	2.4	5.5	0	8.8	0	0	0
	<20	<30	<40	<50	<60	<80	<100	>100	Part	Whole
Totals	**1520.4**	**665.4**	**518.6**	**392.2**	**333.4**	**380.7**	**86.7**	**144.4**	**137.2**	**0**

Table A.10

Mass	(g)	Layer	8ii							
Class	<20	<30	<40	<50	<60	<80	<100	>100	Part	Whole
bag1	14.8	8.3	16.3	9.7	8.2	16.1	26	6.8	0	0
2	60.2	22.4	14.5	22.1	10.3	3.3	0	0	9.2	0
3	37.1	25.1	4.9	4.9	2	4.7	0	0	0	0
4	1.8	17.1	30.6	21.4	31	18.8	0	0	0	0
5	28.9	6.8	16.1	12.9	2.4	0	0	22.6	0	0
6	22.9	11.1	19.5	13.6	0	12.6	0	0	0	0
7	44	23.3	3	2.8	0	0	0	0	0	0
8	21.8	19.8	25.4	3.2	4.1	9	0	0	0	0
9	7.3	4.8	5	7.3	2	0	0	22.6	0	0
10	0	0	0	0	0	0	0	0	0	112.9
11	13	9.5	1.2	0	2.2	0	0	0	0	0
12	45.4	24.6	38.5	20.9	9.7	22.5	0	0	0	0
13	10.4	5	5.1	2	5.9	3.9	0	0	12.6	0
14	13.5	9	5.3	9.9	0	5.7	4.3	0	0	0
15	35.4	14.7	14.8	7.1	8.7	31.3	16.8	14.1	0	0
16	48.6	31.3	6.5	20.9	8.5	5.1	0	0	0	0
17	39.1	10.9	19	8.4	25	7.3	2.7	7.4	0	0
18	33	13.5	6.7	13.8	5.4	1.8	9.7	0	0	0
19	26.7	14.5	7.5	0	9.1	0	0	0	0	24.5
20	28.9	13.2	14.6	3.9	0	3.9	0	0	22	0
21	0.5	4.2	13.4	11.6	3.9	5.7	11.3	0	0	0
22	22.3	6.9	3.6	0	2.5	5.6	0	0	0	0
23	28	22.1	21.8	11.6	11.9	34	15.5	0	0	0
24	14.9	18.5	8.7	7.3	6.9	8.6	0	0	0	0
25	45.5	15.1	8.5	10	1.7	4	7.8	0	0	0
26	28.5	14.7	13.6	3.7	0	3.4	0	0	54.9	0
27	25.3	7.6	17	18.5	28.5	10.5	10.1	0	23.4	0
28	43.5	19.5	16.2	15.6	0	37.9	0	0	0	0
29	33.5	11.5	5	9.8	1.6	0	0	0	0	0
30	17.6	15.7	10.5	8.2	17.8	44.3	0	0	0	0
31	24.5	4.7	6.6	13.6	14.6	6.8	0	0	0	0
32	15.5	15.1	20.6	27.4	34.1	29.4	25.7	0	0	0
33	17.8	7.8	15.6	5.3	8.1	0	32.4	10.9	0	0
34	23	12.5	5.5	2.9	2.5	3	0	0	0	0
35	24.6	12.6	5.8	1	5.4	14.9	3.9	0	0	0
36	30.2	21.2	9.1	4.5	6.8	8.7	0	0	0	0
37	0.1	3.9	19.8	2.7	3.3	4.9	0	0	66.7	0

38	0.1	6.7	4.4	17.6	12.8	30.8	0	0	11.2	0
39	10.1	7	3.6	1.5	1.2	0	0	0	0	0
40	47.2	3.9	23.3	9.5	6.1	19.5	33.9	8.7	0	0
41	0	0	6.8	2.7	5.3	19.1	10.7	0	0	0
42	66.2	28.3	14.1	4.8	8.3	2.2	0	0	0	0
43	78.3	33.4	22.8	18.4	8.1	15.6	29.7	0	0	0
44	34.8	6.2	5.2	4.7	0	7.1	0	0	0	0
45	0	2.9	6.1	7.6	17.6	6	0	0	0	0
46	49.7	32.4	25.3	26	14.9	6.8	10.8	0	0	0
47	37.4	8.8	6.7	8.6	18.4	6.5	22.6	0	0	0
48	40.3	17.2	9.6	4.2	25.4	10.4	7.6	0	0	0
49	14.4	11.7	4.7	9	12.2	11.4	0	0	0	0
50	22.2	11.1	9.2	3	3.7	12.1	16.5	0	0	0
	<20	**<30**	**<40**	**<50**	**<60**	**<80**	**<100**	**>100**	**Part**	**Whole**
Totals	**1328.8**	**668.1**	**597.6**	**456.1**	**418.1**	**515.2**	**298**	**93.1**	**200**	**137.4**

Table A.11

Mass	**(g)**	**Layer**	**31**							
Class	**<20**	**<30**	**<40**	**<50**	**<60**	**<80**	**<100**	**>100**	**Part**	**Whole**
bag1	33.5	21.6	20.7	6.7	15.6	24.6	15	0	0	0
2	18.3	11.5	9.4	7.9	5.4	8.6	0	0	0	0
3	13.8	10.9	8.2	10.9	1.9	0	0	0	0	0
4	18.9	7.5	7.3	1.2	0	0	0	0	0	0
5	26.4	9.4	6.9	4	0	0	0	0	0	0
6	0	3.2	0	11	0	6.6	0	0	0	0
7	8.6	4.7	2.1	11.4	0	0	0	0	0	0
8	6.5	2.5	3.5	1.6	7.6	6.3	0	0	0	0
9	2.4	1.9	5.7	0	0	0	0	0	0	0
10	2.2	4.9	0	0	0	4.3	0	0	0	0
11	5.6	6.3	0	0	0	0	0	0	0	0
12	4	3.7	2.3	0	0	0	0	0	0	0
13	3.3	1.9	0.3	0	0	0	0	0	0	0
14	2.7	0	0	0	0	0	0	0	0	0
15	8.4	0	0	0	0	0	0	0	0	0
16	5.7	1.3	0.8	0	0	0	0	0	0	0
17	0.4	0	0	0	0	0	0	0	0	0
18	0.5	0	0	0	0	0	0	0	0	0
19	0.2	0	0	0	0	0	0	0	0	0
	<20	**<30**	**<40**	**<50**	**<60**	**<80**	**<100**	**>100**	**Part**	**Whole**
Totals	**161.4**	91.3	67.2	54.7	30.5	50.4	15	0	0	**0**

Table A.12

Mass	(g)	Layer	4							
Class	<20	<30	<40	<50	<60	<80	<100	>100	Part	Whole
bag1	211.5	86.6	23.3	26.6	6.1	18.4	0	0	0	0
2	2.3	4.1	8.2	0	7.1	0	0	0	0	0
3	28	10.6	5.3	7.9	0	28.2	0	0	0	0
4	59.1	17.8	11.6	2.3	6.7	0	0	0	0	0
5	16	5.2	1.4	2.9	5.3	0	0	8.5	0	0
6	97.1	20.6	5.7	1.7	0	9.2	0	0	0	0
7	281.8	123.5	52.1	37.4	16.6	27.9	17.9	0	0	0
8	175.1	85.4	51.2	54.5	19.6	57.8	34.1	0	0	0
9	252.5	77.8	46.7	11.3	23.1	14.9	0	11.7	0	0
10	242.1	130.8	70.5	33.5	22.4	34.8	8.7	0	0	0
11	15.7	9	0	2.7	4.6	0	0	0	0	0
	<20	<30	<40	<50	<60	<80	<100	>100	Part	Whole
Totals	1381.2	571.4	276	180.8	111.5	191.2	60.7	20.2	0	0

Table A.13

Mass	(g)	Layer	20							
Class	<20	<30	<40	<50	<60	<80	<100	>100	Part	Whole
bag1	7.9	1.1	0	0.8	0	0	0	0	0	0
2	7.2	0.5	0	0	0	0	0	0	0	0
3	14.1	1.1	0	0	0	0	0	0	0	0
4	6.1	0.4	0	5	0	0	0	0	0	0
5	1.3	0	0	0	0	0	0	0	0	0
6	5.2	0	0	0	0	0	0	0	0	0
7	9.8	0.4	0	0	0	0	0	0	0	0
8	14	1.8	1.6	0	0	0	0	0	0	0
9	11.2	2.3	0	0	0	0	0	0	0	0
10	5.5	1.9	0	0	0	0	0	0	0	0
11	3.1	0.9	2.5	0	0	0	0	0	0	0
12	12.8	0	0	0	0	0	0	0	0	0
13	4.9	0	0	0	0	0	0	0	0	0
14	7.2	0	0	0	0	0	0	0	0	0
15	9.7	1.2	0	0	0	0	0	0	0	0
16	5.7	1.2	0	0	0	0	0	0	0	0
17	6.9	1	0	0	0	0	0	0	0	0
18	6.4	0	0	0	0	0	0	0	0	0
19	4.1	0	2.5	0	0	0	0	0	0	0
20	13.6	0	0	0.5	0	0	0	0	0	0
21	24.6	2.7	0	0	0	0	0	0	0	0
22	3.4	1.3	0	0	0	0	0	0	0	0
23	13.5	0.7	1.7	3	0	0	0	0	0	0
24	8.7	0.9	0	0	0	0	0	0	0	0
	<20	<30	<40	<50	<60	<80	<100	>100	Part	Whole
Totals	206.9	19.4	8.3	9.3	0	0	0	0	0	0

Table A.14

Mass	(g)	Layer	21							
Class	**<20**	**<30**	**<40**	**<50**	**<60**	**<80**	**<100**	**>100**	**Part**	**Whole**
bag1	59.8	6.3	0.8	1.9	0	0	0	0	0	0
2	25.6	5.9	1.5	0.5	0	0	0	0	0	0
3	41.8	14.7	4.1	0	0	0	0	0	0	0
4	31.4	5.9	0.8	0	0	0	0	0	0	0
5	24.4	3.8	0	0	0	0	0	0	0	0
6	21.4	6.3	0.4	0	0	0	0	0	0	0
7	21.2	3.7	1.9	0	0	0	0	0	0	0
8	25.9	3	0	0	0	0	0	0	0	0
9	19.9	1.5	0	0	0	0	0	0	0	0
10	6	0	0	2.7	0	0	0	0	0	0
11	9.4	0	3.4	0	0	0	0	0	0	0
12	4.4	1.3	0	0	0	0	0	0	0	0
13	6.4	1.4	0	0	0.6	0	0	0	0	0
14	2	1.1	0	0	0	0	0	0	0	0
15	4.8	1.6	0	0	0	0	0	0	0	0
16	4	0.6	0	0	0	0	0	0	0	0
17	2.1	0.6	2.3	0	0	0	0	0	0	0
18	1.9	1.5	0	0	0	0	0	0	0	0
19	4.2	1.9	0	0	0	0	0	0	0	0
20	1.4	0.5	0	0	0	0	0	0	0	0
21	9	0	0	0	0	0	0	0	0	0
22	1.7	0.7	0.8	0	0	0	0	0	0	0
23	3.3	0.1	0	0	0	0	0	0	0	0
24	1.1	0.9	0	0	0	0	0	0	0	0
25	4.4	0.5	0	0	0	0	0	0	0	0
26	2.2	0	0	0	0	0	0	0	0	0
27	4.2	0.8	1.9	0	0	0	0	0	0	0
28	3	1.6	0	0	0	0	0	0	0	0
29	0.8	0.5	2.3	0	0	0	0	0	0	0
30	2.6	0.1	0	0	0	0	0	0	0	0
31	1.7	0.4	0	0	0	0	0	0	0	0
32	7.8	0.1	1	0	0	0	0	0	0	0
33	0.8	0	0	0	0	0	0	0	0	0
34	0.9	0	0	0	0	0	0	0	0	0
35	1.4	0	0	0	0	0	0	0	0	0
36	2.1	0	0	0	0	0	0	0	0	0
37	1	0.1	0	0	0	0	0	0	0	0
38	1.9	0	0	0	0	0	0	0	0	0
39	3.2	0	0	0	0	0	0	0	0	0
	<20	**<30**	**<40**	**<50**	**<60**	**<80**	**<100**	**>100**	**Part**	**Whole**
Totals	**371.1**	**67.4**	**21.2**	**5.1**	**0.6**	**0**	**0**	**0**	**0**	**0**

Table A.15

Mass	(g)	Layer	3						
Class	**<20**	**<30**	**<40**	**<50**	**<60**	**<80**	**<100**	**>100**	**Part**	**Whole**
bag1	191.8	71.8	16.9	9.2	0	3.6	0	0	0	0
2	26.1	27	20.3	11	0	24.7	0	0	0	0
3	61.1	55.5	42.9	20.1	6.1	2.5	0	0	0	0
4	36.6	20.2	7.9	6.6	0	0	0	0	0	0
5	219.5	51	15.2	1.9	14.7	4.5	9.3	0	0	0
6	54.6	76.8	18.6	10.4	5.9	0	0	0	0	0
7	36	21.1	14.4	3.1	2.2	0	0	0	0	0
8	43.4	13.8	13.4	2.5	0	0	33	0	0	0
9	142.1	73.6	39.9	19.7	3.3	0	0	0	0	0
10	34.1	7.8	8.8	5.3	0	12.3	0	0	12.4	0
11	83.8	18.6	0	0	0	0	0	0	0	0
12	7.1	6.3	2.2	7.5	6	0	0	0	0	0
13	14.5	3.4	0.9	0	0	0	0	0	0	0
14	21	1.8	0	0	0	0	0	0	0	0
15	8.3	0.6	0	0	0	0	0	0	0	0
16	17.5	1.3	0	0	0	0	0	0	0	0
17	0	7.2	0	7.3	0	0	0	0	0	0
18	16	1.7	0	1	2.4	0	0	0	0	0
19	19.4	4.9	0.7	0	0	0	0	0	0	0
20	21.5	2.6	2	0	0	0	0	0	0	0
21	17.5	20	6	3.9	5.7	0	0	0	0	0
22	0.4	1.2	0	0	0	0	0	24.8	0	0
23	16.7	3.8	7.8	3.2	0	0	0	0	0	0
24	30.7	0	0	0	0	0	0	0	0	0
25	22.3	3.3	0	0	0	0	0	0	0	0
26	9	0	0	0	0	0	0	0	0	0
27	82.6	41.9	9.9	0.6	17.6	0	0	0	0	0
28	30.4	6.5	4.1	0	2.1	0	0	0	0	0
29	24.1	9.3	0.8	0	0	0	0	0	0	0
30	18.4	1.2	0	0	0	0	0	0	0	0
31	18.5	3.1	1.8	0	0	0	0	0	0	0
32	10.1	0.3	0	0	0	0	0	0	0	0
33	15.3	2.7	1.5	0	0	0	0	0	0	0
34	18.6	0	0	0	0	0	0	0	0	0
35	17.4	0.2	0	1.3	0	0	0	0	0	0
36	11.4	1.8	0	0	0	0	0	0	0	0
	<20	**<30**	**<40**	**<50**	**<60**	**<80**	**<100**	**>100**	**Part**	**Whole**
Totals	**1397.8**	**562.3**	**236**	**114.6**	**66**	**47.6**	**42.3**	**24.8**	**12.4**	**0**

Table A.16

Mass	(g)	Layer	7							
Class	<20	<30	<40	<50	<60	<80	<100	>100	Part	Whole
bag1	124	39.1	29.5	34.3	8.9	12.5	20.2	0	0	0
2	47.8	26.4	16.4	31.9	15.7	10.7	5.8	0	0	0
3	82.9	45.5	25.8	20.6	15.1	6.2	0	0	0	0
4	25	13.7	14	1.2	13.7	6.1	0	0	0	0
5	14.4	21.6	23.8	17	30.3	33.2	39.3	0	0	0
6	72.2	37.6	20.1	11.5	10	14	0	0	0	0
7	33.6	29.1	29.2	16.5	14.2	46.3	8.8	0	0	0
8	26.6	13	8.9	4.6	0	9.7	0	0	0	0
9	70.1	20.4	22	1.3	1.9	0	0	0	0	0
10	37.1	33.4	20.3	5.9	15.2	16.4	14.8	0	0	0
11	51.9	16.1	12	3.9	17	7.2	0	0	0	0
12	49.6	18.4	3.2	0	7.3	13.5	0	0	0	0
13	31.8	14.4	11.3	1.1	0	0	0	0	0	0
14	14.2	5.7	11.1	2	4.5	0	0	0	0	0
15	15.2	11.9	16.7	7.8	12.9	6	0	0	0	0
16	131.9	29.5	7.4	1.5	15.6	0	5.1	0	0	0
17	44.7	6.7	3	0	0	0	0	0	0	0
18	24.5	14.4	1.3	4	3.4	0	0	0	0	0
19	89.8	23.5	23.8	12.5	13.4	8.8	0	0	0	0
20	52.9	23.3	16.9	9.4	10.2	0	0	9.9	0	0
21	65.5	30.6	7	9.2	6.9	10.6	0	0	0	0
22	33.7	13	8	5	0	13.8	8.6	0	0	0
23	35.1	8.2	5.8	0	0	0	0	0	29.9	0
24	35.7	14.4	13	14.8	0	4.2	0	0	0	0
25	16.5	6.1	3.6	3.3	5.7	0	0	0	0	0
26	29.5	18.3	14.6	8.5	7.5	4.2	0	0	0	0
27	47.1	16.2	15.5	7	5.1	10.6	0	0	0	0
28	45.2	19.4	19.2	10	1.9	7	21.8	9	0	0
29	57.5	25.6	5.5	11.4	18.6	0	0	0	0	0
30	32.1	8.4	2.1	0	4.1	0	12.1	7.1	0	0
31	37.4	30.6	14.9	5.2	18.7	14.9	0	0	0	0
32	32.7	12.4	14.6	12.3	13.4	0	0	0	0	0
33	42.2	29	15.2	8.1	7.9	12.7	7.9	0	0	0
34	62.1	10.6	10.9	5	2.6	29.5	3.9	0	0	0
35	16.6	11.1	9.1	2.7	4.5	0	0	0	68.4	0
36	22.2	13.9	8	2.9	2	2.5	0	0	0	0
37	32.9	6.8	7.5	5	3	0	0	0	0	0
38	42	14.3	9	0.9	2.9	4.4	10.2	0	0	0
39	17.6	15.6	10.8	0	19.5	0	11.5	0	0	0
40	16.5	7.4	4.9	1.7	0	0	0	20	0	0
41	59	13	10.8	6.9	0	3.2	0	0	0	0
42	68.4	19.7	0	4.3	2.4	0	0	0	0	0
43	21.2	13.7	6.7	6.4	0	0	0	16.2	0	0
44	23.4	27.3	14	2.9	0	9.4	9.9	0	0	0
45	29.7	14.4	4.2	18.2	8.1	6.2	13.7	0	0	0
	<20	<30	<40	<50	<60	<80	<100	>100	Part	Whole
Totals	1962	843.7	551.6	338.7	344.1	323.8	193.6	62.2	98.3	0

Table A.17

	Fracture	**Scores**					
Context	**0**	**1**	**2**	**3**	**4**	**5**	**6**
8i	31	34	32	84	42	22	5
8ii	53	31	39	98	49	22	8
31	0	1	6	19	6	1	0
4	22	14	22	40	18	7	2
20	N/A						
21	N/A						
3	11	12	10	21	14	1	1
7	30	16	50	103	23	23	5

APPENDIX B

WALLSEND DATA

Table B.1 - The number and mass of fragments in different size classes in the Wallsend sample

Table B.2 - The proportions of different bone types in different size classes in the Wallsend sample

Table B.3 - The frequency of different fracture freshness index scores in the Wallsend sample

Table B.1

Wallsend		
Class	No.	Mass
<20	36	5
20-30	49	68.2
30-40	92	269.5
40-50	98	551.7
50-60	83	749.1
60-80	71	1180.1
80-100	19	704.8
>100	14	551.8
Part	9	489.9
Whole	7	592.7

Table B.2

Class	Shaft	Misc. Canc.	Axial	App.
20-30	17	32	0	0
30-40	32	60	0	0
40-50	23	75	0	0
50-60	23	0	43	17
60-80	16	0	38	17
80-100	3	0	10	6
>100	3	0	8	3
Part	0	0	2	7
Whole	0	0	0	17

Table B.3

FFI	No.
0	10
1	9
2	11
3	27
4	5
5	10
6	16

APPENDIX C

GREENLANDIC DATA

Table C.1 - Numbers of fragments in each size and bone type class, and numbers of burnt fragments in each size class, for each bag of fragments studied at Sandnes (V51) (excluding seal)

Table C.2 - Mass (g) of fragments in each size class for each bag of fragments studied at Sandnes (V51) (excluding seal)

Table C.3 - Number and mass (g) of fragments in each size class for seal at Sandnes (V51)

Table C.4 - Frequencies of fracture freshness index scores given in the sample from Sandnes (V51)

Table C.5 - Numbers of fragments in each size and bone type class, and numbers of burnt fragments in each size class, for each bag of fragments studied at Niaquussat (V48) (excluding seal)

Table C.6 - Mass (g) of fragments in each size class for each bag of fragments studied at Niaquussat (V48) (excluding seal)

Table C.7 - Number and mass (g) of fragments in each size class for seal at Niaquussat (V48)

Table C.8 - Frequencies of fracture freshness index scores given in the sample from Niaquussat (V48)

Table C.9 - Numbers of different bone types in different size classes at in the sample from Qeqertasussuk

Table C.10 - Mass (g) of different bone types in different size classes at in the sample from Qeqertasussuk

Table C.11 - Numbers of fragments in each size and bone type class, and numbers of burnt fragments in each size class, for each bag of fragments studied at Itivnera

Table C.12 - Mass (g) of fragments in each size class for each bag of fragments studied at Itivnera

Table C.13 - Frequencies of fracture freshness index scores given in the sample from Itivnera

Table C.1

	V51		exc.	seal																									
Class	<20		<30			<40			<50			<60				<80			<100			>100			part			whole	
Type	Indet.	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Axial	Artic.	Shaft	Burnt	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	App.
bag1	24	0	2	9	0	2	13	0	5	23	0	1	2	34	0	1	5	44	0	3	28	0	0	14	0	0	0	0	0
2	12	0	5	0	0	2	0	0	2	0	0	6	0	0	0	12	0	1	10	0	0	14	0	0	0	0	0	0	0
3	0	0	9	0	0	12	0	0	17	0	0	18	0	2	0	28	0	0	8	0	1	8	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	2	6	0	1	2	0	1	5	0	0	0	0	2
5	34	0	5	0	0	4	0	0	4	0	0	2	1	0	0	8	0	0	7	0	0	5	0	0	0	2	0	0	0
6	0	0	1	0	0	3	0	0	1	2	0	1	1	0	0	0	3	3	0	0	0	0	0	1	0	1	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
8	0	0	0	0	0	2	0	0	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	8	0	11	0	0	8	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	3	0	4	0	0	4	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	2	0	5	0	0	2	0	0	2	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
12	153	0	105	13	1	52	12	1	36	4	0	12	1	7	0	1	0	4	1	0	1	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	1	2	2	0	0	0	0	0
17	1	0	5	7	0	1	33	0	5	25	0	9	1	31	0	2	0	12	1	0	6	0	0	3	0	0	0	0	0
	<20		<30			<40			<50			<60				<80			<100			>100			part			whole	
	Indet.	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Axial	Artic.	Shaft	Burnt	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	App.
total	237	0	152	29	1	92	58	1	79	55	0	54	6	74	0	52	10	72	31	4	38	29	3	25	0	7	0	0	2
grand total	237		181			150			134			134				134			73			57			7			2	

Table C.2

Mass	(g)	V51	Exc.	Seal					
Class	**<20**	**<30**	**<40**	**<50**	**<60**	**<80**	**<100**	**100<**	**Part**	**Whole**
bag1	1.6	6.6	34.1	92.6	231.4	456.5	434.8	316.9	0	0
2	1	1.8	2.5	3.8	18.3	51.9	40.1	147.4	0	0
3	0	3.8	9.7	14.6	20.9	46.6	24.2	31.8	0	0
4	0	0	0	22.4	1.9	66.9	64.1	126.6	0	52.1
5	1.5	1	11.4	8.3	31.5	36.2	99.3	137.9	84.8	0
6	0	2	7.8	14.5	14	44.4	0	13.9	14.1	0
7	0	0	0	0	16.9	0	0	8.1	0	0
8	0	0	4.5	7.9	11.6	0	0	0	0	0
9	2.5	9.2	13	3	0	0	0	0	0	0
10	0.3	3.3	4.9	2.8	0	0	0	0	0	0
11	1.1	10	12.6	4	0	0	11.4	0	0	0
12	18.4	47.7	54.1	66.4	34.9	12.1	17	0	0	0
13	0	0	0	0	0	0	0	0	14.7	0
14	0	0	0	0	0	0	0	0	12.4	0
15	0	0	0	0	0	0	0	0	7.2	0
16	0	0	0	0	0	22.8	32.1	390.8	0	0
17	0.1	12.8	52.8	60	120.6	54.1	37.3	34.2	0	0
	<20	**<30**	**<40**	**<50**	**<60**	**<80**	**<100**	**100<**	**Part**	**Whole**
Total	**26.5**	**98.2**	**207.4**	**300.3**	**502**	**791.5**	**760.3**	**1207.6**	**133.2**	**52.1**

Table C.3

Seal	V51	
Size Class	**Number**	**Mass**
<20	5	3.8
<30	19	31.5
<40	17	52.1
<50	30	105.3
<60	18	83.3
<80	32	190.3
<100	15	103.8
100<	28	292.3
Part	1	9.3
Whole	0	0

Table C.4

V51	
FFI	**Number**
0	135
1	40
2	28
3	30
4	2
5	0
6	0

Table C.5

	V48		exc.	seal																									
Class	<20		<30			<40			<50			<60				<80			<100			>100			part			whole	
Type	Indet.	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Axial	Artic.	Shaft	Burnt	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	App.
bag1	117	35	71	7	19	35	5	1	17	6	1	6	1	3	0	8	1	5	3	1	0	3	0	0	0	1	0	0	0
2	2	1	2	1	1	5	1	0	2	0	0	0	1	0	0	4	0	0	1	0	0	1	0	0	0	0	0	1	0
3	65	11	60	4	17	27	5	3	10	5	1	11	0	1	1	7	1	4	0	0	2	2	1	1	0	1	0	0	2
4	70	22	25	4	3	10	8	1	1	4	0	2	0	1	0	1	0	1	1	0	0	2	0	3	0	0	0	0	0
5	32	10	23	2	1	10	7	0	11	5	0	6	0	3	0	5	0	0	1	0	3	1	0	0	0	0	0	0	0
6	76	24	47	9	9	31	4	3	13	3	0	13	0	1	0	2	0	6	0	0	1	2	0	0	0	0	0	0	0
7	55	26	27	2	9	5	3	1	2	0	0	1	0	1	0	2	0	3	1	0	0	0	0	1	0	0	0	0	0
8	65	25	37	5	8	20	2	5	5	3	2	2	0	2	0	2	0	0	0	0	0	0	0	0	0	1	0	0	0
9	66	32	59	4	11	19	6	6	7	4	1	11	0	0	0	0	0	1	1	0	2	1	0	2	0	0	0	0	0
10	27	6	36	11	11	15	7	3	10	2	2	4	0	3	2	3	0	1	0	0	0	0	0	1	0	0	0	0	1
11	38	5	72	13	12	22	6	5	17	6	3	8	0	3	0	6	0	3	1	0	3	0	0	2	0	0	0	0	0
12	36	10	43	9	14	13	11	5	13	4	0	1	0	1	1	4	0	0	0	0	0	1	0	0	0	0	0	0	0
13	109	31	51	9	9	13	6	6	6	4	2	3	0	3	0	5	1	1	0	0	1	1	0	0	0	0	0	0	0
14	18	10	13	2	1	9	0	2	0	3	0	0	0	3	1	4	0	1	0	0	0	0	0	0	0	0	0	0	0
15	93	37	36	8	8	9	5	1	6	3	1	1	0	1	0	2	0	2	0	0	1	0	0	0	0	0	0	0	0
16	44	9	28	6	5	7	1	1	5	1	1	3	0	3	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0
17	2	2	10	3	3	1	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	<20		<30			<40			<50			<60				<80			<100			>100			part			whole	
	Indet.	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Axial	Artic.	Shaft	Burnt	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	App.
totals	915	296	640	99	141	251	78	43	128	53	14	72	2	29	6	55	3	29	9	1	14	14	1	10	0	3	0	1	3
grand totals	915		739			329			181			103				87			24			25			3			4	

Table C.6

Mass	(g)	V48	Exc.	Seal					
Class	**<20**	**<30**	**<40**	**<50**	**<60**	**<80**	**<100**	**100<**	**Part**	**Whole**
bag1	28.2	60.2	64.3	52	39.7	59.5	28.6	43.1	12.7	0
2	0.7	2.5	12.5	4.3	2.7	20.6	8.7	3	0	18.1
3	16	55.5	44.3	41.3	76.2	73	16.3	72.5	23.1	50.1
4	21.9	23	33.1	21.1	15.6	20.9	25.5	146.7	0	0
5	12.7	24.1	31.3	46.8	26	24.7	60.9	8.3	0	0
6	26.5	46.7	47.6	54.3	62.2	34.2	9.6	19.2	0	0
7	21.1	25	16.8	4.8	7	31.3	11.4	38.3	0	0
8	21.1	50.9	36.8	17.9	21.4	4.3	0	0	7.8	0
9	18.9	43.1	38	26.5	48.4	2.8	27.4	30.2	0	0
10	6.7	44.2	35.5	32	27.8	25.8	0	18.8	0	8.6
11	15.4	70.2	49.7	70.2	49.8	40.4	30.2	57.4	0	0
12	13.9	40.6	32.8	51.5	16.2	7.4	0	14.6	0	0
13	31.8	39	28	32.8	21.9	29.5	2.1	5.8	0	0
14	4.7	14.4	12.4	5.8	13.3	41.2	0	0	0	0
15	20.7	36.5	27.5	27.3	5.4	19.4	14.5	0	0	0
16	10.9	31.9	10.8	25.4	20.8	3.4	5.5	0	0	0
17	1.2	10.2	4.8	5.7	0	0	0	0	0	0
	<20	**<30**	**<40**	**<50**	**<60**	**<80**	**<100**	**100<**	**Part**	**Whole**
Totals	**272.4**	**618**	**526.2**	**519.7**	**454.4**	**438.4**	**240.7**	**457.9**	**43.6**	**76.8**

Table C.7

Itivnera	Seal	
Class	No.	Mass(g)
<20	0	-
<30	0	-
<40	0	-
<50	0	-
<60	1	-
<80	2	-
<100	24	147.4
100<	56	756.5
Part	38	528.8
Whole	101	1348.3

Table C.8

Itivnera	
FFI	No.
0	93
1	45
2	31
3	29
4	8
5	2
6	0

Table C.9

QT	Phocid	No.			
Class	Rib	Vertebrae	Misc.Axial	Append.	Misc.Frags.
<30	-	-	-	-	450
<40	56	18	31	52	-
<50	25	7	19	13	-
<60	16	4	8	6	-
<80	16	1	9	2	-
<100	5	0	5	1	-
100+	11	0	0	1	-
Part	0	4	3	27	-
Whole	5	17	0	54	-

Table C.10

QT	Mass(g)		
Class	Axial	Append.	Misc.
<30	-	-	232.6
<40	135.3	108.4	-
<50	123.6	39.1	-
<60	93.4	19.3	-
<80	109.2	8.4	-
<100	150	19.3	-
100+	84.8	10.4	-
Part	84	305.8	-
Whole	338.4	489.8	-

Table C.11

Itiv.																													
Class	<20		<30			<40			<50			<60				<80			<100			>100			part			whole	
Type	Indet.	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Axial	Artic.	Shaft	Burnt	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	App.
bag1	4	0	5	4	0	1	13	0	0	24	0	2	0	13	0	2	1	17	3	0	13	2	0	8	1	8	0	2	3
2	10	0	11	25	1	9	23	0	5	9	0	3	0	4	0	1	0	1	1	0	0	1	0	0	0	0	0	0	0
3	5	0	4	7	0	3	5	0	2	13	0	0	0	17	0	1	3	18	2	0	13	4	0	9	0	4	0	1	4
4	9	0	11	19	0	11	17	0	6	10	0	3	0	9	0	6	0	4	1	0	0	0	0	0	0	0	0	0	0
5	25	1	21	29	1	16	34	0	7	26	0	5	0	30	0	6	0	32	3	1	19	2	1	13	1	4	0	1	7
6	15	0	17	11	4	12	15	0	7	17	0	3	1	8	0	5	2	9	3	0	5	0	0	9	2	7	0	0	4
7	1	0	2	1	1	13	6	0	2	5	0	0	1	13	0	1	2	12	0	2	7	1	3	5	1	6	0	0	5
8	7	0	8	8	0	4	8	0	6	8	0	3	1	5	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
9	3	0	5	7	0	5	16	0	4	9	0	3	0	12	0	4	1	13	3	1	7	0	1	4	1	0	0	0	2
10	1	1	1	3	0	4	8	0	0	12	0	0	3	15	0	1	5	30	1	0	13	0	0	9	1	6	0	2	7
11	10	0	8	20	0	11	22	1	6	21	0	2	0	7	0	1	0	4	0	0	0	0	0	0	0	0	0	0	0
	<20		<30			<40			<50			<60				<80			<100			>100			part			whole	
	Indet.	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Canc.	Shaft	Burnt	Axial	Artic.	Shaft	Burnt	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	Artic.	Shaft	Axial	App.
totals	90	2	93	134	7	89	167	1	45	154	0	24	6	133	0	31	14	140	17	4	77	10	5	57	7	35	0	6	32
grand totals	90		227			256			199			163				185			98			72			42			38	

Table C.12

Mass	**(g)**	**Itiv.**								
Class	**<20**	**<30**	**<40**	**<50**	**<60**	**<80**	**<100**	**100<**	**Part**	**Whole**
bag1	0.5	16.9	25.8	68.5	56.7	98.6	141	243.9	324.4	62.8
2	1.8	23.7	30.8	17.3	13.1	5.4	1.4	13.3	0	0
3	0.9	13.7	18.5	41.1	69.6	174.7	162.1	312.3	93.3	108.1
4	1.7	24.5	34.2	20.6	19.6	29.2	1.9	0	0	0
5	8.1	51.1	74.8	80.7	147.5	200.5	184.5	402.6	129.1	230.4
6	2.2	20.2	30.5	49.8	42.6	115.4	88.3	179.8	287.5	16.5
7	0.3	1.3	21.5	27.7	56.4	93.1	79.7	191.7	138	36.5
8	2.8	11.7	12.9	16.6	14.6	6.7	0	0	0	0
9	0.4	8.7	43.7	24.8	55.7	115.4	106.3	141	16.4	75
10	1	4	31.3	39.5	83.4	232.8	167.4	227.1	160.4	77.9
11	2.5	17.9	33.9	41.8	21.7	12.2	0	0	0	0
	<20	**<30**	**<40**	**<50**	**<60**	**<80**	**<100**	**100<**	**Part**	**Whole**
Total	**22.2**	**193.7**	**357.9**	**428.4**	**580.9**	**1084**	**932.6**	**1711.7**	**1149.1**	**607.2**

Table C.13

Itivnera	
FFI	**No.**
0	437
1	49
2	26
3	32
4	0
5	0
6	0

APPENDIX D

AJVIDE DATA

Table D.1 - The numbers of fragments of different types, masses of bone fragments and number of fragments burnt in each size class for pig and indet. bones in Layer 1, Test Area 1, Ajvide

Table D.2 - The numbers of fragments of different types, masses of bone fragments and number of fragments burnt in each size class for pig and indet. bones in Layer 2, Test Area 1, Ajvide

Table D.3 - The numbers of fragments of different types, masses of bone fragments and number of fragments burnt in each size class for pig and indet. bones in Layer 3, Test Area 1, Ajvide

Table D.4 - The numbers of fragments of different types, masses of bone fragments and number of fragments burnt in each size class for pig and indet. bones in Layer 4, Test Area 1, Ajvide

Table D.5 - The numbers of fragments of different types, masses of bone fragments and number of fragments burnt in each size class for pig and indet. bones in Layer 5, Test Area 1, Ajvide

Table D.6 - The numbers of fragments of different types, masses of bone fragments and number of fragments burnt in each size class for pig and indet. bones in Layer 6, Test Area 1, Ajvide

Table D.7 - The numbers, masses and numbers burnt for seal bones in each size class for each layer in Test Area 1, Ajvide

Table D.8 - The frequencies of fracture freshness index scores in each layer in Test Area 1 Ajvide

Table D.9 - The numbers of fragments of different types and masses of bone fragments in each size class for pig and indet. bones in the sample from the "black layer", Ajvide, also the percentage of pig and indet. shaft fragments that were burnt in each size class

Table D.10 - The numbers, masses and numbers burnt for seal bones in each size class for each layer in the sample from the "black layer", Ajvide

Table D.11 - The frequencies of fracture freshness index scores in the sample from the "black layer", Ajvide

Table D.1

Layer 1	**Number**					**Grams**	**Number**
Class	**Shaft**	**Misc.Canc.**	**Axial**	**Artic.**	**Cranial**	**Mass**	**Burnt**
<20	37	17				25.1	23
<30	40		10	17	20	112.0	39
<40	24		11	5	15	212.8	27
<50	5		7	5	4	76.6	7
<60	2		3	1	1	34.2	3
<80	2		15	0	0	29	2
<100	0		0	0	0	0	0
>100	0		0	0	0	0	0
Part	0		0	3	0	44.9	2
Whole	0		0	5	0	15.3	2

Table D.2

Layer 2	**Number**					**Grams**	**Number**
Class	**Shaft**	**Misc.Canc.**	**Axial**	**Artic.**	**Cranial**	**Mass**	**Burnt**
<20	19	42				33.7	23
<30	47		32	30	56	226.3	85
<40	38		41	13	35	228.4	60
<50	19		22	6	22	198.6	25
<60	11		15	8	5	184.2	11
<80	10		13	4	0	144.0	7
<100	3		3	0	2	77.5	1
>100	0		3	1	0	32.6	0
Part	0		1	3	0	34.7	2
Whole	0		0	35	0	177.3	12

Table D.3

Layer 3	**Number**					**Grams**	**Number**
Class	**Shaft**	**Misc.Canc.**	**Axial**	**Artic.**	**Cranial**	**Mass**	**Burnt**
<20	1	13				6.7	0
<30	13		2	7	1	20.5	0
<40	10		4	2	7	50.6	2
<50	11		5	2	5	70.3	1
<60	5		2	1	3	68.1	0
<80	1		0	2	0	32.5	0
<100	0		2	0	0	17.1	0
>100	0		0	0	0	0	0
Part	0		0	4	0	53.9	0
Whole	0		0	7	0	48.2	0

Table D.4

Layer 4	**Number**					**Grams**	**Number**
Class	**Shaft**	**Misc.Canc.**	**Axial**	**Artic.**	**Cranial**	**Mass**	**Burnt**
<20	9	35				19.4	3
<30	24		3	8	2	33.9	2
<40	17		7	3	8	58.3	1
<50	9		6	2	3	37.9	0
<60	5		1	1	2	37.3	1
<80	3		5	1	0	58.6	1
<100	1		3	0	1	30.7	0
>100	0		1	0	0	5.7	0
Part	0		0	1	0	41.3	0
Whole	0		0	4	0	9.2	0

Table D.5

Layer 5	**Number**					**Grams**	**Number**
Class	**Shaft**	**Misc.Canc.**	**Axial**	**Artic.**	**Cranial**	**Mass**	**Burnt**
<20	6	16				10.9	0
<30	11		0	3	2	10.5	1
<40	2		0	0	1	3.0	0
<50	1		0	0	1	4.5	0
<60	2		2	0	2	24.2	0
<80	1		1	0	1	30.5	0
<100	1		1	0	0	20.9	0
>100	0		0	0	1	74.4	0
Part	0		0	1	0	14.3	0
Whole	0		0	0	0	0	0

Table D.6

Layer 6	**Number**					**Grams**	**Number**
Class	**Shaft**	**Misc.Canc.**	**Axial**	**Artic.**	**Cranial**	**Mass**	**Burnt**
<20	1	0				0.1	0
<30	1		0	0	0	0.3	0
<40	0		0	0	0	0	0
<50	2		0	0	0	5.9	0
<60	0		0	0	0	0	0
<80	0		0	0	2	36.6	0
<100	0		0	0	0	0	0
>100	0		0	0	0	0	0
Part	0		0	0	0	0	0
Whole	0		0	0	0	0	0

Table D.7

Layer	**<20**	**<30**	**<40**	**<50**	**<60**	**<80**	**<100**	**>100**	**Part**	**Whole**
1 No.	108	128	86	23	19	9	1	2	6	11
1 (g)	65.9	206.4	238.9	60.8	93.4	47.3	7.2	28.7	60.5	49.9
1 burnt	42	82	53	12	12	4	1	1	2	4
2 No.	*213*	*233*	*128*	*66*	*33*	*37*	*10*	*10*	*12*	*74*
2 (g)	*123.4*	*283.1*	*248.8*	*200.1*	*162.7*	*212.9*	*35.4*	*75.1*	*80.3*	*361.6*
2 burnt	*93*	*138*	*59*	*33*	*14*	*17*	*5*	*0*	*8*	*21*
3 No.	73	76	24	20	16	8	6	0	0	35
3 (g)	33.7	83.3	41.4	58.4	75.9	43.9	66.2	0	0	63.2
3 burnt	21	31	15	11	4	0	1	0	0	4
4 No.	*164*	*101*	*50*	*35*	*29*	*25*	*10*	*23*	*3*	*60*
4 (g)	*70.4*	*86.4*	*61.2*	*80.1*	*94.7*	*74.8*	*36.3*	*188.6*	*62.2*	*196.8*
4 burnt	*10*	*7*	*9*	*6*	*4*	*0*	*0*	*0*	*0*	*0*
5 No.	47	25	19	10	7	10	4	6	3	34
5 (g)	25.4	25.5	26.2	24.1	33.9	26.8	19.2	36.7	34.7	114.8
5 burnt	0	0	0	0	0	0	0	0	0	0
6 No.	*8*	*5*	*4*	*0*	*1*	*2*	*1*	*2*	*0*	*4*
6 (g)	*4.0*	*7.9*	*14.5*	*0*	*2.3*	*6.0*	*2.6*	*11.1*	*0*	*3.8*
6 burnt	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*

Table D.8

Layer	**FFI Scores**						
	0	**1**	**2**	**3**	**4**	**5**	**6**
1	0	2	0	9	2	3	1
2	0	2	11	33	11	9	6
3	0	3	1	10	3	4	0
4	0	4	4	7	1	3	0
5	0	0	0	3	0	1	0
6	0	0	2	0	0	0	0

Table D.9

Black	**Number**					**Grams**	**pig + indet. shaft only**
Class	**Shaft**	**Misc.Canc.**	**Axial**	**Artic.**	**Cranial**	**Mass**	**%Burnt**
<20	1413	1975				1334.5	54.6
<30	534	84	477	53	100	1086.8	36.8
<40	113	3	68	12	16	456.5	28.3
<50	32		25	5	7	229.3	6.8
<60	13		4	0	0	84.0	7.7
<80	9		0	1	0	74.3	0
<100	0		1	0	0	20.8	0
>100	0		0	0	0	0	0
Part	0		1	2	0	24.3	33.3
Whole	0		0	27	0	87.4	18.5

Table D.10

Class	**Number**	**Mass (g)**	**Number Burnt**
<20	67	57.0	19
<30	78	135.6	25
<40	34	115.3	5
<50	6	30.4	0
<60	9	55.4	0
<80	3	34.8	0
<100	0	0	0
>100	0	0	0
Part	1	11.2	1
Whole	19	29.9	4

Table D.11

FFI Score	**Number**
0	1
1	4
2	11
3	47
4	20
5	52
6	37

APPENDIX E

UXBRIDGE DATA

Table E.1 - Fracture freshness index scores, observations of impact scars (y = yes, n = no and r = rebound scar) and element identification (where known) given by half metre squares (given as Easting and Northings) and spit depth

Table E.2 - Classification of fragments by size (small, medium or large) and type (cancellous or shaft) given by half metre squares (given as Easting and Northings) and spit depth

Table E.1

Easting	Northing	Spit	Index	Element	Impact
1425	375	3	3	mt	n
1425	375	3	3	mt	n
1425	375	3	3	mt	n
1425	375	5	3		n
1425	375	6	3	f	n
1425	425	4	5	t	n
1425	475	4	3	mc	n
1425	475	4	3	mc	n
1425	525	4	3	mt	n
1425	525	4	3	mt	n
1425	525	4	5	mt	n
1425	525	4	3	mt	n
1425	575	3	3	t	n
1425	575	3	5	t	n
1425	575	3	5	t	n
1475	425	4	0		n
1475	425	4	3	mc	n
1475	425	4	3	h	n
1475	425	5	6	mc	n
1475	475	4	3		n
1475	475	4	3	mc	n
1475	475	4	3	mc	n
1475	475	4	3	mc	n
1475	475	5	3	mc	n
1525	175	2	3	h	n
1525	225	3	4		y
1525	475	3	2		y
1525	525	2	5	h	n
1525	525	2	3	h	n
1525	525	2	4	h	n
1525	525	2	4	h	n
1525	525	3	1	t	n
1525	525	3	5		n
1525	675	3	3		n
1525	775	4	3		n
1575	275	4	4	f	n
1575	275	4	6	f	n
1575	525	2	1	h	n
1575	525	2	3	h	n
1575	525	2	6	t	n
1575	525	2	5	t	n
1575	525	3	5	h	n
1575	575	3	3		n
1575	675	3	0	h	n
1625	75	3	3	mt	n
1625	125	3	4		n
1625	175	3	3	mc	n
1625	175	3	4	f	n
1625	175	3	3	f	n
1625	175	3	3	t	n
1625	175	3	3	mt	n
1625	175	3	6	mt	n
1625	175	3	3		n
1625	175	3	3	t	n
1625	175	3	3	mc	n
1625	175	3	3	t	n
1625	175	3	3	mt	n
1625	175	4	4		n
1625	225	3	3	mt	n
1625	275	3	3	h	n
1625	275	5	5		n
1625	325	4	3		n
1625	325	5	3		n
1625	375	4	3	f	n
1625	375	4	4	mt	n

Table E.1

Easting	Northing	Spit	Index	Element	Impact
1625	375	4	3	mt	n
1625	375	5	3		n
1625	525	2	3	mt	n
1625	525	2	5		n
1625	525	3	3	h	n
1625	525	3	2		n
1625	575	2	3	t	n
1625	575	2	6		n
1625	575	3	6		n
1625	625	4	3	mt	n
1625	625	5	3		n
1625	625	5	2		n
1625	675	5	4	f	n
1625	675	5	3		n
1625	675	5	3	t	n
1625	675	5	5	f	n
1625	675	5	1	mc	n
1625	675	5	3	h	n
1625	725	5	3	t	n
1625	725	5	3	t	n
1625	725	5	2	mc	n
1625	775	5	3	t	n
1625	775	5	4		n
1625	775	5	3		n
1625	775	5	3	t	n
1675	125	3	3	f	n
1675	175	3	1	t	n
1675	175	3	3	mc	n
1675	175	3	3	mc	n
1675	175	4	6		n
1675	325	3	3	mt	n
1675	375	3	5	f	n
1675	375	4	3		n
1675	575	4	3	f	n
1675	625	4	4		n
1675	625	4	3	mt	n
1675	625	4	1	t	y
1675	625	5	2	t	n
1675	675	4	2		n
1675	675	4	3	h	n
1675	675	4	5	h	n
1675	675	4	4	t	n
1675	675	4	3	t	n
1675	675	4	3		n
1675	675	4	5		n
1675	675	4	2	mt	n
1675	725	4	4		n
1675	725	5	4		n
1675	775	4	2	r	n
1675	775	4	3	t	n
1675	775	5	2	mc	y
1675	775	5	3	t	n
1675	775	5	5		n
1675	775	5	3	t	n
1675	775	6	1	r	n
1725	25	3	5		n
1725	25	3	3		n
1725	25	3	5		n
1725	25	3	3		n
1725	25	3	5		n
1725	25	3	3		n
1725	25	5	3	mc	n
1725	75	3	5	t	n
1725	75	3	4		n
1725	75	3	5		n

Table E.1

Easting	Northing	Spit	Index	Element	Impact
1725	75	4	5		n
1725	75	4	5		n
1725	125	3	3	t	n
1725	125	3	1	h	n
1725	125	3	4		n
1725	125	3	3	h	n
1725	125	3	3		n
1725	125	3	3	t	n
1725	125	3	3	t	n
1725	125	3	2	t	n
1725	125	4	4		n
1725	125	4	2		n
1725	125	4	5		n
1725	175	3	3		n
1725	175	3	2		n
1725	175	3	1		n
1725	175	3	3		n
1725	175	3	3		n
1725	175	3	3		n
1725	175	3	3		n
1725	175	3	3		n
1725	175	3	3	h	n
1725	175	3	3	h	n
1725	175	3	3	h	n
1725	175	3	3	t	n
1725	175	3	3		n
1725	175	4	3	mt	n
1725	175	4	3	mt	n
1725	175	4	5	mc	n
1725	175	4	2	mc	n
1725	175	4	4		n
1725	175	4	3	mc	n
1725	175	4	3	f	n
1725	175	4	3	t	n
1725	175	4	3		n
1725	225	3	6	t	n
1725	225	3	2		n
1725	225	3	3	h	n
1725	225	3	5	t	n
1725	225	3	4		n
1725	225	3	3	t	n
1725	225	3	6	t	n
1725	225	4	6		n
1725	225	4	5	mt	n
1725	225	4	3	mt	n
1725	225	4	1		n
1725	225	5	5		n
1725	225	5	3		n
1725	225	5	2		n
1725	225	5	1		n
1725	225	5	3	h	n
1725	225	5	0		n
1725	275	3	2		n
1725	275	3	3	h	n
1725	275	3	3	h	n
1725	275	3	6		n
1725	275	3	3	mc	n
1725	275	3	3	mc	n
1725	275	3	3	mc	n
1725	275	4	5	u	n
1725	275	4	4		n
1725	275	4	3		n
1725	275	4	3		n
1725	275	4	2		n
1725	275	4	5		n

Table E.1

Easting	Northing	Spit	Index	Element	Impact
1725	275	5	5		n
1725	275	6	1	h	n
1725	325	2	4		n
1725	325	2	3		n
1725	325	2	3	f	n
1725	325	3	3	t	n
1725	325	3	5	mt	n
1725	325	3	3		n
1725	325	3	3		n
1725	325	3	2	mt	n
1725	325	3	3		n
1725	325	3	3	mt	n
1725	325	4	4		n
1725	325	4	3		n
1725	375	1	3		n
1725	375	2	1		n
1725	375	2	4	r	n
1725	375	2	3	r	n
1725	375	3	5		n
1725	375	3	4	f	n
1725	375	4	3		n
1725	375	4	3	mc	n
1725	525	2	5		n
1725	525	3	4		n
1725	525	3	5	t	n
1725	525	4	5	mc	n
1725	575	3	4	h	n
1725	675	4	3	r	n
1725	725	2	6	mc	n
1775	75	4	5		n
1775	125	3	4		n
1775	125	3	3		n
1775	125	3	2	t	n
1775	125	3	1	h	n
1775	175	3	4		n
1775	175	3	3	f	n
1775	175	3	3	t	n
1775	175	3	3	t	n
1775	175	3	3	t	n
1775	225	3	4	mc	n
1775	225	3	3	mc	n
1775	225	3	3		n
1775	225	4	3		n
1775	225	4	3	mc	n
1775	225	4	6	mc	n
1775	225	4	3		n
1775	225	4	2		n
1775	225	4	3		n
1775	225	4	4	f	n
1775	225	4	4		n
1775	275	3	2		n
1775	275	3	6		n
1775	275	3	3	mt	n
1775	275	3	3	t	n
1775	275	3	2	mt	n
1775	275	3	1		n
1775	275	3	3		n
1775	275	3	4		n
1775	275	3	4		n
1775	275	3	3		n
1775	275	3	5		n
1775	275	3	3		n
1775	275	3	3	mc	n
1775	275	3	3		n
1775	275	3	3		n

Table E.1

Easting	Northing	Spit	Index	Element	Impact
1775	275	3	3		n
1775	275	3	4		n
1775	275	3	4		n
1775	275	3	5		n
1775	275	3	3	mc	n
1775	275	3	5		n
1775	275	4	3		n
1775	275	4	4		n
1775	275	4	4	f	n
1775	275	4	3	mc	n
1775	325	3	3	h	n
1775	325	3	5		n
1775	325	4	2		n
1775	325	4	3		n
1775	325	4	4	h	n
1775	325	4	1		n
1775	325	4	2	h	n
1775	325	4	4	t	n
1775	325	4	3	t	n
1775	325	4	3	h	n
1775	325	6	3	f	n
1775	375	2	4		n
1775	375	2	3	h	n
1775	375	2	4	f	n
1775	375	2	3		n
1775	375	2	5		n
1775	375	2	3		n
1775	375	2	3	mt	n
1775	375	2	5		n
1775	375	3	3	t	n
1775	375	3	3	t	n
1775	375	3	5	t	n
1775	375	3	2	mc	n
1775	375	5	5		n
1775	375	5	5	h	n
1775	375	5	2		n
1775	375	6	1		n
1775	375	6	4		n
1775	475	2	2		n
1775	475	2	6	mt	n
1775	475	3	3	f	n
1775	475	3	5		n
1775	475	3	1		y
1775	475	4	3		n
1775	475	4	6		n
1775	475	4	3	t	y
1775	475	4	3	t	n
1775	525	2	5	mt	n
1775	525	2	4		n
1775	625	3	5		n
1775	625	4	2	h	y
1775	625	4	5	t	n
1775	675	4	4	mc	n
1775	725	3	3	mc	n
1775	725	3	5	mc	n
1775	775	2	5	mt	n
1775	775	2	3	mt	n
1825	25	3	3	t	n
1825	25	3	2	t	n
1825	25	3	3	mt	n
1825	25	3	3	mt	n
1825	25	3	3	mt	n
1825	25	3	3	mc	n
1825	25	4	6	t	n
1825	25	4	5		n

Table E.1

Easting	Northing	Splt	Index	Element	Impact
1825	25	4	6	t	n
1825	75	2	3	t	n
1825	75	3	4		n
1825	75	3	4		n
1825	75	3	5		n
1825	75	4	3	h	n
1825	75	4	3	h	n
1825	75	4	2	h	n
1825	125	2	5	t	n
1825	125	2	1	t	n
1825	125	2	5	t	n
1825	125	2	0	t	n
1825	125	2	3	t	n
1825	125	2	4	t	n
1825	125	2	6	t	n
1825	125	2	5		n
1825	125	2	3	t	n
1825	125	2	2	mc	n
1825	125	2	1	f	n
1825	125	3	3	f	n
1825	175	2	6	mc	n
1825	175	2	3	mt	n
1825	175	2	3	mc	n
1825	175	2	4	mc	n
1825	175	2	3	mt	n
1825	175	2	5	mt	n
1825	175	2	3	f	n
1825	175	2	6	mc	n
1825	175	2	3	f	n
1825	175	2	5	t	n
1825	175	2	1	f	n
1825	175	2	3	f	n
1825	175	2	3	mc	n
1825	175	2	3	t	n
1825	175	2	1	h	n
1825	175	2	3	h	n
1825	175	2	3	h	n
1825	175	2	3	mc	n
1825	175	2	3	f	n
1825	175	2	3	f	n
1825	175	2	3	f	n
1825	175	2	3	t	n
1825	175	2	3	f	y
1825	175	2	5	f	n
1825	175	2	5	f	n
1825	175	4	3		n
1825	175	5	4	mt	n
1825	225	2	2	mc	n
1825	225	2	6		n
1825	225	2	3	t	n
1825	225	2	4	mc	n
1825	225	2	5	t	n
1825	225	2	4	t	n
1825	225	2	0	t	n
1825	225	2	2	mt	n
1825	225	2	5	mt	n
1825	225	2	2	t	n
1825	225	2	3	mt	n
1825	225	2	3	mt	n
1825	225	2	3	f	n
1825	225	2	3	t	y
1825	225	2	3		n
1825	225	2	6	mt	n
1825	225	2	4		n
1825	225	2	5	f	n

Table E.1

Easting	Northing	Spit	Index	Element	Impact
1825	225	2	3	mt	n
1825	225	2	3		n
1825	225	2	3	mt	n
1825	225	3	1	h	n
1825	225	3	0	h	n
1825	225	3	1	h	n
1825	225	3	3	h	n
1825	225	3	1	h	n
1825	225	3	3	h	n
1825	225	3	2	h	n
1825	225	3	2	h	n
1825	225	3	3	h	n
1825	225	3	3	h	n
1825	225	3	3	h	n
1825	225	3	2	h	n
1825	225	3	2	h	n
1825	225	3	1	h	n
1825	225	3	3	h	n
1825	225	3	5	h	n
1825	225	3	4	t	n
1825	225	3	0	h	n
1825	225	3	5	h	n
1825	225	3	1	h	n
1825	225	3	2	f	n
1825	225	3	3	f	n
1825	225	3	5	h	n
1825	225	3	6	h	n
1825	275	2	5	h	n
1825	275	2	3	h	n
1825	275	2	3	h	n
1825	275	2	5	h	n
1825	275	2	3	h	n
1825	275	2	2	f	n
1825	275	2	5	f	n
1825	275	2	4	f	n
1825	275	2	4	f	n
1825	275	2	1	r	n
1825	275	2	3	r	n
1825	275	2	4	h	n
1825	275	2	3	h	n
1825	275	2	4	f	n
1825	275	2	4	t	n
1825	275	2	3		n
1825	275	2	3	t	n
1825	275	2	3	h	r
1825	275	2	0		n
1825	275	2	3	t	n
1825	275	2	3		n
1825	275	2	3		n
1825	275	2	3		n
1825	275	3	1		n
1825	275	4	5	f	n
1825	275	4	6	f	n
1825	325	2	3	mc	n
1825	325	2	1	h	n
1825	325	3	3	t	n
1825	325	3	6		n
1825	325	3	2		n
1825	325	3	2	mt	n
1825	325	4	3	mt	n
1825	325	4	3	mt	n
1825	325	4	0	mt	n
1825	375	2	5		n
1825	375	2	5		n
1825	375	3	3		n

Table E.1

Easting	Northing	Spit	Index	Element	Impact
1875	25	3	5		n
1875	25	4	3	mt	n
1875	25	4	5	mt	n
1875	25	4	2	f	y
1875	25	5	3	t	n
1875	75	3	3	t	n
1875	75	4	5	f	n
1875	75	4	3		n
1875	75	4	3	h	n
1875	75	4	6	mc	n
1875	75	5	5	h	n
1875	75	5	4	h	n
1875	75	5	3	h	n
1875	125	2	6		n
1875	125	2	1	t	n
1875	125	2	4		n
1875	125	2	5		n
1875	125	2	5	f	n
1875	125	2	3		n
1875	125	2	3		n
1875	125	2	3		n
1875	125	2	3		n
1875	125	2	5	mt	n
1875	125	2	4		n
1875	125	4	3	mc	n
1875	125	5	3		n
1875	175	2	2	mt	n
1875	175	2	3		n
1875	175	2	4	mt	n
1875	175	2	3	mt	n
1875	175	3	1	h	n
1875	175	5	3		n
1875	175	6	2	h	n
1875	225	2	3		n
1875	225	2	3	f	n
1875	225	2	5		n
1875	225	2	5		n
1875	225	2	3		n
1875	225	2	3		n
1875	225	2	5		n
1875	225	2	5		n
1875	225	2	2	mc	n
1875	225	2	0	h	n
1875	225	2	1	h	n
1875	225	2	2	h	n
1875	225	2	3	u	n
1875	225	2	3	mc	n
1875	225	2	5	mc	n
1875	225	2	6	mc	n
1875	225	2	3	mc	n
1875	225	2	3		n
1875	225	2	3	mc	n
1875	225	2	5	mc	n
1875	225	2	3	mc	n
1875	225	2	3	mc	n
1875	225	2	3	mc	n
1875	225	2	1		n
1875	225	2	3	f	n
1875	225	2	1		n
1875	225	2	2	mc	n
1875	225	2	6	mt	n
1875	225	2	3	mc	n
1875	225	2	5	mt	n
1875	225	2	3	t	n
1875	225	3	3	t	n

Table E.1

Easting	Northing	Spit	Index	Element	Impact
1875	225	3	3	t	n
1875	225	3	3	h	n
1875	225	3	3	h	y
1875	225	3	3	h	n
1875	275	2	3		n
1875	275	2	1		n
1875	275	2	3		n
1875	275	2	5		n
1875	275	2	2	h	n
1875	275	2	1	t	n
1875	275	2	6		n
1875	275	2	4	mc	n
1875	275	2	6	t	n
1875	275	2	4	t	n
1875	275	2	4		n
1875	275	2	0	h	n
1875	275	2	3	mc	n
1875	275	2	3	f	n
1875	275	2	3	f	n
1875	275	2	3	h	n
1875	275	2	3		n
1875	275	2	3		n
1875	275	2	3		n
1875	275	2	3		n
1875	275	2	2	mc	n
1875	275	2	2	h	n
1875	275	2	3	f	n
1875	275	2	5	mt	n
1875	275	2	6	mt	n
1875	275	2	5	mt	n
1875	275	2	3	mt	n
1875	275	3	3	t	n
1875	325	2	3	t	n
1875	325	2	3		n
1875	325	3	4	mc	n
1875	325	4	3		n
1875	325	4	3		n
1875	375	2	1		n
1875	375	2	3		n
1875	375	3	3	h	n
1875	425	3	3	t	n
1875	475	3	2	t	n
1875	775	3	1	t	n
1925	25	3	3		n
1925	25	3	4		n
1925	25	3	5	t	n
1925	25	4	5	h	n
1925	25	4	5		n
1925	25	4	2	h	n
1925	25	4	5	h	n
1925	125	3	0	h	n
1925	125	3	3	f	n
1925	125	3	6	mc	n
1925	125	3	3	mc	n
1925	125	3	5		n
1925	125	3	4	t	n
1925	125	3	5	mc	n
1925	125	3	4		n
1925	125	3	4	t	n
1925	125	3	3		n
1925	125	3	3	t	n
1925	125	3	5		n
1925	125	3	3	h	n
1925	125	3	3	mc	n
1925	125	3	4	t	n

Table E.1

Easting	Northing	Spit	Index	Element	Impact
1925	125	3	3	mc	n
1925	125	3	4		n
1925	125	3	3	mc	n
1925	125	3	5	mc	n
1925	125	3	3	t	n
1925	125	3	0	t	n
1925	125	3	3	t	n
1925	125	3	3	t	n
1925	125	3	3		n
1925	125	3	3	mc	n
1925	175	3	3	t	n
1925	175	3	3	t	n
1925	175	3	2	t	n
1925	175	3	3	t	y
1925	175	4	0	t	y
1925	175	4	3	mc	n
1925	225	3	3	h	n
1925	225	3	3	mt	n
1925	225	3	3	mt	n
1925	225	3	5		n
1925	225	3	3	f	n
1925	225	3	4	h	n
1925	225	3	2	mt	n
1925	225	3	5	mt	n
1925	225	3	3	mt	n
1925	225	3	5	mt	n
1925	225	3	3	f	n
1925	225	3	3	h	n
1925	225	4	1	h	n
1925	225	4	3	t	n
1925	225	4	5	t	n
1925	225	5	4		n
1925	275	3	3	f	n
1925	275	3	3		n
1925	275	3	5		n
1925	275	3	3	f	n
1925	275	3	5	h	n
1925	275	3	4	h	n
1925	275	3	5		n
1925	275	4	3	f	n
1925	275	4	1	mt	n
1925	275	4	3	f	n
1925	275	4	2		n
1925	275	4	3	f	n
1925	325	3	5		n
1925	375	3	3		n
1925	675	1	5		n
1975	25	4	5		n
1975	25	5	6		n
1975	25	5	4	mc	n
1975	75	5	3		n
1975	125	3	2	t	n
1975	125	3	5		n
1975	125	3	4		n
1975	125	4	0	h	n
1975	125	4	0	h	n
1975	125	5	3	f	n
1975	175	4	4	h	n
1975	175	4	2	t	n
1975	225	2	2	mc	n
1975	225	3	3	t	n
1975	225	3	3		n
1975	225	3	3	f	n
1975	225	3	2		n
1975	225	3	5	mt	n

Table E.1

Easting	Northing	Spit	Index	Element	Impact
1975	225	3	3	f	n
1975	225	3	3	t	n
1975	225	3	3		n
1975	225	3	2	t	n
1975	225	3	6		n
1975	225	3	1	h	n
1975	225	3	6	t	n
1975	225	3	3	t	n
1975	225	3	2	h	n
1975	225	3	2	mc	n
1975	225	3	3	f	n
1975	225	3	3	t	n
1975	225	3	2	t	n
1975	225	4	2	mc	n
1975	225	4	6		n
1975	225	4	3	h	n
1975	225	4	2	t	n
1975	225	4	2	mc	n
1975	225	4	4	f	n
1975	225	4	4	f	n
1975	225	4	3	f	n
1975	225	4	3	mt	n
1975	225	4	3	f	n
1975	225	4	3	mt	n
1975	275	3	5		n
1975	275	3	4		n
1975	275	3	3	mt	n
1975	275	3	5	f	n
1975	275	3	4		n
1975	275	3	3	mt	n
1975	275	4	4		n
1975	275	4	5	mt	n
1975	275	4	4		n
1975	275	4	4		n
1975	275	4	4	mc	n
1975	275	4	3	h	n
1975	275	4	5		n
1975	275	5	4		n
1975	325	2	6		n
1975	325	3	5		n
1975	325	3	3	mc	n
1975	325	3	3	t	n
1975	325	4	3		n
1975	375	3	3	mc	n
1975	375	3	4	mc	n
1975	375	3	4	mc	n
1975	375	3	2	f	n
1975	375	4	5	mc	n
1975	475	4	2	h	n
2025	25	3	5	mc	n
2025	25	4	6	mt	n
2025	75	3	3		n
2025	75	3	6		n
2025	175	3	3	mt	n
2025	225	3	4	t	n
2025	225	3	1	r	n
2025	225	3	2	r	n
2025	225	3	3	r	n
2025	225	3	3	r	n
2025	225	3	3	mc	n
2025	225	3	3	t	n
2025	225	3	3	t	n
2025	225	3	2	t	n
2025	225	3	1	h	n
2025	225	3	5	h	n

Table E.1

Easting	Northing	Spit	Index	Element	Impact
2025	225	3	0	h	y
2025	225	4	3	mt	n
2025	225	4	3	mc	n
2025	275	3	1		n
2025	275	3	3	mc	n
2025	275	3	3	mc	n
2025	275	4	5	mc	n
2025	275	4	3		n
2025	275	4	2	t	n
2025	275	5	5		n
2025	375	2	2		n
2025	375	2	4		n
2025	375	2	3	t	n
2025	375	2	3		n
2025	375	3	3		n
2025	375	3	2	t	n
2025	375	4	3		n
2025	575	3	6	f	n
2025	575	3	4	f	n
2025	775	2	4		n
2075	25	3	3		n
2075	25	4	3	r	n
2075	25	4	2	t	n
2075	75	3	2	t	n
2075	75	3	5	t	n
2075	75	4	6	r	n
2075	125	3	3	h	n
2075	125	3	4	t	n
2075	125	4	3	mt	n
2075	125	5	3	mc	n
2075	125	5	3		n
2075	175	3	3	h	n
2075	175	4	3	mc	n
2075	175	8	2	t	n
2075	225	3	3	mc	n
2075	225	3	3	mc	n
2075	225	3	5	mc	n
2075	225	3	3	mc	n
2075	225	3	1		y
2075	225	3	2		n
2075	225	3	6	mc	n
2075	225	3	3	t	n
2075	225	3	4	mc	n
2075	225	4	5	h	n
2075	225	4	3	h	n
2075	225	4	3		n
2075	225	4	3	t	n
2075	225	4	0	mt	n
2075	225	4	4		n
2075	225	4	3	mc	n
2075	275	4	4	h	n
2075	275	4	3	h	n
2075	325	3	3	mt	n
2075	325	4	4		n
2075	375	2	4	mc	n
2075	375	2	3		n
2075	375	3	1		n
2075	375	4	4		n
2075	475	3	4		n
2075	475	4	4		n
2125	25	2	2		n
2125	225	3	3		n
2125	225	3	5		n
2125	225	3	4		n
2125	225	3	0	mc	n

Table E.1

Easting	Northing	Spit	Index	Element	Impact
2125	225	3	3	h	n
2125	225	3	3	h	n
2125	225	4	3	h	n
2125	275	3	5		n
2125	275	3	3	mc	n
2125	325	3	1	mc	n
2125	325	3	4		n
2125	375	3	3	mc	n
2125	425	3	4		n
2125	425	3	3		n
2125	425	3	3	mc	n
2125	425	4	3		n
2125	425	4	5		n
2125	425	4	3		n
2125	425	4	4		n
2125	475	4	3		n
2125	725	1	2	t	n
2175	75	3	2	mt	n
2175	125	3	3		n
2175	125	3	3		n
2175	225	3	2		n
2175	225	3	3		n
2175	325	3	4	mt	n
2175	325	3	3	f	n
2175	325	3	3	mt	n
2175	325	3	3		n
2175	325	3	4		n
2175	325	5	5		n
2175	375	3	4		n
2175	425	3	4		n
2175	475	4	3		n
2175	475	4	3		n
2175	525	6	4		n
2175	675	3	3		n
2175	675	3	6		n
2225	225	5	3		n
2225	425	3	5	t	n
2225	425	4	4		n
2275	125	3	3	mt	n
2275	125	3	4	mt	n
2275	125	3	3	t	n
2275	125	3	3	mt	n
2275	125	4	5	f	n
2275	125	4	4	f	n
2275	225	3	2		n
2275	225	4	4		n
2275	275	3	5		n
2275	275	4	2	f	n
2275	325	5	6		n
2275	375	3	3		n
2275	475	3	3		n
2275	525	4	4	h	n
2275	525	4	3	h	n
2325	25	2	3	h	n
2325	25	2	3	h	n
2325	125	4	0	h	n
2325	125	4	2	h	n
2325	125	4	3		n
2325	225	5	1	h	n
2325	325	5	1		n
2325	375	4	5	h	n
2325	375	5	2	h	y
2375	75	3	3	h	n
2375	325	3	2	t	n
2375	525	3	3		n

Table E.1

Easting	Northing	Spit	Index	Element	Impact
2425	25	4	4		n
2425	75	4	2		n
2425	325	2	3		n
2425	375	2	3	mc	n
2475	375	2	2	mc	n
2475	375	2	5	mc	n
2475	425	3	6		n

Table E.2

Easting	Northing	Spit	Small Shaft	Medium Shaft	Large Shaft	Small Canc	Medium Canc	Large Canc
1325	475	3	10	2	0	0	0	0
1375	475	3	0	1	0	1	0	0
1425	25	3	2	0	0	0	0	0
1425	75	3	0	1	0	0	0	0
1425	275	3	0	1	0	0	0	0
1425	325	3	11	2	0	0	0	0
1425	375	3	2	0	0	0	0	0
1425	375	3	0	0	1	0	0	2
1425	375	4	0	4	0	0	0	0
1425	375	5	0	1	0	0	0	0
1425	375	6	0	0	0	0	1	0
1425	375	6	0	0	1	0	0	0
1425	425	3	8	1	0	0	1	0
1425	425	4	0	0	0	0	1	0
1425	425	4	0	6	0	0	0	0
1425	425	4	0	0	1	0	0	0
1425	475	3	16	1	0	0	0	0
1425	475	4	0	1	0	0	0	0
1425	475	4	1	4	2	0	0	0
1425	525	3	10	0	0	0	0	0
1425	525	4	0	1	1	0	1	0
1425	525	4	8	3	2	0	0	0
1425	575	3	11	1	0	0	0	0
1425	575	3	0	1	1	0	0	1
1425	575	4	40	2	0	0	0	0
1475	425	3	2	5	0	0	1	0
1475	425	4	0	0	0	2	2	0
1475	425	4	5	0	2	2	1	0
1475	425	4	0	0	1	0	0	0
1475	425	4	0	2	1	7	7	1
1475	425	5	0	0	0	0	1	0
1475	425	5	5	2	0	0	0	0
1475	475	3	2	2	0	0	0	0
1475	475	4	1	3	0	0	0	0
1475	475	4	0	0	0	0	0	1
1475	475	4	1	0	1	0	0	0
1475	475	4	0	2	1	0	0	0
1475	475	4	0	1	0	0	0	0
1475	475	4	0	0	0	3	1	1
1475	475	4	0	6	3	0	0	0
1475	475	5	0	3	0	1	3	0
1475	475	5	25	6	0	15	1	0
1475	475	6	0	1	0	0	1	0
1475	525	3	10	2	0	0	0	0
1475	525	4	9	1	0	3	0	0
1475	575	3	22	6	0	0	0	0
1475	575	3	0	0	0	0	0	1
1475	575	4	48	6	0	0	0	0
1475	575	4	0	0	0	3	5	1
1475	575	5	1	1	0	0	1	0
1525	75	3	4	2	0	0	0	0
1525	175	2	2	3	0	2	6	2
1525	225	1	1	0	0	0	0	0
1525	225	1	3	0	0	0	0	0
1525	225	2	12	3	0	0	0	0
1525	225	3	17	3	0	0	0	0
1525	225	3	0	1	1	0	0	0
1525	225	3	0	0	1	0	0	0
1525	225	3	0	0	0	0	2	0
1525	275	2	11	6	0	2	0	0
1525	425	2	7	0	0	0	0	0
1525	425	2	1	0	0	2	2	0
1525	475	2	7	1	0	0	0	0
1525	475	3	1	3	0	2	0	0
1525	525	2	0	3	1	0	0	0

Table E.2

Easting	Northing	Spit	Small Shaft	Medium Shaft	Large Shaft	Small Canc	Medium Canc	Large Canc
1525	525	2	0	2	0	2	2	1
1525	525	3	0	1	0	0	0	0
1525	525	3	1	4	0	2	2	1
1525	525	3	0	3	0	0	0	0
1525	525	3	0	0	0	0	2	1
1525	525	4	0	1	0	0	0	0
1525	575	3	0	1	0	0	0	0
1525	575	3	0	0	0	0	1	0
1525	575	3	0	0	0	1	5	0
1525	625	3	0	0	0	0	0	1
1525	625	3	0	3	0	0	0	0
1525	625	4	0	1	0	0	0	0
1525	675	3	0	1	0	0	0	0
1525	675	4	0	1	0	0	0	0
1525	725	4	4	1	0	1	0	0
1525	775	3	0	0	0	0	1	0
1525	775	4	4	3	0	0	0	0
1575	75	3	8	2	0	0	0	0
1575	175	2	0	0	0	0	1	0
1575	175	2	0	1	0	0	0	0
1575	225	2	2	2	0	1	0	0
1575	225	3	8	0	0	0	0	0
1575	275	1	4	0	0	0	0	0
1575	275	2	6	1	0	0	0	0
1575	275	3	8	3	0	0	0	0
1575	275	4	1	2	1	0	0	0
1575	325	1	1	0	0	0	0	0
1575	375	1	8	1	0	0	0	0
1575	375	2	0	4	0	0	0	0
1575	425	3	4	4	0	0	0	0
1575	475	2	2	0	0	0	0	0
1575	525	2	2	2	2	0	1	1
1575	525	2	0	0	0	0	1	0
1575	525	2	0	0	1	0	0	0
1575	525	2	1	0	1	0	0	1
1575	525	3	0	1	0	0	0	0
1575	525	3	0	1	0	0	0	0
1575	575	3	0	1	0	0	0	0
1575	625	3	1	0	2	23	3	1
1575	625	3	3	1	0	0	0	0
1575	625	4	2	0	0	0	0	0
1575	675	3	0	0	0	0	0	1
1575	675	4	0	2	0	0	0	0
1575	675	4	4	1	0	0	0	0
1575	675	6	2	2	0	0	0	0
1575	725	3	0	0	0	1	0	0
1575	725	4	1	0	0	0	0	0
1575	775	3	0	0	0	3	3	0
1575	775	4	0	1	0	1	0	0
1625	25	3	1	0	0	0	0	0
1625	25	4	1	0	0	0	0	0
1625	75	3	2	0	0	0	0	0
1625	75	3	22	3	0	1	0	0
1625	75	3	0	0	1	0	0	0
1625	75	3	1	1	0	2	1	2
1625	75	4	4	0	0	0	0	0
1625	75	5	1	0	0	0	0	0
1625	125	3	17	6	0	0	0	0
1625	125	3	3	1	0	0	0	0
1625	125	3	0	0	1	0	0	0
1625	125	3	13	1	0	0	0	0
1625	125	4	4	0	0	0	0	0
1625	175	3	0	0	2	0	0	0
1625	175	3	1	1	1	0	0	0
1625	175	3	11	5	0	0	0	0

Table E.2

Easting	Northing	Spit	Small Shaft	Medium Shaft	Large Shaft	Small Canc	Medium Canc	Large Canc
1625	175	3	8	1	0	0	0	0
1625	175	3	1	1	0	0	0	0
1625	175	3	2	0	2	0	0	0
1625	175	3	3	1	0	0	0	0
1625	175	3	0	1	1	0	0	0
1625	175	3	0	1	1	0	0	2
1625	175	3	0	1	1	0	0	0
1625	175	4	1	7	0	0	0	0
1625	225	1	0	1	0	0	0	0
1625	225	2	1	1	0	0	0	0
1625	225	3	18	11	0	0	0	0
1625	225	3	10	4	0	0	0	0
1625	225	3	0	0	0	0	0	1
1625	225	4	1	1	1	0	0	0
1625	225	4	9	2	0	0	0	0
1625	275	1	1	0	0	0	0	0
1625	275	3	2	0	0	0	0	0
1625	275	3	22	8	0	0	0	0
1625	275	3	0	1	0	0	0	0
1625	275	4	23	9	0	0	1	0
1625	275	4	13	2	0	1	0	0
1625	275	4	0	0	0	0	1	0
1625	275	5	0	2	0	0	0	0
1625	325	3	3	0	0	0	0	0
1625	325	4	3	3	0	0	0	0
1625	325	4	1	0	0	0	0	0
1625	325	5	4	2	0	0	0	0
1625	325	5	0	1	0	0	0	0
1625	375	2	1	3	0	0	0	0
1625	375	3	4	3	0	0	0	0
1625	375	4	0	0	1	0	0	0
1625	375	4	12	8	0	1	0	0
1625	375	5	15	3	1	0	0	0
1625	375	6	3	1	0	0	0	0
1625	425	1	0	3	0	0	0	0
1625	475	1	1	4	0	0	0	0
1625	525	2	8	3	1	0	0	0
1625	525	2	0	0	0	0	0	1
1625	525	2	0	0	1	0	0	0
1625	525	3	13	2	0	0	0	0
1625	525	3	0	0	1	0	0	0
1625	525	4	0	1	0	0	0	0
1625	575	1	10	5	0	1	0	0
1625	575	2	0	1	1	0	0	0
1625	575	2	0	0	0	0	0	1
1625	575	3	4	5	0	0	0	0
1625	575	4	9	4	0	0	0	0
1625	625	4	8	4	1	0	0	0
1625	625	5	0	1	0	0	0	0
1625	625	5	0	0	1	0	0	0
1625	675	4	10	5	0	0	0	0
1625	675	5	0	0	1	0	0	0
1625	675	5	0	1	2	0	0	0
1625	675	5	0	0	1	0	0	0
1625	675	5	1	0	1	0	0	0
1625	725	3	7	0	0	0	0	0
1625	725	4	4	1	0	0	0	0
1625	725	4	20	0	0	3	0	0
1625	725	4	5	0	0	0	0	0
1625	725	5	0	1	0	0	0	0
1625	725	5	0	1	1	0	0	0
1625	725	5	30	0	0	2	0	0
1625	725	5	0	1	0	0	0	0
1625	725	6	0	0	0	1	0	0
1625	775	1	0	1	0	0	0	0

Table E.2

Easting	Northing	Spit	Small Shaft	Medium Shaft	Large Shaft	Small Canc	Medium Canc	Large Canc
1625	775	4	0	1	0	0	0	0
1625	775	4	8	1	0	1	0	0
1625	775	5	10	1	0	1	0	0
1625	775	5	0	1	1	0	0	0
1625	775	5	0	0	2	0	0	0
1625	775	6	3	0	0	2	0	0
1625	1525	3	0	0	0	2	0	0
1675	25	3	4	3	0	0	0	0
1675	25	4	3	0	0	0	0	0
1675	75	3	12	0	0	2	0	0
1675	75	3	0	1	0	0	0	0
1675	75	4	6	1	0	0	0	0
1675	75	5	0	1	0	0	0	0
1675	125	3	0	2	1	0	0	0
1675	125	3	1	0	0	0	1	0
1675	125	3	7	1	0	0	0	0
1675	125	4	5	4	0	0	0	0
1675	175	3	0	0	1	0	0	0
1675	175	3	6	1	0	0	0	0
1675	175	3	10	9	1	9	0	0
1675	175	3	0	0	0	0	1	0
1675	175	4	5	2	0	0	0	0
1675	225	1	1	0	0	0	0	0
1675	225	2	2	1	0	1	0	0
1675	225	3	33	4	0	0	0	0
1675	225	3	2	1	0	0	0	0
1675	225	4	2	1	0	0	0	0
1675	225	4	2	0	0	0	0	0
1675	275	1	2	0	0	0	0	0
1675	275	3	0	0	0	0	1	0
1675	275	3	0	0	0	1	1	0
1675	275	3	56	6	0	0	0	0
1675	275	4	7	5	0	0	0	0
1675	275	4	0	2	0	0	0	0
1675	325	2	0	1	0	0	0	0
1675	325	3	22	3	0	0	0	0
1675	325	3	0	1	1	0	0	0
1675	325	4	2	0	0	0	0	0
1675	325	4	19	6	0	0	0	0
1675	325	5	7	2	0	1	0	0
1675	375	2	1	1	0	0	0	0
1675	375	3	3	0	0	0	0	0
1675	375	3	16	9	0	0	0	0
1675	375	4	0	1	0	0	0	0
1675	375	4	34	11	0	0	0	0
1675	375	4	0	1	0	0	0	0
1675	375	5	6	2	0	0	0	0
1675	375	5	2	4	0	3	0	0
1675	375	6	6	0	0	0	0	0
1675	375	6	4	4	0	0	0	0
1675	525	2	2	5	0	0	0	0
1675	525	3	3	2	0	0	0	0
1675	575	2	4	0	0	0	0	0
1675	575	2	1	7	0	0	1	0
1675	575	3	2	4	0	0	0	0
1675	575	4	0	0	1	0	0	0
1675	625	4	4	3	0	0	0	0
1675	625	4	0	0	1	0	0	0
1675	625	4	0	0	1	0	0	0
1675	625	5	8	3	0	1	0	0
1675	625	5	0	0	0	0	1	0
1675	675	4	0	0	0	0	0	1
1675	675	4	1	2	2	0	0	0
1675	675	4	0	1	0	0	0	0
1675	675	4	1	0	2	0	0	0

Table E.2

Easting	Northing	Spit	Small Shaft	Medium Shaft	Large Shaft	Small Canc	Medium Canc	Large Canc
1675	675	4	0	0	1	0	0	0
1675	675	4	0	0	1	0	0	0
1675	675	4	19	10	0	2	0	0
1675	675	5	0	0	1	0	0	0
1675	675	5	0	1	0	0	0	0
1675	725	1	0	1	0	0	0	0
1675	725	4	1	0	0	0	0	0
1675	725	4	3	3	0	4	2	0
1675	725	4	1	1	1	0	0	0
1675	725	5	4	2	1	3	0	0
1675	725	5	3	3	0	0	0	0
1675	725	6	1	0	0	0	0	0
1675	775	3	0	2	0	0	0	0
1675	775	3	0	1	0	0	0	0
1675	775	3	2	2	0	4	0	0
1675	775	4	1	1	0	0	0	0
1675	775	4	20	3	0	3	0	0
1675	775	4	0	1	0	0	0	0
1675	775	4	0	1	0	0	0	0
1675	775	4	2	0	1	0	0	0
1675	775	4	1	0	0	0	0	0
1675	775	5	1	1	1	0	0	0
1675	775	5	6	1	0	2	0	0
1675	775	5	0	0	1	0	0	0
1675	775	6	4	0	0	2	0	0
1675	775	6	0	0	1	0	0	0
1675	775	6	2	1	1	0	0	0
1725	25	3	20	6	0	1	0	0
1725	25	4	0	0	1	0	0	0
1725	25	5	0	1	0	0	0	0
1725	25	5	1	0	0	0	0	0
1725	75	3	0	2	0	0	0	0
1725	75	3	0	1	2	0	0	0
1725	75	4	4	5	0	0	0	0
1725	75	5	4	1	0	0	0	0
1725	125	3	0	0	0	0	0	1
1725	125	3	0	0	0	0	6	1
1725	125	3	0	0	1	0	0	0
1725	125	3	0	1	1	0	0	0
1725	125	3	0	0	0	0	0	1
1725	125	3	0	0	1	0	0	0
1725	125	3	4	5	0	0	0	0
1725	125	3	7	7	0	0	0	0
1725	125	3	61	10	0	0	0	0
1725	125	4	0	0	0	0	0	1
1725	125	4	0	1	0	0	0	0
1725	125	4	0	1	2	0	0	0
1725	175	0	0	0	0	0	0	1
1725	175	3	0	1	0	0	0	1
1725	175	3	0	1	1	0	0	0
1725	175	3	0	0	1	0	0	0
1725	175	3	0	3	1	0	0	0
1725	175	3	0	0	0	0	1	0
1725	175	3	20	14	0	0	0	0
1725	175	3	12	22	0	2	0	0
1725	175	3	0	4	2	0	0	0
1725	175	3	5	5	0	0	0	0
1725	175	4	2	1	0	0	0	0
1725	175	4	0	1	0	0	0	0
1725	175	4	0	1	0	0	0	0
1725	175	4	49	13	0	2	0	0
1725	175	4	0	0	1	0	0	0
1725	175	4	0	0	1	0	0	0
1725	175	4	1	0	1	0	0	0
1725	175	4	16	10	0	0	0	0

Table E.2

Easting	Northing	Spit	Small Shaft	Medium Shaft	Large Shaft	Small Canc	Medium Canc	Large Canc
1725	175	4	0	4	2	0	0	0
1725	225	2	14	1	0	0	0	0
1725	225	3	0	1	0	0	0	0
1725	225	3	0	1	0	0	0	0
1725	225	3	0	1	0	0	0	0
1725	225	3	38	25	0	1	0	0
1725	225	3	1	6	0	0	0	0
1725	225	3	16	9	0	0	0	0
1725	225	3	8	1	0	0	0	0
1725	225	4	0	2	0	0	0	0
1725	225	4	0	0	0	0	2	0
1725	225	4	0	0	0	0	0	1
1725	225	4	5	13	1	0	0	0
1725	225	4	3	11	0	0	0	0
1725	225	5	0	0	1	0	0	0
1725	225	5	0	0	0	0	1	0
1725	225	5	3	13	0	3	2	0
1725	225	5	0	6	1	0	0	0
1725	225	5	0	1	0	0	0	0
1725	225	6	1	3	0	0	0	0
1725	275	2	7	0	0	0	0	0
1725	275	3	31	11	0	0	0	0
1725	275	3	0	0	0	0	1	0
1725	275	3	0	1	0	0	0	0
1725	275	3	0	1	0	0	0	0
1725	275	3	1	0	1	0	0	0
1725	275	3	1	1	0	0	0	0
1725	275	3	1	1	1	0	0	0
1725	275	4	0	0	1	0	0	0
1725	275	4	1	1	0	0	0	0
1725	275	4	12	7	0	0	0	0
1725	275	4	0	0	1	0	0	0
1725	275	4	20	13	0	0	0	0
1725	275	4	0	1	1	0	0	0
1725	275	5	0	1	0	0	0	0
1725	275	6	0	0	1	0	0	0
1725	325	2	0	0	1	0	0	0
1725	325	2	5	5	0	0	0	0
1725	325	3	4	20	1	0	0	0
1725	325	3	0	0	1	0	0	0
1725	325	3	0	2	1	0	0	0
1725	325	3	11	1	0	1	0	0
1725	325	4	0	0	1	0	0	0
1725	325	4	0	1	1	0	0	0
1725	325	4	19	6	0	0	0	0
1725	325	5	0	0	0	1	2	0
1725	325	5	4	0	0	0	0	0
1725	375	1	1	2	0	0	0	0
1725	375	1	4	0	0	0	0	0
1725	375	2	0	3	0	0	0	0
1725	375	2	0	0	3	0	0	0
1725	375	2	21	2	0	0	0	0
1725	375	3	0	1	0	0	0	0
1725	375	3	1	2	0	0	0	0
1725	375	3	15	3	0	0	0	0
1725	375	3	0	3	0	0	0	0
1725	375	4	0	1	0	0	0	0
1725	375	4	5	2	0	0	0	0
1725	375	5	0	2	0	0	0	0
1725	475	1	4	0	0	0	0	0
1725	525	1	3	2	0	0	0	0
1725	525	2	1	2	0	0	0	0
1725	525	2	36	4	0	1	0	0
1725	525	3	0	1	2	0	0	0
1725	525	3	2	3	1	0	2	1

Table E.2

Easting	Northing	Spit	Small Shaft	Medium Shaft	Large Shaft	Small Canc	Medium Canc	Large Canc
1725	525	3	2	3	1	0	0	0
1725	525	4	0	0	1	0	0	0
1725	525	4	0	1	0	0	0	0
1725	525	5	0	2	0	0	0	0
1725	575	1	4	1	0	2	0	0
1725	575	1	0	1	0	0	0	0
1725	575	2	11	3	0	0	0	0
1725	575	3	20	0	0	5	0	0
1725	575	3	2	1	1	0	0	0
1725	575	3	0	4	0	0	0	0
1725	625	3	2	4	0	0	0	0
1725	625	4	3	0	0	1	0	0
1725	675	3	12	5	0	3	3	0
1725	675	4	0	0	1	0	0	0
1725	725	2	15	3	0	1	0	0
1725	725	2	1	2	0	0	0	0
1725	775	2	0	0	0	0	1	0
1775	25	3	39	3	0	0	0	0
1775	25	3	4	4	3	0	0	0
1775	75	3	5	2	0	1	0	0
1775	75	3	8	7	0	0	0	0
1775	75	4	14	3	0	4	0	0
1775	75	5	4	1	0	0	0	0
1775	75	5	6	0	0	0	1	0
1775	75	6	1	0	0	0	1	0
1775	125	3	0	3	2	1	0	0
1775	125	3	0	0	1	0	0	0
1775	125	3	0	0	0	4	1	0
1775	125	3	11	6	0	6	2	0
1775	125	3	0	1	1	0	0	0
1775	125	3	8	5	0	5	0	0
1775	125	3	6	10	0	1	0	0
1775	125	4	0	1	0	0	0	0
1775	175	3	23	11	1	0	0	0
1775	175	3	0	1	2	0	0	0
1775	175	3	0	0	1	0	0	0
1775	175	3	9	11	0	0	0	0
1775	175	3	4	3	0	0	0	0
1775	225	0	0	1	1	0	0	0
1775	225	3	4	3	0	0	0	0
1775	225	3	0	0	1	0	0	0
1775	225	4	0	1	0	0	0	0
1775	225	4	1	1	0	0	0	0
1775	225	4	8	8	3	0	0	0
1775	225	4	13	9	0	0	0	0
1775	225	5	1	0	0	0	0	0
1775	275	3	12	0	0	6	3	0
1775	275	3	0	6	0	0	0	0
1775	275	3	0	0	0	0	0	1
1775	275	3	0	0	0	0	0	1
1775	275	3	0	1	1	0	0	0
1775	275	3	0	0	1	0	0	0
1775	275	3	0	0	1	0	0	0
1775	275	3	7	2	0	0	0	0
1775	275	3	0	2	0	0	0	0
1775	275	3	1	3	4	0	0	0
1775	275	3	3	0	0	1	0	0
1775	275	3	121	48	0	3	0	0
1775	275	4	0	1	0	0	0	0
1775	275	4	0	0	1	0	0	0
1775	275	4	0	1	0	0	0	0
1775	275	4	0	1	0	0	0	0
1775	275	4	0	2	0	0	0	0
1775	275	4	9	4	1	0	0	0
1775	275	5	5	1	0	0	0	0

Table E.2

Easting	Northing	Spit	Small Shaft	Medium Shaft	Large Shaft	Small Canc	Medium Canc	Large Canc
1775	275	5	2	0	0	0	0	0
1775	275	6	2	3	0	0	0	0
1775	325	1	0	2	0	0	0	0
1775	325	2	4	5	0	0	0	0
1775	325	2	0	2	0	0	0	0
1775	325	3	5	8	0	0	0	0
1775	325	3	0	1	0	0	0	0
1775	325	3	0	1	0	0	0	0
1775	325	3	0	1	0	0	0	0
1775	325	4	17	18	0	0	1	0
1775	325	4	0	2	1	0	0	0
1775	325	4	3	3	0	1	1	1
1775	325	4	6	2	0	0	0	0
1775	325	4	0	0	3	0	0	0
1775	325	5	10	7	0	0	0	0
1775	325	6	0	1	0	0	0	0
1775	325	6	14	1	0	0	0	0
1775	375	1	0	2	0	0	0	0
1775	375	2	0	0	1	0	0	0
1775	375	2	0	0	1	0	0	0
1775	375	2	1	1	0	0	0	0
1775	375	2	24	15	0	0	1	0
1775	375	2	0	5	3	0	0	0
1775	375	2	2	0	0	0	0	0
1775	375	2	12	5	0	0	0	0
1775	375	3	0	0	1	0	0	0
1775	375	3	5	10	0	0	0	0
1775	375	3	3	0	0	0	0	0
1775	375	4	1	1	0	0	0	0
1775	375	5	5	1	0	0	0	0
1775	375	5	0	0	1	0	0	0
1775	375	5	0	0	1	0	0	0
1775	375	5	3	0	0	0	0	0
1775	375	6	0	2	1	0	0	0
1775	425	2	7	1	0	0	0	0
1775	425	3	6	2	0	0	0	0
1775	425	4	2	0	0	1	0	0
1775	425	5	9	2	0	0	0	0
1775	475	2	0	1	0	0	0	0
1775	475	2	21	6	0	0	0	0
1775	475	2	0	0	1	0	0	0
1775	475	3	0	0	0	0	1	0
1775	475	3	0	3	1	0	0	0
1775	475	3	18	2	0	0	0	0
1775	475	4	0	1	1	0	0	0
1775	475	4	11	7	1	1	0	0
1775	525	2	10	6	0	0	0	0
1775	525	3	5	1	0	0	0	0
1775	525	5	2	0	0	0	0	0
1775	625	3	2	3	1	0	0	0
1775	625	4	3	2	0	0	0	0
1775	625	4	0	3	1	0	0	0
1775	625	5	3	1	0	0	0	0
1775	675	3	7	4	0	0	0	0
1775	675	4	11	5	0	1	0	0
1775	675	4	2	0	1	0	0	0
1775	725	2	9	0	0	0	0	0
1775	725	3	2	4	0	0	0	0
1775	725	3	0	1	0	0	0	0
1775	775	2	1	2	0	0	0	0
1775	5252	0	2	1	0	0	0	0
1825	25	2	0	0	1	0	0	0
1825	25	2	49	11	0	0	0	0
1825	25	3	0	1	0	0	0	0
1825	25	3	0	0	1	0	0	0

Table E.2

Easting	Northing	Spit	Small Shaft	Medium Shaft	Large Shaft	Small Canc	Medium Canc	Large Canc
1825	25	3	0	0	1	0	0	0
1825	25	3	53	28	1	1	0	0
1825	25	4	10	6	1	0	0	0
1825	25	4	0	0	1	0	0	1
1825	25	4	0	1	0	0	0	0
1825	75	2	0	0	0	0	2	0
1825	75	2	30	5	0	1	0	0
1825	75	2	5	0	0	0	0	0
1825	75	3	44	7	0	0	0	0
1825	75	3	7	8	0	0	0	0
1825	75	4	26	13	1	0	1	0
1825	125	2	0	0	1	0	0	0
1825	125	2	34	7	0	0	0	0
1825	125	2	0	1	0	0	0	0
1825	125	2	0	0	1	0	0	0
1825	125	2	0	1	0	0	0	1
1825	125	2	0	0	1	0	0	0
1825	125	2	1	2	1	0	0	0
1825	125	2	0	0	1	0	0	0
1825	125	2	0	0	1	0	0	0
1825	125	2	3	5	0	0	1	0
1825	125	2	13	12	0	1	0	0
1825	125	2	0	2	1	0	0	1
1825	125	2	2	2	0	0	0	0
1825	125	3	8	13	0	1	0	0
1825	125	3	0	1	0	0	0	0
1825	125	5	0	1	0	0	0	0
1825	175	2	2	6	0	0	0	0
1825	175	2	2	13	0	1	1	0
1825	175	2	4	1	2	0	0	0
1825	175	2	0	0	0	0	0	1
1825	175	2	4	4	2	0	0	0
1825	175	2	0	1	1	0	0	0
1825	175	2	11	2	0	1	1	0
1825	175	2	0	0	1	0	0	0
1825	175	2	0	0	0	0	0	1
1825	175	2	0	2	0	0	0	0
1825	175	2	1	0	0	0	1	0
1825	175	2	0	2	1	0	0	0
1825	175	2	0	1	1	0	0	0
1825	175	2	6	5	0	0	1	0
1825	175	2	0	2	0	0	0	0
1825	175	2	1	6	3	0	0	0
1825	175	2	0	1	0	0	0	0
1825	175	2	0	1	1	0	0	0
1825	175	4	2	6	1	0	0	0
1825	175	5	1	0	1	0	0	0
1825	175	5	0	1	0	0	0	0
1825	225	2	0	0	1	0	0	0
1825	225	2	0	0	1	0	0	0
1825	225	2	0	1	0	0	0	0
1825	225	2	0	1	0	0	0	0
1825	225	2	0	0	1	0	0	0
1825	225	2	2	0	1	0	0	0
1825	225	2	12	11	1	0	0	0
1825	225	2	0	1	0	0	0	0
1825	225	2	1	4	0	0	0	0
1825	225	2	0	2	0	0	0	0
1825	225	2	0	0	1	0	0	0
1825	225	2	0	0	0	0	1	0
1825	225	2	1	0	1	0	0	0
1825	225	2	0	1	0	0	1	0
1825	225	2	20	17	1	0	0	0
1825	225	2	10	8	0	0	1	0
1825	225	2	0	0	1	0	0	0

Table E.2

Easting	Northing	Spit	Small Shaft	Medium Shaft	Large Shaft	Small Canc	Medium Canc	Large Canc
1825	225	3	45	25	3	0	0	0
1825	225	3	0	1	1	0	0	0
1825	225	3	0	0	1	0	0	0
1825	225	3	0	1	1	0	0	0
1825	225	3	1	3	1	0	0	0
1825	225	5	0	0	1	0	0	0
1825	275	2	1	4	4	0	0	0
1825	275	2	2	5	1	0	0	0
1825	275	2	2	3	0	0	0	0
1825	275	2	10	24	1	0	0	0
1825	275	2	2	2	0	0	0	0
1825	275	2	7	8	1	0	0	0
1825	275	2	2	0	0	0	0	0
1825	275	2	1	0	2	0	0	0
1825	275	2	17	5	0	0	0	0
1825	275	2	0	0	1	0	0	0
1825	275	2	0	1	3	0	0	0
1825	275	2	1	4	0	0	0	0
1825	275	2	0	0	1	0	0	0
1825	275	2	18	11	1	0	1	0
1825	275	3	0	1	1	0	1	0
1825	275	3	0	0	1	0	0	0
1825	275	3	6	5	0	0	0	0
1825	275	4	2	5	0	0	0	0
1825	325	2	0	0	1	0	0	0
1825	325	2	2	1	0	0	0	0
1825	325	2	4	7	0	0	0	0
1825	325	2	15	3	0	0	0	0
1825	325	2	0	1	1	0	0	0
1825	325	2	1	0	0	0	0	0
1825	325	3	0	1	0	0	0	0
1825	325	3	9	3	0	0	0	0
1825	325	3	0	1	2	0	0	0
1825	325	3	11	1	0	0	0	0
1825	325	3	8	9	0	1	0	0
1825	325	4	5	4	0	0	0	0
1825	375	2	4	3	0	0	0	0
1825	375	2	0	0	1	0	0	0
1825	375	2	4	4	0	0	0	0
1825	375	2	5	3	0	0	0	0
1825	375	3	5	6	0	0	0	0
1825	375	3	0	2	0	0	0	0
1825	375	4	2	0	0	0	0	0
1825	425	2	0	1	0	0	0	0
1825	425	3	6	0	0	0	0	0
1825	425	4	1	0	0	0	0	0
1825	475	2	0	2	0	0	0	0
1825	475	3	5	0	0	0	0	0
1825	475	4	6	0	0	0	0	0
1825	525	1	0	1	0	0	0	0
1825	525	1	0	2	0	0	0	0
1825	525	2	2	0	0	0	0	0
1825	775	2	2	0	0	0	0	0
1875	25	2	12	8	0	0	0	0
1875	25	2	15	1	0	0	0	0
1875	25	3	29	10	1	2	0	0
1875	25	4	0	0	1	0	0	0
1875	25	4	0	0	1	0	0	0
1875	25	4	17	6	0	0	0	0
1875	25	4	0	1	0	0	0	0
1875	25	4	0	0	1	0	0	0
1875	25	5	0	3	0	0	0	0
1875	75	2	4	0	0	0	0	0
1875	75	3	0	0	1	0	0	0
1875	75	3	26	5	0	0	0	0

Table E.2

Easting	Northing	Spit	Small Shaft	Medium Shaft	Large Shaft	Small Canc	Medium Canc	Large Canc
1875	75	4	16	4	0	1	0	0
1875	75	4	0	0	1	0	0	0
1875	75	4	0	0	1	0	0	0
1875	75	5	0	3	1	0	0	0
1875	125	2	1	2	0	0	0	0
1875	125	2	17	28	6	0	0	0
1875	125	2	3	2	0	0	0	0
1875	125	2	0	0	1	0	0	0
1875	125	2	18	6	0	0	0	0
1875	125	2	0	0	1	0	0	0
1875	125	3	4	2	0	0	0	0
1875	125	4	5	3	0	0	0	0
1875	125	5	0	0	1	0	0	0
1875	125	5	0	0	1	0	0	0
1875	125	5	0	2	0	0	0	0
1875	175	2	2	2	0	0	3	0
1875	175	2	1	7	0	0	0	0
1875	175	2	8	0	1	0	0	0
1875	175	2	0	0	0	0	1	0
1875	175	2	2	25	0	0	0	0
1875	175	3	2	1	1	0	0	0
1875	175	3	0	0	1	0	0	0
1875	175	4	6	5	0	0	0	0
1875	175	5	6	4	0	0	0	0
1875	175	6	0	1	0	0	0	0
1875	225	2	3	17	4	0	0	0
1875	225	2	0	1	0	0	1	1
1875	225	2	0	1	2	0	0	0
1875	225	2	33	4	0	0	0	0
1875	225	2	0	2	0	0	0	0
1875	225	2	40	40	0	2	1	0
1875	225	2	0	1	1	0	0	0
1875	225	2	0	1	0	0	1	0
1875	225	2	0	0	0	0	1	0
1875	225	2	0	0	1	0	0	0
1875	225	2	0	1	1	0	0	0
1875	225	2	5	10	0	0	0	0
1875	225	2	0	2	0	0	0	0
1875	225	2	0	0	0	0	0	1
1875	225	2	2	0	1	0	0	0
1875	225	2	0	1	0	0	0	0
1875	225	2	0	0	1	0	0	0
1875	225	3	0	0	1	0	0	0
1875	225	3	0	1	1	0	0	0
1875	225	3	0	0	1	0	0	0
1875	225	3	14	9	0	0	0	0
1875	225	3	0	1	0	0	0	0
1875	225	4	0	3	0	2	0	0
1875	225	4	0	0	1	0	0	0
1875	275	2	0	0	0	0	1	0
1875	275	2	2	3	1	0	0	0
1875	275	2	0	3	1	0	0	0
1875	275	2	0	0	1	0	0	0
1875	275	2	2	2	0	0	0	0
1875	275	2	37	7	0	0	0	0
1875	275	2	7	14	0	0	1	0
1875	275	2	0	2	0	0	0	0
1875	275	2	1	9	0	0	0	0
1875	275	2	0	0	1	0	0	0
1875	275	2	2	1	1	0	0	0
1875	275	2	0	0	0	0	1	0
1875	275	2	3	3	3	1	1	0
1875	275	2	0	3	0	0	0	0
1875	275	2	0	0	1	0	0	0
1875	275	2	0	4	0	0	0	0

Table E.2

Easting	Northing	Spit	Small Shaft	Medium Shaft	Large Shaft	Small Canc	Medium Canc	Large Canc
1875	275	2	0	1	2	0	0	0
1875	275	2	0	9	0	0	0	0
1875	275	3	0	2	0	0	0	0
1875	275	3	1	3	1	0	0	0
1875	275	4	1	3	0	0	0	0
1875	325	2	3	2	1	0	0	0
1875	325	2	0	0	1	0	0	0
1875	325	3	15	10	0	0	0	0
1875	325	3	0	0	0	4	3	2
1875	325	3	0	0	1	0	0	0
1875	325	3	1	0	0	0	0	0
1875	325	4	2	4	0	0	0	0
1875	375	2	9	5	0	0	0	0
1875	375	2	26	11	1	0	0	0
1875	375	3	0	0	1	0	0	0
1875	375	3	1	0	0	0	0	0
1875	425	2	13	2	0	0	0	0
1875	425	2	0	1	0	0	0	0
1875	425	3	0	0	1	0	0	0
1875	425	3	19	8	0	0	0	0
1875	425	3	2	2	0	0	0	0
1875	425	4	2	3	0	0	0	0
1875	475	2	2	0	0	0	0	0
1875	475	3	6	2	0	0	0	0
1875	475	3	0	0	1	0	0	0
1875	475	4	1	1	0	0	0	0
1875	575	1	0	1	0	0	0	0
1875	625	1	6	0	0	0	0	0
1875	675	1	0	1	0	0	0	0
1875	675	2	5	0	0	0	0	0
1875	775	3	0	0	0	0	0	1
1875	775	3	11	1	0	7	1	0
1925	25	3	10	16	0	0	0	0
1925	25	3	0	1	1	0	0	0
1925	25	4	13	7	0	0	0	0
1925	25	4	8	2	0	0	0	0
1925	25	4	0	0	0	0	0	1
1925	25	4	0	0	1	0	0	0
1925	25	5	5	9	0	0	0	0
1925	25	5	0	0	0	0	0	1
1925	75	3	5	10	0	0	0	0
1925	75	4	4	6	0	0	0	0
1925	125	3	0	1	2	0	0	0
1925	125	3	0	0	1	0	0	0
1925	125	3	0	0	0	1	0	0
1925	125	3	0	8	1	0	0	0
1925	125	3	0	0	1	0	0	0
1925	125	3	0	0	1	0	0	0
1925	125	3	1	3	5	0	0	0
1925	125	3	1	1	0	0	0	0
1925	125	3	0	0	0	3	0	1
1925	125	3	2	1	1	0	0	0
1925	125	3	0	1	0	0	0	1
1925	125	3	0	1	1	0	0	0
1925	125	3	0	2	0	0	0	0
1925	125	3	0	1	1	0	0	0
1925	125	3	0	1	0	0	0	0
1925	125	3	15	27	3	0	0	0
1925	125	3	16	4	0	0	0	0
1925	125	4	4	6	0	2	0	0
1925	125	4	0	2	0	0	0	0
1925	175	3	0	1	0	0	0	0
1925	175	3	0	0	1	0	0	0
1925	175	3	0	0	1	0	0	0
1925	175	3	8	9	0	4	0	0

Table E.2

Easting	Northing	Spit	Small Shaft	Medium Shaft	Large Shaft	Small Canc	Medium Canc	Large Canc
1925	175	3	17	2	0	2	0	0
1925	175	3	0	0	1	0	0	0
1925	175	3	0	1	0	0	2	0
1925	175	3	0	1	1	0	0	0
1925	175	3	0	3	1	0	0	0
1925	175	4	0	0	0	0	0	1
1925	175	4	0	1	0	0	0	0
1925	175	4	0	0	1	0	0	0
1925	175	4	0	3	0	0	0	0
1925	175	5	3	0	0	0	0	0
1925	225	3	0	2	1	0	0	0
1925	225	3	0	0	0	5	2	0
1925	225	3	1	0	1	0	0	0
1925	225	3	3	1	4	0	0	0
1925	225	3	22	11	0	1	0	0
1925	225	3	0	0	1	0	0	0
1925	225	3	0	1	0	0	0	0
1925	225	4	0	1	1	0	0	0
1925	225	4	0	0	1	0	0	0
1925	225	4	2	7	0	0	0	0
1925	225	4	1	1	0	0	0	0
1925	225	4	0	1	0	0	0	0
1925	225	5	0	1	0	0	0	0
1925	275	3	0	0	2	0	0	0
1925	275	3	14	10	0	0	0	0
1925	275	3	0	0	0	0	2	0
1925	275	4	0	0	2	0	0	0
1925	275	4	0	0	1	0	0	0
1925	275	4	0	0	1	0	0	0
1925	325	2	11	5	0	0	0	0
1925	325	3	8	6	0	0	0	0
1925	325	4	0	2	0	0	0	0
1925	375	3	2	1	0	0	0	0
1925	425	2	1	1	0	0	0	0
1925	675	1	0	2	0	0	0	0
1925	725	2	0	1	0	0	0	0
1975	25	3	7	7	0	0	0	0
1975	25	4	7	1	0	1	0	0
1975	25	5	0	0	1	0	0	0
1975	25	5	1	1	0	0	0	0
1975	75	3	4	16	0	0	0	0
1975	75	3	0	1	0	0	0	0
1975	75	4	6	7	0	0	0	0
1975	75	5	1	0	0	0	0	0
1975	75	5	3	1	0	0	0	0
1975	75	5	0	1	0	0	0	0
1975	125	2	5	0	0	0	0	0
1975	125	3	35	19	0	2	0	0
1975	125	3	0	0	1	0	0	0
1975	125	3	0	1	0	0	0	0
1975	125	3	0	1	1	0	0	0
1975	125	3	1	5	0	0	0	0
1975	125	4	0	1	1	0	0	0
1975	125	4	5	4	0	1	0	0
1975	125	5	0	2	0	0	0	0
1975	125	5	2	1	0	0	0	0
1975	125	6	1	0	0	0	1	0
1975	175	3	0	1	0	0	0	0
1975	175	3	1	2	0	0	0	0
1975	175	3	5	10	0	0	0	0
1975	175	4	4	9	0	0	0	0
1975	175	4	0	1	0	0	0	0
1975	175	4	20	3	0	0	0	0
1975	175	4	0	1	0	0	0	0
1975	175	4	0	0	1	0	0	0

Table E.2

Easting	Northing	Spit	Small Shaft	Medium Shaft	Large Shaft	Small Canc	Medium Canc	Large Canc
1975	175	5	7	4	0	1	0	0
1975	175	6	3	0	0	0	0	0
1975	175	6	0	1	0	0	0	0
1975	225	3	0	1	0	0	0	0
1975	225	3	0	1	1	0	0	1
1975	225	3	1	1	0	0	0	0
1975	225	3	0	0	1	0	0	0
1975	225	3	0	0	0	0	0	1
1975	225	3	0	1	1	0	0	0
1975	225	3	0	1	0	0	0	0
1975	225	3	0	0	1	0	0	0
1975	225	3	0	0	1	0	0	0
1975	225	3	2	4	0	0	0	0
1975	225	3	0	0	0	0	0	1
1975	225	3	0	2	1	0	0	0
1975	225	3	18	19	0	2	1	0
1975	225	4	0	2	1	0	0	0
1975	225	4	51	2	0	5	0	0
1975	225	4	0	0	1	0	0	0
1975	225	4	1	0	0	0	0	1
1975	225	4	0	0	1	0	0	0
1975	225	4	0	0	1	0	0	0
1975	225	4	0	0	1	0	0	0
1975	225	4	0	0	1	0	0	0
1975	225	4	0	1	1	0	0	0
1975	225	4	0	0	1	0	0	0
1975	225	4	7	8	0	1	1	0
1975	225	4	0	0	1	0	0	0
1975	275	3	0	1	0	0	0	0
1975	275	3	0	1	0	0	0	0
1975	275	3	0	0	1	0	0	0
1975	275	3	18	8	0	0	0	0
1975	275	3	7	6	0	0	0	0
1975	275	3	15	14	0	0	0	0
1975	275	3	4	6	0	0	0	0
1975	275	4	0	0	1	0	0	0
1975	275	4	0	0	0	0	0	1
1975	275	4	0	0	2	0	0	1
1975	275	4	0	1	0	0	0	0
1975	275	4	3	1	0	0	0	0
1975	275	4	0	0	1	0	0	0
1975	275	4	12	18	3	0	0	0
1975	275	5	0	0	1	0	0	0
1975	325	2	10	3	0	0	1	0
1975	325	2	9	3	0	0	0	0
1975	325	3	0	0	1	0	0	0
1975	325	3	9	4	0	0	0	0
1975	325	3	0	0	1	0	0	0
1975	325	3	3	2	0	0	0	0
1975	325	4	0	0	1	0	0	0
1975	325	4	2	0	0	0	1	0
1975	375	3	0	1	0	0	0	0
1975	375	3	0	0	1	0	0	0
1975	375	3	0	0	1	0	0	0
1975	375	3	2	3	0	1	0	0
1975	375	3	2	2	3	0	0	0
1975	375	3	0	1	0	0	0	0
1975	375	3	0	0	0	3	1	0
1975	375	4	1	1	1	0	0	0
1975	375	4	4	1	0	6	0	0
1975	425	2	7	1	0	0	0	0
1975	425	3	0	0	0	0	0	1
1975	425	3	0	2	0	0	0	0
1975	475	3	3	0	0	0	0	0
1975	475	4	0	1	0	0	1	0

Table E.2

Easting	Northing	Spit	Small Shaft	Medium Shaft	Large Shaft	Small Canc	Medium Canc	Large Canc
2025	25	3	1	1	0	0	0	0
2025	25	3	0	0	1	0	0	0
2025	25	4	0	1	1	0	0	0
2025	25	4	0	2	0	0	0	0
2025	25	4	3	8	0	2	1	0
2025	25	5	2	2	0	1	0	0
2025	75	3	0	4	0	0	1	0
2025	75	4	1	0	0	0	0	0
2025	125	3	0	0	0	0	0	1
2025	125	4	0	3	0	0	0	0
2025	125	5	0	0	0	0	1	0
2025	175	3	1	3	0	1	1	0
2025	225	3	0	0	0	0	0	1
2025	225	3	4	3	2	0	0	0
2025	225	3	0	1	1	0	0	0
2025	225	3	2	1	1	0	0	0
2025	225	3	0	0	2	0	0	0
2025	225	3	0	0	0	0	1	0
2025	225	3	0	2	1	0	0	0
2025	225	3	0	0	2	0	0	1
2025	225	3	19	14	0	0	0	0
2025	225	3	0	0	1	0	0	0
2025	225	3	0	1	0	0	0	0
2025	225	4	0	0	1	0	0	0
2025	225	4	2	8	0	0	1	0
2025	275	3	8	6	0	1	0	0
2025	275	3	0	0	0	0	3	1
2025	275	3	1	0	1	0	0	0
2025	275	3	0	1	1	0	0	0
2025	275	3	27	1	0	11	0	0
2025	275	3	0	0	1	0	0	0
2025	275	4	1	3	0	0	0	0
2025	275	4	0	0	0	0	0	1
2025	275	4	0	0	1	0	0	0
2025	275	5	2	0	1	0	0	0
2025	325	3	0	2	0	0	0	0
2025	375	1	1	1	0	0	0	0
2025	375	2	0	1	0	0	0	0
2025	375	2	0	1	1	0	0	0
2025	375	2	1	4	3	0	0	0
2025	375	3	0	0	1	0	0	0
2025	375	3	1	2	0	0	0	0
2025	375	4	0	0	1	0	0	0
2025	375	5	0	1	0	0	0	0
2025	425	3	0	1	0	0	0	0
2025	475	3	0	0	0	4	3	2
2025	475	3	1	1	0	0	0	0
2025	475	4	1	0	0	0	0	0
2025	475	5	3	0	0	0	0	0
2025	525	2	0	1	0	0	0	0
2025	575	3	0	2	1	0	0	0
2025	775	1	0	2	0	0	0	0
2025	775	2	0	1	0	0	0	0
2075	25	3	4	6	0	0	0	0
2075	25	3	8	0	0	0	0	0
2075	25	4	0	0	1	0	0	0
2075	25	5	0	0	0	0	0	1
2075	25	5	0	2	0	0	0	0
2075	75	3	11	8	0	1	0	0
2075	75	3	0	0	1	0	0	0
2075	75	4	0	0	1	0	0	0
2075	75	4	2	2	0	0	0	0
2075	125	2	4	0	0	4	0	0
2075	125	3	0	1	0	0	0	0
2075	125	3	0	1	0	0	0	0

Table E.2

Easting	Northing	Spit	Small Shaft	Medium Shaft	Large Shaft	Small Canc	Medium Canc	Large Canc
2075	125	3	0	0	0	0	1	0
2075	125	4	2	3	0	0	0	0
2075	125	5	0	0	1	0	0	0
2075	125	5	2	1	0	0	0	0
2075	125	6	0	1	0	0	1	0
2075	175	3	0	0	1	0	0	0
2075	175	3	0	0	0	0	0	1
2075	175	4	1	1	1	0	0	2
2075	175	8	0	0	0	0	0	1
2075	225	3	7	18	0	0	0	0
2075	225	3	0	0	0	0	1	0
2075	225	3	0	0	1	0	0	0
2075	225	3	0	0	1	0	0	0
2075	225	3	5	6	0	0	0	0
2075	225	3	0	0	2	0	0	0
2075	225	4	0	0	0	0	3	0
2075	225	4	0	0	0	0	1	0
2075	225	4	0	0	0	0	0	1
2075	225	4	0	3	1	0	0	0
2075	225	4	0	0	2	0	0	0
2075	225	4	9	12	0	1	2	0
2075	225	4	0	0	0	0	0	1
2075	225	4	0	5	0	0	0	1
2075	225	4	0	0	2	0	0	0
2075	225	4	1	0	0	0	0	0
2075	225	5	4	1	0	1	0	0
2075	225	6	1	4	0	0	0	0
2075	275	3	12	3	0	0	0	0
2075	275	3	27	2	0	10	0	0
2075	275	4	3	5	0	0	0	0
2075	275	4	19	3	0	6	1	2
2075	275	4	7	0	0	1	0	0
2075	325	3	0	1	0	0	0	1
2075	325	3	4	1	0	2	0	0
2075	325	4	0	1	0	0	0	0
2075	375	1	2	2	0	0	0	0
2075	375	2	0	0	1	0	0	0
2075	375	2	4	5	1	1	0	0
2075	375	3	0	1	0	0	0	0
2075	375	4	0	0	1	0	0	0
2075	375	5	3	1	0	0	0	0
2075	475	3	4	0	1	0	0	0
2075	475	4	25	0	0	0	0	0
2075	475	4	2	4	1	0	0	0
2075	725	4	0	2	0	0	0	0
2075	775	2	0	1	0	0	0	0
2075	775	2	0	1	0	0	0	0
2075	775	4	0	1	0	0	0	0
2125	-75	3	3	0	0	1	0	0
2125	-25	3	3	0	0	0	0	0
2125	-25	4	2	2	0	0	0	0
2125	25	2	3	2	1	1	0	0
2125	25	2	5	0	0	0	0	0
2125	25	3	6	0	0	0	0	0
2125	75	2	1	2	0	0	0	0
2125	75	3	11	6	1	0	0	0
2125	75	3	10	6	0	0	0	0
2125	75	4	0	1	0	0	0	0
2125	125	2	0	1	0	0	0	0
2125	125	2	2	0	0	1	1	0
2125	125	2	1	1	0	0	0	0
2125	125	5	7	0	0	0	0	0
2125	225	3	0	0	1	0	0	0
2125	225	3	0	1	0	0	0	0
2125	225	3	0	0	0	0	1	0

Table E.2

Easting	Northing	Spit	Small Shaft	Medium Shaft	Large Shaft	Small Canc	Medium Canc	Large Canc
2125	225	3	0	1	0	0	0	0
2125	225	3	2	5	1	1	0	0
2125	225	4	0	0	1	0	0	0
2125	225	6	0	1	0	1	0	0
2125	275	3	0	1	1	0	0	0
2125	275	3	0	1	1	2	0	0
2125	325	1	10	0	0	0	0	0
2125	325	3	65	3	0	18	1	0
2125	325	3	0	0	1	0	0	0
2125	325	3	3	2	1	0	1	0
2125	325	4	0	0	0	1	0	0
2125	375	3	3	2	1	23	4	1
2125	375	3	1	0	0	0	0	0
2125	375	4	0	0	0	0	1	0
2125	375	4	0	2	0	0	0	0
2125	425	3	0	0	1	0	0	0
2125	425	3	2	1	1	0	0	0
2125	425	4	5	11	1	0	0	0
2125	475	3	0	0	0	0	1	0
2125	475	4	0	1	0	0	0	0
2125	525	4	3	5	0	0	0	0
2125	575	3	2	0	0	0	0	0
2125	575	4	0	0	0	1	1	0
2125	675	2	3	1	0	0	0	0
2125	675	3	1	0	0	0	0	0
2125	675	4	1	0	0	0	0	0
2125	725	1	0	1	0	0	0	1
2125	775	1	1	2	0	0	0	0
2175	-75	3	0	0	0	0	0	1
2175	-75	3	0	0	0	0	0	1
2175	-75	3	5	0	0	2	0	0
2175	-25	4	0	1	0	0	0	0
2175	25	2	3	2	0	0	0	0
2175	25	3	1	2	0	0	0	0
2175	25	4	5	0	0	0	0	0
2175	75	2	3	1	0	0	0	0
2175	75	3	0	0	1	0	0	0
2175	75	3	4	3	0	0	0	0
2175	75	4	3	1	0	0	0	0
2175	125	2	0	0	0	0	0	1
2175	125	2	0	4	0	0	0	0
2175	125	3	1	3	0	0	0	0
2175	125	3	0	2	1	0	0	0
2175	125	4	1	3	0	0	0	0
2175	175	2	0	1	0	0	0	0
2175	175	3	0	1	0	0	0	0
2175	225	3	0	3	0	0	1	0
2175	225	3	0	0	2	0	0	0
2175	225	6	2	0	0	2	0	0
2175	275	2	11	0	0	8	0	0
2175	275	3	80	6	0	3	0	0
2175	275	3	0	3	0	1	0	0
2175	275	4	0	0	1	0	0	0
2175	325	3	0	1	1	0	0	0
2175	325	3	0	0	1	0	0	0
2175	325	3	1	0	1	0	1	0
2175	325	3	5	4	2	3	0	0
2175	325	4	1	1	0	0	0	0
2175	325	4	1	1	0	0	0	0
2175	325	4	0	2	0	0	0	0
2175	325	5	0	1	0	0	0	0
2175	325	5	2	1	1	0	0	0
2175	375	3	12	4	1	0	0	0
2175	425	3	4	8	0	0	0	0
2175	425	3	0	0	1	0	0	0

Table E.2

Easting	Northing	Spit	Small Shaft	Medium Shaft	Large Shaft	Small Canc	Medium Canc	Large Canc
2175	475	3	2	2	0	0	0	0
2175	475	4	3	3	0	0	0	0
2175	525	4	0	1	2	0	0	0
2175	525	4	1	2	0	0	0	0
2175	525	6	0	0	1	0	0	0
2175	575	3	0	0	0	2	1	0
2175	575	4	0	1	0	0	1	0
2175	675	3	13	1	0	0	0	0
2175	675	3	6	5	0	0	0	0
2175	675	4	4	1	0	0	0	0
2175	725	2	13	1	0	0	0	0
2225	225	1	0	1	0	0	0	0
2225	225	2	5	1	0	0	0	0
2225	225	3	2	0	0	0	0	0
2225	225	4	40	0	0	7	0	0
2225	225	4	1	0	0	0	0	0
2225	225	5	1	1	1	0	0	0
2225	225	6	10	2	0	3	0	0
2225	275	5	1	3	0	0	0	0
2225	275	5	36	2	0	6	0	0
2225	275	5	0	1	0	0	0	0
2225	275	6	4	1	0	1	0	0
2225	275	6	0	0	0	0	1	0
2225	325	2	3	0	0	0	0	0
2225	325	3	0	1	0	0	0	0
2225	325	3	5	2	0	0	0	0
2225	325	4	3	2	0	1	1	0
2225	325	4	1	0	0	0	0	0
2225	325	6	0	1	0	0	0	0
2225	375	2	1	1	0	2	0	0
2225	375	3	1	0	0	0	0	0
2225	375	3	5	3	0	0	0	0
2225	375	5	3	3	0	0	0	0
2225	375	5	1	0	0	0	0	0
2225	425	3	28	28	0	18	9	3
2225	425	3	0	0	1	0	0	0
2225	425	4	4	0	1	0	0	0
2225	475	4	0	0	0	3	1	0
2225	475	4	1	4	0	0	0	0
2225	525	3	1	1	0	0	0	0
2225	575	4	2	2	0	0	0	0
2225	625	4	0	0	0	0	3	1
2225	625	4	1	2	0	0	0	0
2225	625	5	0	1	0	0	0	0
2225	675	3	2	0	0	1	0	0
2225	675	4	1	3	0	0	0	0
2275	125	3	0	2	1	0	0	0
2275	125	3	0	1	1	0	0	0
2275	125	4	0	0	2	0	0	0
2275	175	3	8	12	0	5	4	4
2275	225	3	2	2	0	0	0	0
2275	225	4	0	3	0	0	0	0
2275	275	3	2	0	0	0	0	0
2275	275	3	0	0	1	0	0	0
2275	275	5	0	2	0	0	0	0
2275	275	6	0	1	0	0	0	0
2275	325	3	2	0	0	0	0	0
2275	325	3	17	0	0	2	0	0
2275	325	3	0	1	0	0	0	0
2275	325	4	0	0	0	2	0	0
2275	325	5	26	1	0	2	0	0
2275	325	5	0	5	0	0	0	0
2275	325	5	1	2	0	0	0	0
2275	325	6	5	0	0	1	0	0
2275	375	3	8	2	0	0	0	0

Table E.2

Easting	Northing	Spit	Small Shaft	Medium Shaft	Large Shaft	Small Canc	Medium Canc	Large Canc
2275	375	3	1	3	0	0	0	0
2275	375	4	4	1	0	1	0	0
2275	375	5	1	1	0	0	0	0
2275	475	3	30	0	0	6	0	0
2275	475	3	22	1	0	8	0	0
2275	475	3	0	1	0	0	0	0
2275	475	4	1	0	0	0	0	0
2275	525	4	1	2	1	0	0	0
2275	525	4	1	3	0	0	0	0
2275	575	4	21	0	0	5	0	0
2275	575	4	0	0	0	16	2	0
2275	675	4	3	0	0	0	0	0
2325	25	2	2	1	0	4	1	0
2325	25	2	0	2	0	0	0	0
2325	75	3	4	2	0	2	0	0
2325	125	4	2	3	0	0	0	0
2325	125	4	0	2	0	0	0	0
2325	225	3	1	2	0	0	0	0
2325	275	3	3	0	0	0	0	0
2325	325	2	13	0	0	1	0	0
2325	325	3	13	0	0	1	0	0
2325	325	4	17	1	0	0	0	0
2325	325	5	11	0	0	1	0	0
2325	325	5	0	0	1	0	0	0
2325	325	6	4	0	0	5	1	0
2325	375	2	10	0	0	1	0	0
2325	375	3	13	0	0	5	0	0
2325	375	3	15	2	0	4	0	0
2325	375	4	0	1	0	0	0	0
2325	375	5	12	0	0	3	0	0
2325	375	6	6	0	0	3	0	0
2325	425	3	1	1	0	0	0	0
2325	425	3	14	0	0	6	0	0
2325	475	4	13	12	0	0	0	0
2375	75	3	0	0	1	0	0	0
2375	175	5	13	0	0	0	0	0
2375	225	5	5	2	0	0	0	0
2375	325	3	6	0	0	1	0	0
2375	325	3	0	0	1	0	0	0
2375	325	3	5	2	0	0	0	0
2375	325	3	6	0	0	6	0	0
2375	325	4	7	1	0	1	0	0
2375	375	3	5	0	0	0	0	0
2375	375	4	4	1	0	0	0	0
2375	375	4	7	0	0	2	0	0
2375	375	5	1	1	0	0	0	0
2375	425	3	0	5	0	0	0	0
2375	475	5	29	7	0	8	0	0
2375	475	5	0	4	0	0	0	0
2375	525	3	0	0	1	0	0	0
2375	725	2	0	2	0	0	0	0
2425	-75	3	6	0	0	0	0	0
2425	-25	5	0	1	0	0	0	0
2425	25	4	0	1	0	0	0	0
2425	75	3	3	3	0	0	0	0
2425	75	4	0	0	1	0	0	0
2425	125	5	1	0	0	2	0	0
2425	325	2	0	1	1	0	1	0
2425	375	2	1	0	0	0	0	0
2425	475	2	2	3	0	0	0	0
2425	475	3	20	6	0	1	0	0
2425	675	2	5	0	0	0	0	0
2475	125	4	0	2	0	0	0	0
2475	125	6	3	0	0	0	0	0
2475	175	6	5	0	0	3	0	0

Table E.2

Easting	Northing	Spit	Small Shaft	Medium Shaft	Large Shaft	Small Canc	Medium Canc	Large Canc
2475	225	3	0	1	0	0	0	0
2475	375	2	0	0	0	0	1	1
2475	375	2	0	1	0	0	0	1
2475	375	2	0	1	0	0	0	0
2475	425	2	2	2	0	1	0	0
2475	425	3	1	1	0	0	0	0
2475	425	3	13	9	0	0	0	0
2475	475	2	3	0	0	1	0	0
2475	475	3	1	3	0	0	0	0

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