Bone, antler, tooth and horn technology and utilisation in prehistoric Scotland.

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Volume I

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VOLUME I CONTENTS

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DEDICATION

For Jane and Alasdair.

SUMMARY

This study is concerned with the technology and utilisation of skeletal hard tissue in prehistoric Scotland. The natural properties of skeletal tissues were considered, their reaction to particular methods of manufacture and utilisation were studied and a detailed examination made of material from a number of archaeological sites. Whilst the conclusions reached are site-specific, their usefulness as general statements on technology and utilisation are explored. There are two volumes - volume I containing the main text and volume II the catalogues and illustrations.

Volume I begins with an introduction (Chapter 1). There then follow two sections. Section I starts by examining the approaches which were taken, identifies parallel studies, the range of techniques which were used in the study and the nature of the generalisations presented here (Chapter 2). The structure and properties of skeletal materials, and the determinant effect which these have on the techniques of manufacture, are discussed in Chapters 3 & 4.

Section II comprises four case studies of large assemblages from settlement sites which date from the Mesolithic Period to the Iron Age - the site of Risga, Loch Sunart, Ardnamurchan (Mesolithic, Chapter 5); Skara Brae, Orkney (Neolithic, Chapter 6); Midhowe in Rousay, Orkney and Cnoc Sligeach at Sollas, North Uist (both Iron Age, Chapters 7 & 8). In each study the site and its excavation are discussed. All the objects from the sites were examined afresh and those from animals sources analysed in terms of skeletal origin, techniques of manufacture, object classification and distribution on site. Volume I concludes with Chapter 9 in which the results are summarised and the general applicability of the results is discussed.

Volume II contains simplified object catalogues for each site which are intended as a concordance to enable the individual objects studied to be identified by others. Illustrations are given of representative objects within the categories. For ease of reference volume II also contains the bibliography and all the other illustrations for the study.

CHAPTER 1
INTRODUCTION

The purposes of this thesis are to establish the extent to which hard skeletal materials are represented amongst the material on four prehistoric archaeological sites in Scotland; to determine the ways these materials were utilised and to consider the roles they played within their originating societies. This information is examined for its usefulness in forming generalisations about such material usage in prehistoric Scotland. The approach taken may be described as a 'holistic' one, since it is not simply the study in isolation of these materials which is considered important, but also their interrelationship with other materials, and the interplay with elements of material culture within the dynamic system we call 'society'. As a result, the basis of the study is not a complete database of all objects from Scotland, since this would mix information from many different types of contexts and from sites with variable levels of survival. Rather a small number of occupation sites was identified on the grounds of appropriate date and from which objects had been recovered with such well-preserved condition that species identification and the study of marks of manufacture and utilisation could be undertaken. Published and unpublished sites were considered. It was soon realised that skeletal materials had been misunderstood and misidentified on a regular basis, and that the generally held views about techniques of manufacture have been grounded in the study of a small number of exceptional pieces.

Since both the organic and inorganic components of bone are potentially subject to biological and chemical decay and attrition, the survival of objects made from skeletal materials is dependent on their being protected either by the physical exclusion of air and water to reduce biological decay or the chemical buffering of alkaline soils to minimise acidic attack. As a result skeletal materials tend to be best preserved in alkaline environments, and the initial survey to locate sites in Scotland which might have yielded reasonable collections of material therefore concentrates on coastal areas and particularly in the calcareous dune systems of the

Northern and Western Isles. Further selection took place on the basis of a cursory examination of accompanying objects of other materials, and the final choice was determined by which assemblages were available for examination. It is believed that the general conclusions reached on each site about technology and utilisation, have some applicability for the appropriate periods throughout Scotland (and beyond) although differences in detail will be met. It would be surprising, for example, for marine cetacean bone to be a major resource on inland sites and so generalisations on the interplay of marine, coastal and terrestrial sources of raw material are only meaningful in a coastal context.

The use of objects as funerary goods is not within the scope of this work. The choices made about the selection of items for burial with the dead are guided by principles different from those related to the disposal of domestic refuse, even if the cosmology within which such depositions take place views both as unclean.

Therefore the only generalisations which can be applied across the periods and area studied are those which concern the nature of the raw materials themselves and the effects of particular techniques of manufacture. These are related to the 'natural' properties of skeletal materials and the implements used to manufacture them. The extent to which details of manufacture, utilisation and significance can be applied from one site to another, or may be the basis of broad generalisations about a particular period, can only be determined by establishing some level of congruity between the sites studied. It would thus be completely inappropriate, for example, to assume that all the conclusions reached for Skara Brae, were applicable to all Neolithic sites in Scotland, although some of the conclusions about general approaches to animals as resources and basic techniques of manufacture do seem to apply. As for the particular objects made, the way they were used, and the extent to which they overlap with objects of other materials, none of these can be taken and applied uncritically to other sites. There are settlement sites in Orkney which do have close parallels to Skara Brae, but there are also differences significant enough to warrant care. The consequence of this is that the site case study can only ever be a site case study. Some conclusions may have implications for other sites and areas within which one can identify broadly similar cultural traditions, but others will have no significance beyond the individual site.

Since the work presented here was focused on a number of case studies, it is important to realise that there may be problems inherent in those sites which also limit their more general applicability. The excavation information from Risga, for example, is very poor, especially by modern standards. The site was, however, the only large assemblage of its period which was freely available for study. Sites with more comprehensive recording of the distribution of finds, such as the excavations on Oronsay by Mellars (in preparation), will be a more fruitful source of information with a greater likelihood of being generally applicable to West Coast Scottish Mesolithic midden sites, assuming that enough similarity can be seen in the sites to make comparison valid, but the information from the Oronsay sites was not available during the course of the work.

The emphasis here has been on similarity, but there is a sense in which establishing differences is as important. Most previous studies of objects made from skeletal materials have concentrated on the form of the finished object, but this study is intended to extend the discussion beyond simple object morphology to material sources, techniques of manufacture and the interplay of materials on specific archaeological sites. It was realised from the beginning that the examination of objects made from bone, antler, tooth and horn had to be grounded in a study of raw materials from a materials science and biomechanical approach. This also had to be supported by an understanding of their physical properties and fracture mechanics, as well as those of the lithic and metal tools with which they were worked.

Some practical and experimental work was necessary in order to appreciate first hand the properties and reactions of particular bones and the effect of treatment techniques, although full replication of object classes was never undertaken. All the objects from the sites identified as worthy of further study were examined, and recorded in a manner devised for this study which sought to establish standards and formats of description in an area where they were almost totally lacking. On the one hand, this lack had its advantages, in that the sometimes conflicting interests of technology, morphology and function could be dealt with as was thought appropriate for this study, without having to refer in detail to procedures of description established by others. An absence of precedents was, however, also a major disadvantage, as there was virtually no groundwork to establish procedures for the analysis of bone technology on which one could build when this study was begun. The materials science information and that relating to animal structure and anatomy is, therefore, derived from published sources and from the direct examination of skeletal collections. Its application to the study of technology is original, though parallelled in a number of other contemporary, or near contemporary, studies (e.g. A MacGregor 1980, 1985; Olsen 1984a; Johnson 1985:: the latter was published after most of the work presented here was undertaken). The observations made about the objects and the direction from which they were studied are original, nothing having been taken on trust from any previous examinations.

Whilst the terms 'skeletal materials' or 'skeletal hard tissue' are probably the most accurate general terms for the materials discussed here, the phrases themselves are cumbersome to use and at times confusing within the sentence structure. Equally, the continued use of the phrase 'bone, antler, tooth and horn' is unwieldy. As a result the word 'bone' is used in some of the general discussions of materials or objects as standing for all the materials examined, and this expanded meaning will be recognisable in the contexts in which it is used. Within the chapters on structure and properties the terms are used very strictly and horn, antler and tooth are only used for the specific materials.

This thesis is divided into two main sections. Section I examines the practical and theoretical background to the study and the general implications of the structure and properties of skeletal materials for their use in tool manufacture. Section II comprises four case studies which are supplemented in Volume II by catalogues of objects.

In Chapter 2 it is argued that a proper understanding of particular material categories or artefact classes is effectively meaningless in isolation from an archaeological and social context. With Shanks & Tilley (1987) it is agreed that all such work takes place in the present and for contemporary reasons. There is no question of reconstructing the past for its own sake; rather, particular images of the past are created for modern reasons. The modern interest here is in the establishment of an 'ecology' of technology which identifies the interplay between resources and argues for an ancient understanding of resources and materials. Within such a framework, the identification of utilised materials and techniques of manufacture is per se evidence of an appreciation of resources. The fact that variations in evidence and differences in its interpretation are possible is taken as an indication that there is genuine diversity and variation through time, which can be understood in terms which are 'cultural' and 'processual' by trying to model the generative principles and other unobservable elements which brought about the surviving material remains which were studied.

From such a perspective, the examination of a restricted group of materials and objects can only hint at the broader conclusions and generalisations which would follow from a more detailed analysis of all the objects and site records. The work presented here can only be partial, as its focus is on the use of certain materials within a site context rather than the site itself. It is made clear, however, that the objects can not be seen in isolation as this would be to ignore the fact that they had significance in their own context and time. Such an approach does lead to further questions about the sites concerned, rather than happily placing 'bone objects' with all the other material categories in independent and unintegrated specialist reports.

Chapters 3 and 4 examine, at a number of levels, the origin and structure of the range of skeletal materials and the resultant physical and mechanical properties which they possess. In materials science terms, they are very complex, composite materials and whilst it is possible to list most of the structural details and the manner in which they develop in a living animal, it is much more difficult to be precise about the way in which such structures determine fracture patterning, although the general principles involved can be identified. It is important to understand the effect that certain techniques of manufacture have on the raw materials, and the nature of the breakage, cutting and abrasion which occurs.

The individual site discussions, Chapters 5 - 8, examine the location, environment and excavation history of each site as an introduction to the reasons for its excavation, and as a background to the activities on the site. The range of species represented at the site is identified and the variety of raw materials other than those available from animals discussed. After listing the animals and parts used to make tools and the variety of techniques identifiable, the objects are discussed in terms of artefact categories devised specifically for this study. The significance of these categories and any recognisable distributions is assessed. Note is taken of previous discussions, but all the material was examined first hand and recorded on a standard form which was developed during the work (Fig 1.1). The level of detail given in these preparatory records varies. Methods of examining, describing and recording such material had to be devised from scratch, there being no generally accepted format for such work, and as a result later records are fuller and of a higher quality than some of the earlier ones. The analyses and discussion reported here are, however, always supported by records made by the writer. Over two thousand objects or groups (representing over seven thousand individual items) were studied in detail and are presented here. Several thousand more were handled in the course of the project.

Chapter 5 examines the Mesolithic site of Risga, Loch Sunart, Ardnamurchan, excavated during the 1920s. The site was probably a temporary settlement site for the exploitation of marine and coastal resources. Some of the bone and antler material from the site has been given cursory study (Lacaille 1951, 1954; Clark 1956; Stevenson

1978) but this is the first time that it has been fully examined. The range of objects made from skeletal materials is restricted and is dominated by the 'limpet scoop' or bevel-ended tool. A very large assemblage of lithic material was also recovered from the site. It seems likely that the site was used for a limited number of activities related to hunting and animal processing and that it would have been one of a number of sites occupied by the same social group in the West Highlands. The importance of fracture as a technique of manufacture is emphasised at Risga.

In Chapter 6 the major Neolithic settlement of Skara Brae, Orkney is discussed. This village, astonishingly well preserved, has been excavated on a number of occasions and produced a wide range of distinctive classes of objects in bone, pottery and stone (Petrie 1868, Traill 1868, Childe & Paterson 1929, Childe 1930a, 1931a, 1931b). The material from the 1972-73 excavations (Clarke 1976a; 1976b) was not included in this examination since the results of the sorting of wet-sieved material were not completely available, but a cursory look at the range of objects identified closely parallels those recovered from the 19th century excavations and those observed by Childe. The collections are widely dispersed throughout museums in Orkney, Edinburgh and London, but because of detailed study reported here, it has been possible for the first time since the early 1930s to identify exactly which of the objects from Childe's excavations came from where. Previously there was a list of objects separate from a description giving a rough indication of distribution, but it was impossible to link the two. The completion of the details of this study of Skara Brae is a major undertaking in itself. Fracture and grinding with pumice were the major techniques recognised at this site.

Two Iron Age sites of slightly different date are discussed in Chapters 7 and 8 - the broch of Midhowe, Rousay, Orkney and the wheelhouse sites at Cnoc Sligeach, Sollas, N Uist. The former was excavated and published in the 1930s (Callander & Grant 1934) and contained a wide range of objects of bone and antler. This present study shows that some of the material was misidentified in regard to its animal origin, and misattributed to the artefact classes listed.

Midhowe is one of a number of sites in the Northern and Western Isles whose inhabitants used a broadly similar repertoire of materials and objects. The artefacts from the unpublished site of Cnoc Sligeach, Sollas are, similarly, broadly 'typical' of wheelhouse sites and parallel some of the finds made at broch sites which were occupied to a date later than Midhowe. Both sites exhibit the increased freedom gained by the use of heavy-bladed metal implements in tool manufacture and at these later sites substantial changes to the shape of bones were made. Bone here takes the status of a raw material, as opposed to individual bones being viewed as preforms or blanks for tools as appear to be the case with the earlier sites.

The main implications of these studies are summarised in the concluding Chapter 9 which also discusses the effectiveness of the techniques of analysis and synthesis used here.

Volume II comprises simple catalogues of all the objects from the four sites studied for this thesis. No attempt is made to give a detailed description since the intention is to list key features which would enable other scholars to identify which objects are being discussed. This is the first occasion on which most of the objects listed are individually identifiable. An introduction prefaces the catalogues and notes the parameters of their composition.

The second volume concludes with the figures, plates and bibliography for the thesis. Where suitable English names exist for animals, these have been used. Animals which may have been sheep or goats and should strictly be called ovicaprids are here called sheep. No firm evidence for goats has been found at any of the sites studied. Parts of the skeletal structure are usually referred to by their Latin names.

CHAPTER 2
APPROACHES AND METHODOLOGY

The purpose of this chapter is to introduce the range of approaches which were used in the studies undertaken, the types of questions they address and to give some theoretical and methodological underpinning to the work. After a brief review of other relevant studies in Britain and in parts of Europe, America and the Near East, the approaches taken are presented and their strengths and weaknesses examined. The chapter finishes with a discussion of the type of archaeology which is being practised here and the nature of the archaeological knowledge which is constructed.

STUDIES IN THE TECHNOLOGY OF SKELETAL MATERIALS

Throughout the world and from at least Middle Palaeolithic times the bones and other parts of animals which were released as the result of butchery were used to make tools (Clark 1969, 38). The study of bone objects has never had the prominence or attention which that of lithics or ceramics has attracted and this is probably due to two factors. The survival of items made from any material with organic and inorganic components is dependent on them being disposed of in a favourable environment i.e. in an accumulating deposit which is anaerobic or in one which has an alkaline pH value. As a result the survival rate of bone from archaeological sites is very variable indeed and dependent on local conditions. In the Neolithic period in Britain, for example, most discussion of the use of skeletal materials for tool manufacture centres on the site of Skara Brae because it has one of the best preserved collections of material which is accessible, though as yet only partially, published. Under no other circumstances would one expect a North Atlantic coastal settlement in a virtually treeless environment to provide a general model for the rest of the British Isles, particularly given the differences in the range of animal resources available. One of the usual archaeological techniques of analysis is inter-site study but such an approach to skeletal materials must be dependent on equivalent conditions of survival pertaining. Comparison between Skara Brae and the contemporary Orcadian Grooved Ware site of Rinyo, for example, cannot encompass the worked bone since so little of it survived at the latter site. For this reason inter-site variability, and most artefact studies in general, have dealt with the more durable lithic and ceramic assemblages.

The second main factor for the lack of prominence of studies of objects made from skeletal materials arises from the methods by which the finds made at archaeological sites have been researched. Small assemblages have usually been dealt with directly by the co-ordinator of the post-excavation archive and site report. Larger assemblages have involved the use of specialists and often bone objects have fallen between two stools - that of the faunal analyst who, until recently, has not been encouraged to investigate butchering practice or general approaches to animal (as opposed to species) management and exploitation; and that of the post-excavation researcher for whom such objects are rare and usually considered as peripheral to the general thrust of artefact studies. Few artefact researchers have the knowledge of animal anatomy and faunal analysis necessary to recognise the origins of materials utilised and few faunal analysts have an expertise in the technological aspects of tool manufacture. The development of a system where individual workers are responsible for the study and interpretation of particular categories of material (e.g. lithics, ceramics, metals, faunal material etc.) in relative isolation from each other, inevitably leads to an imbalance in the understanding of the interrelationship of materials as actually exploited on the site under study. What is argued here is not that skeletal studies should follow the same direction taken by those of lithics and ceramics, but that there is an appropriate, wide body of information and expertise which is specific to the study of skeletal materials which needs to be brought into an area of common ground so that sequences of production, circulation, use and discard of particular object classes can better be understood.

On some occasions, however, the study of skeletal materials has been given appropriate prominence, and this work has centred on a number of sites rich in such materials, investigations by a few interested individuals, and research concerned with particular problems which required study of bone objects as part of their solution. The work undertaken in the western world can be examined in terms of British, North European and North American studies.

Within Britain a few sites, and groups of sites, have been considered important enough to have attracted attention because of the wealth of skeletal material found there, or because objects made from these materials formed the majority of finds. Early references to Skara Brae (Petrie 1868; Traill 1868) can be seen in this light and there are several broch sites from the Northern Isles which commanded the same interest. Childe's work at Skara Brae drew attention to the wealth of material from that site (e.g. 1931b) and investigations around the same time at brochs (e.g. Midhowe, (Callander & Grant 1934)) treated all the materials and objects from the sites on an equal basis. Later Clark (1956) summarised the evidence from the 'Obanian' mesolithic sites as a whole and gave an analysis of the post-glacial site of Star Carr (1954). More recently Arthur MacGregor (1974) examined all the objects from Burrian, N Ronaldsay, a substantial element of which was the collection of objects of bone and antler, and Britnell (1977) has studied the assemblage from Cadbury/Camelot. MacGregor's later work (1985), a publication of his M Phil thesis (1980), was not site-based but focused on establishing general principles concerning the structure and properties of skeletal materials, the range of techniques of manufacture and the major artefact categories from Roman times onward in NW Europe. Other work by Newcomer (e.g. 1974) and by Olsen (1984a) has been based at the Institute of Archaeology in London but has largely dealt with a range of sites outside the U.K. The approach taken in this thesis combines the identification of general principles concerning the structure and properties of skeletal materials, their influence on techniques of manufacture and the use of bone, and explores these principles through four detailed case studies. It is only through understanding the material and its technology as part of the general questions concerning site history, development and function, that they can best be interpreted and the interrelationships between materials can be established.

In France and W Europe, another trend can be seen under the guidance of Camps-Fabrer (1974, 1976, 1979, 1982) whose work centres on bone and antler objects and initially concentrated on the rich Palaeolithic assemblages, although more recently attention has been directed towards material from the Neolithic, Bronze and Iron Ages. Most of this work is grounded within traditional typological studies where an object category is examined in isolation, or else the work is site based and restricted solely to the bone and antler objects.

In North America, interest in bone objects has grown with arguments about the antiquity of human settlement within the continent. This has centred on questions concerned with the ability to identify humanly-worked, as opposed to naturally broken or split, pieces, from a range of difficult contexts (Bonnichsen 1979; Morlan 1980). Work based in the USA on ancient sites in Africa has seen the development of techniques which identify cut marks from other, similar lines and scratches (Potts & Shipman 1981). In both continents, the identification of features which are distinctively human in origin is an important matter in interpreting the accumulation of skeletal material. As a result, additional work has been undertaken to establish the differences between natural and human modification (Bonnichsen 1979; Brain 1980; <u>Abstracts: first international conference on bone modification</u>, Nevada, 1984) and these are now quite well understood. It is unnecessary to become involved in the sometimes contorted arguments associated with many of these problems for the purposes of this study, since the status of the excavated material as artefactual is not in question (although a small quantity of naturally modified material has been shown to have been misidentified).

A particularly perceptive piece of work was carried out by Johnson (1985) which recognises the nature of the controversy which has raged in N America over the nature of bone modification. It dispassionately approaches the question of how bone reacts in particular circumstances to stresses and impacts. There is a clear survey of the properties and fracture mechanics of bone and the effect of natural modifications. It concludes, as does the study presented here, that there are bone fracture patterns which are distinctively human and that fracture technology was important. Johnson's work is particularly useful in the extent to which it defines the effects of specific techniques of delivering a blow with, for example, a hammerstone, and the type of fracture pattern which results. Much of what she discusses was independently recognised in the studies reported here. At a more general level Binford (1981) has used faunal analysis and the techniques mentioned above to reinterpret many of the bone accumulations in terms of natural agencies. Use was made of these studies for the practical help it gave in recognising natural patterns.

A number of sites in the Near East have assemblages of bone objects which have been studied to various levels of detail. Newcomer's work on Ksar Akil (1974) involved experimental replication as did Campana's on Natufian material (1982). Semenov's work (1964) on experimental and use wear analysis is one of several important investigative studies in E Europe.

There are definite trends in the study of the artefactual use of skeletal materials which follow regional interests and, of course, their survival. In Britain studies have been pursued more or less independently but there is a developing consensus around the work of A MacGregor, Olsen, the writer and unpublished work by Armour-Chelu and others, as to the range of questions which can be addressed.

MATERIALS SCIENCE AND BIOMECHANICS

Materials science is concerned with the structure and properties of materials and their relationships. Biomechanics is the study of the mechanical properties of biological materials, and materials science and biomechanics combine to analyse the structure of bone, antler, tooth and horn and explore the mechanical implications of those structures.

Such approaches are essential if any understanding is to be gained of how these materials may be worked since their mechanical properties determine how they react to impact, stress, chopping etc. The mechanical properties themselves are determined by the structure of materials and, thus, the origin and nature of these structures must be identified. In life, skeletal tissues are dynamic, in that when the needs of an animal change, as it grows or as the result of injury, the structure of its internal tissue can be modified. Thus the shape, structure and mechanical properties of the bones of a juvenile animal are different from those of an adult beast, and not simply in their gross size and thickness. If a bone or limb is subject to a stress different from that to which it is used, then preexisting bone can be resorbed and new bone laid down to compensate for the change in stress.

Therefore, for example, Minor variations do exist between say one cattle femur and another, but, on the other hand, all cattle femora have particular physical features in common which enable the bone to articulate between the pelvis and the lower leg. It is possible, therefore, to make generalisations about the structure and properties of bone as a material and also about specific bones of particular animals which might act as practical guidelines to anyone working with these materials. Such knowledge would be fundamental to the skill of a tool manufacturer.

The role of materials science and biomechanics in a study of these variations is to explain the physical and biochemical basis for the natural properties of the materials utilised in tool manufacture, and to explore their origin through biological functionalism. The form and structure of individual bones is related to the purpose those bones fulfil within the life of the whole animal. Successful exploitation of these elements for tool manufacture depends on an appreciation of their natural properties. This applies at the microscopic level of the differences in structure between the outer surface of a long bone, where collagen fibres are randomly oriented, as opposed to the middle of the bone, where the structure is much more longitudinally oriented. It also applies at a visual level where the diaphyses of long bones are made from a thick layer of compact bone, but the articular ends have only a thin layer over cancellous or spongy bone (cf. Davis 1987).

FAUNAL ANALYSIS

In archaeology, faunal analysis is the study of surviving animal remains, and these usually comprise broken and partial fragments of bones, teeth, antlers and horn cores. Many types of information can be derived from such studies dependent on the techniques of recovery, the range of attributes noted and measurements taken, and the questions asked of the material recovered.

At its most basic, faunal analysis identifies differing species represented on a site, their relative quantities and ages. More detailed study can indicate the strategies taken in butchering, through analysing which elements of the body are present on site and the location of the cut marks on them. Differential survival has to be considered but, in general, a concentration of parts of the head and the lower limb bones of animals, which showed cut marks across the bones, would usually be interpreted as primary butchering debris related to the skinning of the animal and the removal of the prime meat parts to other areas of the site. A large number of split vertebrae would be the debris after the meat from a split carcass had been removed. Cut-marked bones from the prime meat areas, such as the haunch, would be evidence for the removal of meat before or after cooking, and a pile of split long bones implies marrow extraction. Patterns are rarely clear cut, but it is often possible to identify the various stages from kill through butchery, to disposal of the debris by examining the distribution of faunal remains on site and establishing what parts appear to be missing (cf. Grigson 1981, 169-70, 176 for red deer).

The main use made of faunal analysis here is to identify which species might have been available for exploitation to the inhabitants of the particular sites under investigation - the potential range - and which were actually used. It is necessary to establish which animals were important as sources of meat and so it is not simply a case of considering relative numbers, but also taking into account meat weight. Once a general feel for the relative importance of particular species has been gauged, the animals exploited for bone are identified, and the two compared. Usually the antlers of red deer feature more often than their bones would suggest, but this is a result of the collection of shed antler for tool manufacture. Within each species the actual bones used are identified and their relative importance discussed.

It is useful to be able to view faunal analysis as giving information about the husbandry and butchery practices on a site, since it is by linking these with the strategies for exploitation of the whole animal that insight is gained on general attitudes to animals. Care must, however, be taken not to equate generalisations derived from the study of deadstock with the actual maintenance of livestock as the two may not coincide.

One way of viewing the resources which animals provide is in terms of primary and secondary products. Primary products are those which are released with the killing and butchery of an animal - hide, meat, bone, sinew and other soft tissue. Secondary products are those which are obtained from a live animal - e.g. milk, wool, dung and traction (Sherratt 1981; 1983). Clearly there are advantages in keeping animals alive if they can provide a range of useful products, but in any economy, the keeping of animals or the exploitation of wild creatures must leave a viable breeding stock and this consideration will also guide which animals are kept alive.

As an indication of the range of products which might be available from slaughtered animals, modern butchery practice may be considered (Meat and Livestock Commission 1977, 1983, nd; Meat and Livestock Commission & Institute of Meat 1980). Apart from the meat itself (Fig 2.1), there are the fat, blood, liver, kidney, heart, tongue, brain, lungs, sweetbreads and melt all of which can be eaten, as well as other soft tissues such as tripe and chitterlings and the marrow from the bones. Raw materials for further use include the bone, antlers and horns, if they are present, the hide for use as skins with the hair (or wool) still attached (or removed for leather production), a wide range of fats and offcuts which can be rendered to provide tallow, oils and fats, as well as protein meal (such as bone meal) and soft tissues, such as the stomach and intestines, which can be made into containers. The sinew and the intestines can also be cut to provide filaments which are fine but strong. Grigson (1981, 176) quotes a similar resource list for the exploitation of seals. It is likely that any formal butchering strategy will maximise the use which can be made of a carcass, but this will always be within the cultural perceptions of what is acceptable. For example, Halal and kosher rules concerning food not only ban particular species, but give requirements as to how those which are acceptable should be prepared. Kosher beef and lamb can only come from the forequarters of the animals and the major arteries and veins are removed. Such avoidance of species which are available for food might be detectable as an absence within the faunal assemblage derived from food processing, as should the selection or avoidance of particular parts of the body. There is no reason to believe that such dietary rules were not practised in prehistoric times whether they were articulated explicitly, as with kosher and halal, or more deeply embedded and implicit as in the British attitude to horse and dog meat.

The role of faunal analysis is therefore very important in establishing the species and parts of species which were available in the area and/or being exploited on a site, and in helping to identify where particular practices were carried out. For most of the sites discussed here, however, there is only minimal information on bone debris from non-artefactual activities and for Risga, even the species list is not trustworthy. As for the use of bone, it is difficult to be certain at what stage bones were used for implement manufacture. For example, the lower leg bones are some of the most frequently utilised elements. These carry very little meat indeed and would have been released during the preliminary stages of butchery. The scapulae, on the other hand, need to have muscle cut from them and this usually takes place as part of the general butchering of the body of the animal. The question of when bone was worked is discussed in the following section.

TECHNOLOGY, UTILISATION AND EXPERIMENTATION

The use of the term 'technology' is in a very broad sense and with the range of meanings understood by Stuchlik (1976, 10)

> 'Technology (is) built up of knowledge, skills, methods, recipes, tools, equipment etc.'

This suggests that technology comprises mental and physical elements which are brought into being through action and that objects which are used must be seen as one part of a larger whole. The physical material element has a reflexive relationship with the other parts of this whole in the manner suggested in Foxon (1982). Utilisation is one of the aspects of technology which relates to the selection of resources, tool manufacture and tool use.

The forms of analysis one applies to the study of technology and utilisation vary according to the types of question being asked. All draw on observations made of the objects, debris or the archaeological context of their discovery. The identification of raw material (i.e. which animal of what age and which bone) draws on comparison of diagnostic features present on the pieces studied as compared with bones of known origin, taking into account differences in breed and nutrition. The study of techniques of manufacture relies on being able to distinguish marks made during manufacture from natural features on the bone; the effect of root action; of acids in the soil; of gnawing by rodents, carnivores and deer; erosion caused by wind, water and sand; and breakage by trampling. Most of these features are now well defined and there should be little confusion between deliberate working and their effects (Bonnichsen 1979; Binford 1981, 35-86, Olsen 1984b). The recognition of fracture patterns can, however, be quite difficult since humanly-induced fracture simply makes use of the natural properties of bone to produce a response similar to any other form of impact. Several studies have begun to define the differences (e.g. Morlan 1980; Myers et al. 1980) but much of the debate centres on material which is not in a secure archaeological context or is dubious in origin; a situation which is not the case with most of the material discussed here. Johnson (1985) has admirably set such study back in the right direction.

The working of bone, antler, tooth and horn are subtractive manufacturing processes. As a result each technique used will tend to remove the traces left by the previous technique. Utilisation equally the marks of manufacture. Bone objects are, therefore, like palimpsests and require skill to interpret.

The practical problems of carrying out experimental work on bone are many. Only the bones of modern breeds are available, mostly fed with food supplements and it is difficult to assess how close modern materials are to ancient ones as the latter cannot be tested in the same way as the former since they have undergone chemical changes during burial in the ground. Many of the bones which were utilised in the past are the very ones which are disposed of at the abattoir and before releasing such bones for modern experimental work, meat inspectors have to be convinced that the enquirer's intentions are genuine and that there are suitable methods of disposal of unwanted bone and soft tissues which will cause no harm to the experimenter or the general public. Since the handling of fresh cattle metapodia brings one in contact with dung, blood, hide, bone, muscle and marrow and techniques such as fracture result in the liberal distribution of these, the best facilities are provided by rooms which can be thoroughly scrubbed and cleaned, or by working in the open air. Safe disposal of tissue is also a problem. Burial is a possible short term solution, though care has to be taken that bones are not dug up. Access to a medical or veterinary incinerator is ideal.

Personal observation, supported by Olsen (1984a, 43-45), suggests that the 'best' time to work bone is as soon as it has been cut from the carcass, since at this stage it contains most of its natural liquids and fats and is covered with the thin membrane of periosteum. If the periosteum is removed the bone begins to dry at a rapid rate, hairline longitudinal cracks form and the bone gets more difficult to work because it has become more brittle and less elastic.

The techniques of manufacture practised for this work have already been mentioned above. In order to try these techniques out it was necessary to acquire bones from recently butchered animals so that it was as fresh as possible and unaffected by freezing, washing etc. Abattoirs, specialist butchers and ordinary butchers supplied the raw materials. Such work requires an understanding of modern butchery practice so that, for example, metapodia are collected from an abattoir, mandibles from an offal butcher and scapulae and femora from an ordinary butcher. For fracturing and heavy experimental work, an outdoor location was found most satisfactory. Provided the area used was not a hazard to children or animals, outdoor work substantially reduced the need to clean surfaces, although fragments of bone were inevitably lost in grass or soil. Work was usually undertaken over a heavy duty plastic sheet, so that fractured fragments could be recovered. Some bones were stripped chemically and others boiled in order to preserve them once features on their surface had been photographed and recorded. Most were recorded and then either buried directly, or after further modification and use, so as to provide longer term, examples of the effect of burial on bone surfaces.

How can the marks of manufacture and utilisation be identified and interpreted? The main sources of information about such matters are experimental working and the observation of objects whose manufacturing and use history is known. Several workers have independently undertaken experimental working (e.g. Sadek-Kooros 1972; Newcomer 1976; Murray 1979; Olsen 1979, 1984a; Galloway & Newcomer 1981; Campana 1982; Johnson 1985) and some areas are now well documented, such as the diagnostic features of the use of lithic tools and the different patterns left by them.

For the study presented here, basic experimental work was undertaken which involved fracturing, scraping, trimming, grinding and polishing of a number of skeletal elements when fresh, dry and after soaking. The effect of experimental fracture of fresh bone can be seen in Pls 5.1, 5.3 and 5.4. These illustrate a cattle femur which has been taken and struck mid-shaft with a small number of blows placed as closely together as possible until the bone was heard to crack and split. Initially blows were deflected by the periosteum, but after two or three strikes this was damaged, and allowed direct contact with the bone itself. Fracture was rarely achieved with a single blow, and so the pattern of breakage was complicated by the effect of several contact points. Even if attempts are made to strike exactly the same part each time, it is rarely possible to be completely accurate.

If large hammerstones (Pl 5.2) are used to make initial fractures this will usually leave the epiphyseal ends unbroken, but with some parts of the diaphysis still attached. Most of the shaft of the diaphysis will split into a number of segments of different sizes, depending on the type and location of blows struck (Pl 5.1, 5.3). A fracture technique can then be used with a smaller hammerstone (Pl 5.2) in a manner akin to flint knapping, in order to drive flakes from a platform on the bone (Pl 5.4).

Scraping, trimming, grinding and polishing have been more commonly recognised by other writers and can easily be tested with a piece of bone of any reasonable size. Simple tools of pumice, flint (Pl 5.2), stone and metal were used to shape and sharpen bone objects and the differing surface marks left by these tools were examined. The features recognised are paralleled in the works already mentioned and were studied visually and microscopically up to 400 x magnification and compared with objects considered here. Most of the features recognised on the genuine implements were possible to replicate, though allowance has to be made for post-depositional effects on the bone tools which may obliterate the diagnostic features. Different features dominate at different magnifications.

The term 'microwear' analysis is often used in lithic studies to identify the microscopic examination of use-wear patterns. Here it additionally encompassed marks of manufacture. It was felt important to specify the effect of various techniques of manufacture at differing magnifications. Certain features are visible at low magnification and, indeed, to the eye alone and these enable one to distinguish the range of raw materials of which the manufacturing implements were made, as well as the basic techniques of manufacture themselves. In order to establish the existence of marks of manufacture, it is also necessary to recognise marks of use which may have obliterated some of the former. In most cases this was possible, but distinguishing between striations and polishes on utilised surfaces was found difficult and did not present the coherent microwear pattern claimed for some lithic materials. The main reasons for this lack of clarity are likely to be the less durable nature of bone when compared with lithic materials and the effect of soil movements, handling and cleaning.

Chemical changes in the soil and bone mean that original surfaces on bone tools will deteriorate and it is rare that such surfaces will survive to the present day completely intact. Frequently even the best preserved pieces have been affected by root-etching and acid-pitting. The surfaces of a bone can quickly become polished by handling and by brushing. Thus, most techniques of dry and wet cleaning, and any rubbing of the bone surface, will affect marks of manufacture and utilisation, and as a result, most of the work presented here is based on the study of marks of manufacture which have not been affected by use-wear. However, there is little doubt in the writer's mind that use-wear analysis of bone tools is feasible and would be productive on sites with the appropriate degree of preservation. It would, however, be necessary to provide details of exactly what cleaning and handling there had been of the assemblage. A long term programme on the effect of soils on bone tool surface microtopography would be required, and whilst some preliminary study was undertaken in the course of the work presented here, it was not enough to establish definitive and diagnostic results.

In its approach, this work was not strictly replicative since complete objects were not always made nor, perhaps, was it structured well enough to be properly termed experimental (cf. Coles 1979, 46-48). Nonetheless individual techniques of manufacture were studied, and discussion with Olsen in particular suggests that the identifications established for this study have been replicated by other workers.

ARCHAEOLOGICAL CONTEXT

The location in which objects or debris were disposed of in the past is important to their interpretation, since this is our best indicator of which objects were associated. The archaeological record is a 'static contemporary phenomenon' (Binford 1981, 25) but by trying to understand the generative principles which brought it into being it is possible to construct images of the potential dynamic systems which produced them. It is important to realise that the archaeological record is not the result of natural processes but is meaningfully and culturally constructed. We may never be able fully to identify the original intended significance of the objects we excavate, but if we are to interpret archaeological deposits in any realistic manner, it is necessary to speculate on what the cultural, social and material conditions of life were.

In examining archaeological deposits, distinctions are sometimes made between systemic context and archaeological context (Schiffer 1972; 1976). Systemic context refers to the situation in which an object is being actively 'used' (in the broadest sense of the word) within its original society. By archaeological context is meant the static three-dimensional deposit in which an object has been incorporated. At the time of discard, disposal or burial, objects move from systemic context to archaeological context and, usefully, this approach views the archaeological record in terms of the actions which created it. Modifications to that record take place as the result of decay, destruction, discovery and recovery, all of which act as filters for information. The question is how to represent properly this dynamic, historical dimension of the record. Schiffer (1972) defined c-transforms and n-transforms in studying the archaeological record where c-transforms relate to the general statements which can be made about the stage at which an archaeological object is deposited in terms of its life cycle of procurement, preparation, manufacture, use, consumption and discard; and n-transforms are post-depositional processes such as decay and erosion. N-transforms are subtractive from the archaeological record and bear a close relationship to taphonomic studies.

Making judgements about what may have failed to survive, and even being able to indicate at what stage in its life cycle a particular object was deposited, does not go far enough. It is an important preliminary method for addressing what might be called 'social context' (Foxon 1982) which may be seen as the dynamic location of an artefact or action in terms of its meaning to the people who originally used it. It is important to address such questions since it was within particular societies with their own cosmology and value systems that objects were made, deposited, abandoned or lost in the first place and any explanation of distribution patterns must take this into consideration.

There are several ways of moving from the archaeological context to social context and that chosen here focuses on technology and utilisation as broad principles. The archaeological context of individual finds is examined, the position of the material in a production-use sequence is studied and, making use of the general principles of the techniques of manufacture, utilisation and discard, specific explanations are sought for the patterns seen. This is distinct from what Binford (1981, 21-30; 1982, 160-63) terms 'middle range theory' which seems to treat patterns within the archaeological record as independent of the ideational basis within which past peoples were living: a basis which structured the choices which could be made about what animals to use, what tools to make, where it was appropriate to dump refuse, the right way of abandoning a house etc.

Since this study relates to one material category, the level of explanation proposed is low. Indeed, this work begs as many questions as it answers. Such approaches do, however, refine and redefine the questions asked and allow other sources of information from archaeological sites to be incorporated.

METHODOLOGY

Methodology is taken to be the organisation of ideas which enables theory to be linked to method and technique. The theoretical stand taken here is a rather eclectic one which owes a debt to structural marxism and critiques of it (e.g. Kus 1982, Shanks & Tilley 1987), though the approach taken here might not be found acceptable to purists because of its eclectic nature. Work by Giddens (e.g. 1976, 1979, 1981, 1984) has been found stimulating and useful; in particular his theory of 'structuration' which relates to the reproduction of social practices. He sees a distinction between social systems - patterns of relationships between individuals or larger groups in time and space ('situated practices'), and social structures - the moments in which the production and reproduction of systems takes place. There is a reflexive, indeed recursive, relationship so that structure is both the medium and the outcome of social practice.

The implication of this for the study of material culture is that rather than simply being an extrasomatic means of adaptation comprising the tools created to fulfil universal functions, it must be viewed as significant and meaningfully constituted within social practices and having a dialectical relationship with those practices. Material culture therefore plays an active role in social practices and the significance of individual objects will be developed within the different social contexts in which they are used and which they themselves construct (cf. Shanks & Tilley 1987, 79-117).

In interpreting archaeological material, this active role of artefacts is not observable, but, as with all the aspects of things social, must be attributed after investigation. To a certain extent this requires an attitude of mind rather than, necessarily, changing the techniques of analysis one would apply. Attention should, however, focus on establishing similarities and differences in the patterns of buildings and the distributions of objects and debris. Archaeological deposits are rarely random accumulations and patterning within deposits should be explored in order to ascertain whether the patterns might reflect in situ working, decisions made about the deposition of rubbish or deliberate deposits related to religious belief or daily ritual. Raw material acquisition and the effective use of resources will not necessarily follow the line considered to be the most efficient by modern standards. Ideas such as optimal foraging theory (Winterhalder 1981) are useful in modelling the maximisation of resources but do not easily allow for things cultural to show through, i.e. since culture is meaningfully constituted, maximisation must be defined within each context in relation to the value systems of the society concerned. Whilst there may be generalisations which apply to most situations, any explanations of the detail of individual sites must relate to that site as unique and examine what is present as well as the things that are absent, (such as the broad absence of deer bone at Skara Brae).

An approach to the past through technology and utilisation has many advantages for this kind of study, since they are concerned with cultural and practical attitudes to a range of potential resources and the choices which can be made about which to use and in what way. Sometimes these choices relate to which bone, and sometimes to which material (e.g. bone, antler, bronze), should be used to make a particular tool according to how the finished object itself will be used. The study of the interrelationship of materials is an important one, provided that the range, quantity and quality of potential original resources available can be gauged. Distributions on site carry information about the disposal of objects and also their likely patterns of use. When combined, all these components give a picture of the role of a range of materials within a number of individual societies.

CONCLUSION

The areas described in this chapter - a review of work by other writers; materials science and biomechanics; faunal analysis; technology, utilisation and experiment; and the study of archaeological context - were the techniques used in examining the objects and sites discussed here. Some of the problems associated with each technique have been mentioned. The most difficult was achieving a methodology in applying these techniques.

Any perspective which emphasises a holistic view has problems of focus. Bone, antler, tooth and horn are only one small material category within the repertoire of a single society. A procurement strategy links in with that society's approach to maintaining and exploiting animal populations as a whole. Tool manufacture and utilisation are affected by a cultural perception of materials, tools and their interrelationship. To attempt to 'explain' bone tools is to attempt an explanation of the whole of society.

Such a total analysis could only be attempted obliquely in this study since the information about other material categories was not available to the same degree. What has been possible is to show how a particular holistic perspective can open up a range of questions about the use of skeletal materials, and help to integrate conclusions about material use with broader approaches towards the significance of individual objects and categories of material culture in general.

In many cases the 'significance' of individual objects may be almost entirely utilitarian, and it is important not to confuse significance with symbolism. Nevertheless, individual assemblages were studied in order to provide a series of descriptions relating to manufacture, classification and distribution so that broader questions about the nature of the site might be addressed. As already suggested, the results of such study are not clear answers to those questions, but rather a redefinition of these questions which offers scope for re-interpretation of sites when links can be made with parallel studies of other material categories.

CHAPTER 3
THE STRUCTURE OF SKELETAL MATERIALS

This study deals with the skeletal materials available from terrestrial mammals since these are the materials most frequently utilised on the particular sites studied. Additional information concerning marine mammals, fish, birds etc. is given as appropriate.

The four natural materials - bone, antler, tooth and horn - chosen for study can all be classified as skeletal hard tissues. They have a relatively rigid, self-supporting structure which distinguishes them from the soft tissues and organs of the body which have a higher relative fluid content. Thus they form a separate class of materials but the four individual materials do, in turn, have different structures. Bone and antler are related calcified tissues and have substantial organic and inorganic components (mainly collagen and hydroxyapatite respectively). Teeth are composite structures of highly mineral enamel, bone-like dentine and cementum, and the soft tissue of the pulp. Horns are substantially organic, being made of keratinous hard tissue.

All are natural growths but their methods of growth and modification differ. Once a bone begins to form in an animal, it remains with it throughout life, and modification or remodelling of the bone means that its final form is the result of a long and complex history. Antlers are annually shed bony extensions of the pedicles, i.e. two protuberances on the front of the skull of male red and roe deer, and present on both male and female reindeer. In contrast, non-deciduous teeth, once erupted, remain in the mouth to be worn down by continual use. Unless they are lost by accident or affected by decay, the only modifications which change them in life are incremental growth and wear through masticating food. Horns are keratinous sheaths which cover a bony process (the horn core) of the skull of cattle, sheep, goats and some other animals. These also grow incrementally. Bones, antlers and teeth are relatively brittle materials, but horn can easily be rendered malleable and plastic by heating or boiling.

Antlers and horns may be obtained from the animals which bear them whilst they are still alive. In addition, shed antlers may be picked up from the ground without direct contact with the animal itself. Horns, along with their cores, are quite often removed from young animals, or trimmed down on older animals if they have become sharp or dangerous. Whilst teeth can be removed for use from a living animal (or deciduous teeth collected if they are not swallowed) it is better to treat them as materials which are unavailable unless an animal has been killed and butchered. It is these differences in properties and their frequency within the body lend bones, antlers, teeth and horns to the varying uses to which they were put.

BONE

Much of what is said concerning bone in general is applicable to antler, since antlers are similar to bone in a chemical and micro-structural sense. Though they must be considered separately in terms of visual and gross morphology. These in turn are important differences because gross morphology and absolute size in three dimensions are amongst the major limiting or influencing factors in the choice of particular bones or antlers for tool use. Also the final size of the objects is unlikely to be less than that of the original raw material. Because, unlike horn, these are non-plastic materials and parts must be removed to make an object.

In this study a number of texts were found of general use. Individual detailed references for information gathered from these many overlapping sources is felt unnecessary. The following are those which have guided the work undertaken at a general level: Bourne (1956); Currey (1970); Griffin & Novick (1970); Halstead (1974); Ham (1969); A MacGregor (1980, 1985); McLean & Urist (1968); Schmid (1972); Vaughan (1975); Vincent (1982); Vincent & Currey (1980); Wainwright et al. (1976).

Bone serves two basic functions in the bodies of mammals. Firstly, it forms the basic structure of the body, being a stable framework for the other tissues and organs. Secondly, it forms a reservoir of minerals for the whole body which may be deposited or removed at any time in order to maintain mineral stability (Vaughan 1975, 23). Whilst the latter function will affect the structure and properties of the bones of particular animals, in that variations in mineral distribution will occur, it is primarily the structure of bone resulting form its function as a body framework that it is discussed here.

MORPHOLOGY OF BONE

The shape and size of the many bones in the body vary quite dramatically. Fig 3.1 shows the skeleton of a cow,and whilst the size and shape of specific bones vary from animal to animal, according to size and method of locomotion, vertebrates in general exhibit the same basic structure. The form of the bones is related to their function, and their scale in a particular animal is a maximisation of efficiency in response to the various purposes which they serve within the body. Therefore, bones can be grouped together in several ways.

SINGLE ELEMENTS and DOUBLE ELEMENTS

This classification emphasises the symmetry of the body. From a dorsal view, there is an axis of symmetry following the line of the cranium, vertebrae (including the atlas and epistropheus) and pelvis, with the caudal vertebrae behind. To either side of this axial line there are the forelimbs - scapulae, humeri, radii and ulnae, carpal bones, metacarpals and anterior phalanges. Underneath the scapulae lie the ribs which are attached to the anterior vertebrae. The hind limbs, attached to the pelvis, consist of the femora, patellae, tibiae and fibulae, tarsal bones, metatarsals and posterior phalanges.

CRANIUM

The cranium consists of the mandible and a series of bone plates connected together to form a protective covering for the brain (Fig 3.2). This covering is shaped and perforated so as to allow sockets for the eyes and the attachment of the ears and aural canals which have to link to the brain. The premaxillary and maxillary plates house the upper set of teeth which are opposed to those in the mandible. The nasal plate forms the basic bone support for the nose and the front of the face has large areas for muscle attachment to enable facial movement and mastication. Those deer which bear antlers, and cattle, sheep and goats which bear horns, also have outgrowths of the frontal plate to form the pedicle and horn core respectively.

VERTEBRAE

THE ATLAS

The atlas (Schmid 1972, 96) is the basis of the neck. It supports the head, enables it to be turned and is the first of a series of axial bones which contain and protect the spinal chord. Muscles are attached to it to enable the whole head to move.

THE EPISTROPHEUS

The epistropheus fits into the atlas at its cranial end and forms what may be considered the second of the vertebrae which are attached in a line from its caudal end.

OTHER VERTEBRAE

The other vertebrae continue to form a protective covering for the spinal chord and provide the main support for the trunk, being set in such a way that they naturally resist the compressive force of gravity in both quadrupeds and bipeds. Dorsal vertebrae also form the attachment for the ribs. The shape of the other vertebrae in the body reflects their position and function there. They may be split into five groups on this basis (Schmid 1972, 94) - cervical, dorsal, lumbar, sacral and caudal. Cervical vertebrae have a large dorsal spine and joints for rib attachment. Lumbar vertebrae have less prominent dorsal spines, no joints for rib attachments and well developed processi transversi. The sacral vertebrae are very closely grown together so as often to be completely fused into one. The size and number of caudal vertebrae varies with the size of the tail of an animal. Compared to other vertebrae, they are small, have only minor processes and, towards the end of the tail, are virtually no more than cylinders of bone with very slight extensions.

THE PELVIS

The pelvis (Schmid 1972, 102) consists of two each of the ilium, ischium and pubis which join together with the sacrum to form the pelvic girdle. The former six bones grow together to create the single pelvis in the adult. The pelvis allows hind leg locomotion, links with the vertebral column by attaching to the femora and enables defecation and the birth of offspring to take place.

THE RIBS

Attached to the dorsal vertebrae, the ribs form a protective cage for the heart, lungs and other vital soft organs of the body. As such they also provide a relatively rigid base within which these organs are contained.

THE SCAPULAE

The scapulae (Schmid 1972, 100-01) are jointed to the clavicle (though not in ungulates) and are attached to the humerus. The large, flat blade of the scapula provides a surface from which major muscles link the trunk and the forelimb.

THE BONES OF THE LIMBS

In many respects the fore and hind limbs can be treated together, in that they have the same number of principal bones and are organised in similar ways. The two main functions of the limb bones are to support the main trunk of the animal and to enable locomotion. These bones tend to be long cylinders with expanded ends. The cylinders are not made of solid bone i.e. they often have bone marrow inside them, or, in the case of birds, air. They also have surfaces for the attachment of muscles, tendons and ligaments. In cetaceans (the Order of sea mammals including dolphins, porpoises and whales), the limb or paddle bones contain a large quantity of cancellous tissue.

HUMERI AND FEMORA

These are the proximal long bone elements of the limbs and have ball joints proximally with a hinge joint distally. They tend to be thick strong bones (Schmid 1972, 106-13).

PATELLAE

The patellae only occur on the front of the hind limb and are small sesamoid bones, articulating either to the femur or to the femur and tibia.

RADII and ULNAE, TIBIAE and FIBULAE

The two pairs of bones are articulated. In some animals (ungulates) the radius and ulna are fused. In ruminants there is no real fibula, but simply a proximal spur on the tibia (Schmid 1972, 114-23).

CARPAL and TARSAL BONES

These bones consist of a group of 'wrist' and 'ankle' bones which enable the 'hands' and feet to turn. The tarsals tend to be larger than the carpals and have, as their largest component, the astragalus and calcaneus.

METACARPALS and METATARSALS

There is a large amount of variation in the metacarpals and metatarsals of different species. In the ruminants they have fused together to form one bone per limb. In horses there is one main bone with two thin bones on either side. Pigs have four metapodia in each limb, the outer two of each group being reduced in size. In humans, there are five metapodia - one for each finger or toe.

PHALANGES

The phalanges are the true finger and toe bones and again their number depends on the particular development of the lower limbs of each animal. In general, there are three phalanges for each metacarpal and metatarsal. Thus, pigs have twelve phalanges per limb. Ungulates have six per limb forming two 'toes' which are joined to the condyles of the metacarpals and metatarsals. Occasionally the number of phalanges is reduced from three to two.

Bones, therefore, form a complex structural mechanism for the body. They are the strong girder-like basis which provides support for the fleshy parts; they enable locomotion by providing levering joints and surfaces for the attachment of muscle, tendon and ligament; they resist the force of gravity to keep the body able for locomotion and they form protective enclosures for many of the vital organs - brain, heart, lungs, liver, stomach and kidneys (Brown 1975, 314).

The shape of individual bones is related to the specific functions they fulfil within the living animal. The bones of the limbs are primarily concerned with locomotion and are, therefore, strong cylinders able to endure the considerable longitudinal tensile and compressive forces which result from movement. In mammals, the central cavity is filled with two types of marrow (Brown 1975, 320): yellow marrow which consists of fatty tissue and, particularly at the extremities of bones, yellow marrow mixed with red marrow which is a haemopoietic tissue, essential for the maintenance of the blood supply. Protective bones such as the cranium and ribs are lightweight, thin bones capable of absorbing impact. The facial area of the cranium, the neck, scapula, pelvis and parts of the limbs have processes and flat surfaces for muscle attachment. The vertebrae are both protective to the spinal chord and resistant to the compressive and tensile forces encountered as effects of gravity and movement.

Bones are relatively strong, rigid elements within the complex, integrated anatomy of the body. Although space cannot allow a full discussion of the relationship between the hard and soft skeletal tissues, and the biochemical symbiosis of bone and the organs of the body, bone should not be seen as chemically, biologically or physiologically isolated within animal anatomy. It is the jointing of the bones, something which is common to all animals with endoskeltons, that enables an otherwise relatively rigid material to have flexibility (Griffin & Novick 1970, 27). Since bone can grow and modify according to the circumstances in which it exists and the influences which come to bear on it, many different shapes are formed. This range of variation and differentiation in form and function is also evident in the various levels of structure of individual bones.

FORMATION OF BONE

There are two processes by which the ossification of living and growing bone takes place - endochondral and intramembraneous ossification. (Ham 1969, 397-401; McLean & Urist 1968, 20-29; Vaughan 1975, 14-17). Despite there being two mechanisms for bone formation, there is no consequent difference in the bone formed.

Endochondral ossification allows growth in length in e.g. the diaphysis of long bones (Fig 3.3). A cartilaginous preform of the bone grows and gradually the chondroblasts, which produce cartilage, and chondrocytes, which live in and maintain it, die in the area of calcification and it proliferates in osteoblasts. These lay down bone tissue and calcify the cartilage. Osteoclasts are also involved in order to enable remodelling of the surfaces. As more bone tissue is laid down, the osteoblasts are enclosed and develop into osteocytes. The process continues until all the cartilage is ossified.

Intramembraneous or appositional growth allows growth in width and is simpler in concept. No preform of the tissue in cartilage is made. Osteoblasts lay down bone matrix on the surface of preexisting bone and they are enclosed by the bone, again differentiating into osteocytes. This is a mechanism more common in endoskeletal animals and a large amount of appositional growth takes place at the outer surfaces of e.g. long bones. The tissue which covers a long bone surface, the periosteum, is an area of high activity.

When bone growth reaches a mature state ossification decreases in magnitude. Bone modelling and remodelling does not stop, however, since osteoblasts, osteocytes and osteoclasts respond continuously to the varying needs of bone metabolism by local intramembraneous growth.

During the life of animals, one major change which may affect bones is injury. Under such circumstances the various bone cells become highly active again and such damage and repairs as are effected will alter the structure of individual bones.

PROBLEMS IN THE DISCUSSION OF LEVELS OF STRUCTURE

General statements made about a species, or, indeed, the structure of bone in all species on the basis of particular studies, must be bound by the nature of generalisation. The utility of such results is determined by the nature of the questions under research, the methods of investigation and the quality of results. Sufficient research has been undertaken on osteology to show that there are broadly similar patterns, but that there is also a wide range of variation and complexity which must be taken into account. Since it has already been suggested that the dynamic nature of bone enables it to change and develop its structure according to the needs of individual animals and specific environmental circumstances, it should be clear that what holds for a mid-shaft section of an adult cattle femur will be of only limited applicability to a section of juvenile rat skull or even to the distal shaft section of an immature cattle femur. Such variations are even more important when they affect the physical properties of a bone in tool manufacture. The information available concerning the structure of bone is directly influenced by the methods used to obtain this information and the source of the material used in the study. The first problem is that much can be said of the organisation of human, rat, chicken and guinea pig bone simply because human bone is of concern and interest in modern medicine and the other three are creatures often used in laboratory experiments. It is rare for sheep or deer bone to be studied, but cattle bone has been used in a number of cases (Piekarski 1970, 215-23; Smith & Walmsley 1959, 503-23). Two other problems result from the dynamic nature of bones. Often the pieces of bone which have been studied are cut sections of a particular element and results from such examination can only have definite validity for the specific part of the bone chosen and for the particular individual of a particular age.

STRUCTURE OF BONE

At a visual level, bones consist of two structural types - compact and cancellous tissue. Compact tissue appears solid and forms the diaphyses of long bones as well as the surfaces of most other bones.

Cancellous (or spongy) tissue is more porous and is made up of a complex architecture of trabeculae. It is found in the interior of the epiphyses of long bones and underneath the compact surface of other bones. Despite these visual, gross differences, there is no great variation in the more detailed structure of compact and cancellous tissue.

Bone has two main components - one organic, the other inorganic and along with the water present in the naturally occurring fluids, these components make up virtually the total weight and volume of bone. The nature and quantity of the organic component varies with the stage of growth and development of the specific bone and animal (McLean & Urist 1968, 45-71; Vaughan 1975, 57-60). What is clear, however, is that this organic component is protein and that the major protein is collagen (Rouiller 1956, 107-47) with the rest in the form of polysaccharide complexes.

Collagen is a complex protein which forms fibres or fibrils made up of tropocollagen macromolecules (Vaughan 1975,60-65; Vincent 1982, 146-47; Woodhead-Galloway 1980, passim). There are gaps of about 41 nm between the molecules (Vaughan 1975, 62) which are themselves c. 1.5 nm thick, though Brown (1975, 14) suggests a diameter of 1.1-1.4 nm. The collagen fibres in bone have a definite linear orientation, are about 50 nm thick (Wainwright et al. 1976, Fig 5.14), are arranged closely together and often interlink (Currey 1970, Pl 2).

The inorganic component primarily takes the form of hydroxyapatite crystals (a form of calcium phosphate) with other minerals in smaller proportions (Vaughan 1975, 104). There is also some amorphous calcium phosphate. The crystals of hydroxyapatite have a very close relationship with collagen in bone and form in the gaps between tropocollagen macromolecules (Vincent 1982, 146). The space available for crystals in collagen fibrils would account for 50% of the mineral phase of bone. The initial deposit of crystals is succeeded by deposition within the fibrils in addition to the gaps, though the resultant structure and the mechanism which produces it are far from clear (Brown 1975, 333). In mature bone, the hydroxyapatite crystallites are oriented parallel to the collagen fibres. Estimates of the size and shape of the crystals vary dramatically. They are either needle-like or plate-like in shape, and whilst a thickness of 5 nm is now generally accepted (Carlström & Engström 1956, 168-72; Katz 1980, 138; McLean & Urist 1968, 57; Vaughan 1976, 104-06; Vincent 1982, 147), various estimates have been obtained for the other dimensions. Two discussions suggest values of 20 nm and 40 nm for the other two dimensions (Katz 1980, 138) or 35 +/- 15 nm for the c-axis (Vincent 1982, 147). Whilst these estimates are relatively close, they still perpetuate the disagreement as to whether the crystallites are needle-like or plate-like - a problem caused by the nature of the techniques of study used. We may thus view bone as consisting of a fibrous collagen matrix within which is bonded a series of very small hydroxyapatite crystals linearly aligned to follow the orientation of the collagen fibres (Fig 3.4a), though the exact nature of the relationship is uncertain (Carlström & Engström 1956, 168-72).

An important but separate component of in vivo bone is fluid. Water-based fluids are the constant companion of bone in life and enable the nourishment of the living cells within the bone and its remodelling. Bonnichsen (1979, 7), perhaps following Eastoe (1956, 82-83), claims that bone in vivo consists of 20% water by weight but this seems unsupported by any other published results.

Currey (in Wainwright et al. 1976, 169-73) has classified the various arrangements that these components of bone adopt as follows (Fig 3.4).

WOVEN-FIBRED BONE AND LAMELLAR BONE

In woven-fibred bone (Fig 3.4b) there is generally no preferred orientation for the collagen fibres. Rather, they form a tangled mass in which the apatite crystals do not always follow the orientations of the fibres. Woven-fibred bone is the first bone to appear in the development of the foetus (Halstead 1974, 64ff; Vaughan 1975, 5) and in the repair of fractures.

Lamellar bone (Fig 3.4c), however, consists of collagen fibres which form distinct layers (=lamellae). There is a tendency for the fibres within a particular lamella to have a preferred general orientation, although this situation is complicated by the fact that they also form 'domains' within a lamella. In these domains the collagen fibres are more or less parallel to each other. They do not, however, necessarily lie in the same direction as the general tendency in the lamella. Thus, two levels of organisation are represented, that of domains and that of domains within a lamella. Each lamella is about 5 microns thick and domains tend to be c. 30-100 microns wide. What makes each lamella distinct is the discontinuity caused by a change in direction of the general tendency and this results in a rather abrupt change visible between lamellae. There may also be a thin sheet of interlamellar bone between lamellae which is pierced by occasional fibres passing from one lamella to another.

Woven-fibred bone and lamellar bone are the basic units of the next levels of organisation - woven bone, primary lamellar bone, Haversian bone and laminar bone. In order to live, bone needs to have access to nutrients. This is achieved by osteocytes which lie in small sub-spheroidal lacunae which are 35 x 110 x 110 microns in size (Currey 1970, Plates 9 and 10). Blood channels in the bone link the main blood supply of the body to the osteocytes which then distribute nutrients by means of smaller canaliculi c. 0.2 microns in diameter (Wainwright et al. 1976, 172). All types of bone have these cells and cell processes.

Woven bone (Fig 3.4d) is simply made of woven-fibred bone, just as primary lamellar bone (Fig 3.4e) consists of lamellar bone. Within woven bone, the blood channels and canaliculi run randomly, whereas in primary lamellar bone, they tend to follow the same orientations and structure as the lamellae themselves. At this level lamellar orientations relate to the morphology of the individual parts of the bone.

Both woven bone and primary lamellar bone may be modified by the formation of Haversian bone (Fig 3.4f; McLean & Urist 1968, 34-39) which in life is a continually recurring event. Haversian bone is produced when the bone around a blood vessel is resorbed by osteoclasts. The resulting cavity is then filled by layers of lamellar bone, more or less concentric to the blood channel. Such a composite structure of lamellar bone and blood channel is sometimes termed a 'secondary osteone'. In such Haversian bone, the collagen fibres run spirally around each particular blood channel, though their direction changes intermittently as in all lamellar bone. At the outer edge of a Haversian system there is a 'cement line' of calcified mucopolysaccharide through which few canaliculi pass, thus isolating and delineating each system. There is a strong correlation between the size of an animal and the size of Haversian system appropriate to that animal.

The fourth type of bone at this scale is laminar bone (Fig 3.4g), which consists of alternate layers of woven and lamellar bone, each lamina being c. 200 microns thick (Halstead 1974, 67). Fig 3.5 shows how it forms. A layer of woven bone is first laid down, on which is deposited a network of blood vessels. A large cavity is created around these cells by the formation of woven bone above them. As the process continues, lamellar bone is gradually laid down within the cavities to enclose the blood vessels. This is a fast method of bone formation which produces the structures sometimes called 'primary osteones'. The separate laminae are emphasised by a 'bright-line' - an area which is not crossed by canaliculi and osteocytes.

These four major structures of bone go to form on a grosser scale the types visibly recognisable as 'compact' and 'cancellous' tissue. Compact tissue (Fig 3.4h) may be composed of any of the structures of woven bone, laminar bone, Haversian bone or lamellar bone. Cancellous tissue (Fig 3.4i) is, however, composed of either lamellar bone or Haversian bone. In practice, a section of compact bone is likely to contain all four structures in different places in the section and such variation in structure directly determines the physical properties of this hard tissue. The same may be said of cancellous tissue, since the basic lamellar structure is one which will be modified by Haversian systems.

ANTLER

Only the cervids have antlers - paired bony growths which are annually shed. These animals have a wide distribution throughout the world, but only three species will be mentioned here - red deer, roe deer and reindeer. Red deer and roe deer were certainly present in prehistoric Scotland. The status of reindeer, and the question of their existence in Scotland at a time when that land was inhabited by humans, is still much debated (Whitaker 1986). Of roe and red deer, only the males carry antlers. Reindeer are unusual in that they are the only species in which both the male and the female are antlered.

Antlers form impressive bony growths from the heads of male deer and seem to fulfil several functions. Their appearance coincides with puberty and so they are a male secondary sexual characteristic and they are used in clashes with other males during the rut. Henshaw (1971, 469) classifies these as 'largely ritualised in nature', but there does seem to be a correlation between antler size and shape with the position an animal holds in the herd, particularly in relation to the establishment of harems (Chapman 1975, 159-61). Perhaps antlers should be seen as indicators of male sexual prowess, to be used as defensive weapons if necessary. The thrashing of vegetation, scoring trees, and making hollows in the ground are also features of antler use during the rut. Outside the rut, antler size maintains a stag's position within the social hierarchy of the herd. The antlers of the female reindeer seem to establish and maintain position in deer herd hierarchy in a similar way to those of the males and may be used as weapons in times of pressure (Chapman, 1975, 162).

The fact that antlers are usually shed annually means that the acquisition process of antler for artefact manufacture may take several forms. This is because of the cyclical nature of antler growth, maturation and shedding which are different for red deer, roe deer and reindeer (Fig 3.6). As a detailed example, it is worth considering the growth and development of antlers in red deer since theirs are the antlers most frequently utilised on sites of prehistoric date in Scotland. There is not only an annual cycle, but also variation in the size of an individual stag's antlers (Fig 3.8). These increase with age until, in a very old animal, they tend to decrease in size again.

As with most animals there is a general annual cycle in the life of deer (Fig 3.7). Experiments have shown that it is variation in day length which influences the timing of the cycle and this is true not only for red deer but all the species in the genus cervus (Goss 1970, 231; DAFS 1974, 85-86, Fig 11:3, 87). Nutritional deficit or surplus, general condition, status within the herd and age may slightly retard or advance the timing of the rut, birth and antler growth but they have a relatively minor influence (Red Deer Commission 1981, 12). Concomitant with day length, the latitude at which a population lives will affect the timing of the annual cycle, since length of day and the degree of change it shows are related to latitude.

All deer follow an annual cycle but its detail varies from species to species. The formation, growth and casting of antlers is part of this cycle and in male red deer there is a negative correlation between the levels of the hormone testosterone (themselves affected by average day length) and antler growth, since testosterone is an inhibitor of antler growth (DAFS 1974, 44). The cycle for red deer stags begins with low levels of testosterone in early summer promoting antler growth. Rising levels in late summer stop growth, and the 'velvet' which covers the antlers (the skin which enables their growth) dies and is rubbed off by the stag. The antlers remain in place over winter but in spring, as testosterone levels fall again, the sequence begins with resorption of bone at the antler base and shedding of the antlers. New antlers begin to form immediately (Goss 1970, 228-30). Similar cycles are seen in the lives of male deer in other species although the actual months and seasons in which the stages occur depend on the species, latitude and general health of the individual animal as already indicated.

As a stag grows towards maturity, the size of the antlers it grows in each successive year also increases in size. Thus, when discussing the exploitation of antler as a raw material for artefact manufacture, not only must the annual cycle of growth, hardening and casting be taken into consideration, but the whole life cycle of the animal must be examined. Fig 3.8 shows the approximate annual changes in the size of red deer antlers and the appropriate nomenclature.

In Scotland, deer are now born between late May and early July (Chapman 1975, 138; Red Deer Commission 1981, 12). The appearance of the pedicle, a process which extends from the frontal plate and on which the antler grows, generally takes place within the first year of life, although there is some debate (summarised in Chapman 1975, 131-32) about the status of 'incipient' pedicles observed on the heads of foetuses in the first half of the gestation period. The development of the pedicle proper is immediately followed by the growth of the first antler. When, and for how long, the antler grows is greatly affected by nutrition. By the end of their first year, young stags have already begun the annual antler growth cycle (DAFS 1974, 46). Chapman (1975, 136), however, records that deer from the island of Rhum grow their first antlers when 15-18 months old (October-December), substantially out of phase with the fully mature stag, and cast them slightly later than the adult animal in May-June when they are two years old. This delay in the development of the antlers of young stags, as compared to mature animals, appears to be common (de Nahlik 1974, 64). Chapman (1975, 136) mentions other situations where the antlers only develop two-three years after birth. Comparison with figures published concerning animals kept on deer farms (Red Deer Commission 1981, 20) suggests that this difference is primarily nutritional and that the Rhum deer are 'apparently anomalous' because of the extreme conditions in which they live (Chapman 1975, 137).

Another contrast between wild deer living on hill slopes and those kept under farming conditions which can be attributed to nutrition is the variation in size, approximately parallel to change in weight, and number of points. Thus the quantity of antler available to a community is dependent not only on herd size but also on the general health of the animals involved. The animals kept in deer herding experiments which were given extra feeding are likely to be atypical and not an adequate reflection of the situation in prehistoric times.

ANTLER MORPHOLOGY

The general shape of antlers can be seen in Fig 3.9. Red deer and male reindeer antlers are relatively similar in size and shape. Those of roe deer are substantially smaller, as are those of the female reindeer when compared to those of the male. The proximal end of an antler consists of a protruding ring of growth called the corona, coronet or burr. When the antler is being shed, there remains underneath this a convex surface of partially resorbed bone which is one with the pedicle whilst the antler is still attached. The general shape is that of a long cylindrical beam, off which grow numbers of tines. The form of these varies according to the age and species of the animal concerned. As an animal ages, the breadth of the pedicle increases, bringing with it a relative increase in the diameter of the shaft.

In cross-section, antler shows that it is composed of the two macrostructural bone types - compact and cancellous tissue. There is an outer ring of compact tissue, in the centre of which lies a mass of cancellous tissue. There are no hollow areas for marrow or places filled with haemopoietic tissue. The relative proportions of the two types of tissue depend on the species concerned.

ANTLER FORMATION

The growth of antlers puts a large strain on the mineral resources of deer (Goss 1970, 227). The mineral supplies necessary are usually obtained from the food eaten, which may include the chewing of recently cast antlers, but it is clear that during the growing period, minerals in the body can be diverted to the area of growth even from preexisting bones in the body e.g. the ribs, metacarpals and metatarsals (Goss 1970, 236).

Antlers sprout from the pedicles, but the osteogenic material is not supplied from the pedicle, but rather from the skin which covers it and grows along with the antler - the velvet. After considerable debate, the current view is that antlers are formed by both endochondral and intramembraneous ossification, different areas of the antler exhibiting different formation processes (Chapman 1975, 125-31). Intramembraneous ossification is possible since antlers grow from the tip, not from the base i.e. the first part of the antler laid down is beside the pedicle and remains there in contact with it, growth developing from the distal rather than the proximal end. The rate at which antlers grow (and therefore the covering velvet) can be quite dramatic - up to 20 mm per day (Chapman 1975, 129).

ANTLER STRUCTURE

The microscopic structure of antler is the same as that of bone. Since antlers can grow in as little as four months and the rate of growth is rapid, a large amount of the structure is the woven bone, suited to rapid development. This will not have many Haversian systems since little remodelling will take place in such a short period of time. There is, however, little information available for the details of antler mesostructure.

The outer surface of antler tends to have grooves and bumps which generally run longitudinally along the antler. This 'rubicose' morphology results from the shape of the blood channels contained in the velvet which will, in normal circumstances, continue to allow the blood supply to flow whilst the antler tissue is being laid down. The internal cancellous tissue is also a mechanism to allow a blood supply to the growing antler but this is gradually cut off (Goss 1970, 233) by the infilling of the trabecular spaces with more bone. It is at this point that antler growth ceases. The internal blood supply is retarded, that to the velvet stops and the velvet itself dessicates and falls (or is rubbed off), revealing the antlers. From this stage until shedding, they are really no more than lengths of dead bone which extend from the head. Fluids gradually evaporate from them and they harden. The only subsequent changes which take place are caused by contact with other antlers or with the earth or trees, which frequently rub down the surface and tips of the tines and, sometimes, those of the shaft also.

Shedding takes place because of localised resorption by osteoclasts at the antler base. This causes the antler to loosen gradually from the pedicle and it falls from the animal's head by its own weight, or is knocked off by contact with a branch or the ground. The end of antler growth, the death of the velvet and the final shedding all are primarily affected by hormonal changes related to day-length variation (Chapman 1975, 149-50).

TEETH

Teeth cannot be discussed in the same terms as bone and antler, since they are structures composed of four separate materials. Whilst reptiles and fish also have teeth, only those of mammals will be discussed here.

The function of teeth is to enable the initial break-up of food into small pieces prior to swallowing and digestion in the stomach. For this reason, there are two basic groups of teeth - the incisors and canines which act as cutting and tearing teeth and the pre-molars and molars which serve the purposes of grasping and grinding.

Since different animals are adapted to different diets - carnivorous, herbivorous, omnivorous - the relative number of teeth of the different types varies from species to species and thus the teeth of a dog are different in type, and in shape, from those of cattle as well as in relative number. There is, though, a general correlation across the species between the size of teeth and the size of animal.

In mammals there are generally two generations of teeth. The first are deciduous ('milk' teeth) and are a temporary set of incisors, canines and pre-molars in both 'upper' and lower jaws. Molars are not deciduous and form as part of the second set. When the first set of deciduous teeth is lost, they are immediately replaced by the permanent dentition of incisors, canines, pre-molars and molars. All mammal teeth grow from within the mandible or maxilla, the roots firmly set within the bony substance of the jaw and the crowns protruding from the skin which forms the gums.

The warning given regarding bone and the nature of the studies undertaken on them must be repeated for teeth. A large amount is known about human dentition because of the modern concern for dentistry and whilst more is being discovered about non-human mammal dentition, this is, of course, question-oriented research. Much has been achieved within studies of zooarchaeology, particularly in the fields of incremental growth and general wear for the purposes of aging, but non-human teeth and the substances which go to make them can still only be discussed in broad terms.

TOOTH MORPHOLOGY

Fig 3.10 shows cross-sections of a canine and a molar. The canine is elongated and pointed and the molar more rectangular and flatter on its surface. This directly relates to the purposes the teeth fulfil. As tearing teeth, the canines have pointed, piercing ends and molars form efficient grinding surfaces because of their relatively large surface area.

From the cross-sections illustrated, the four basic materials which make up teeth can be distinguished - enamel, dentine, pulp and cementum. The enamel surface or crown covers the part of the tooth which extends beyond the gum and forms the contact surface for food. Underneath the enamel it is a layer of dentine running into the jaw, and enclosing a cavity like a fine tube for dental pulp. The pulp contains cells, nerves and blood vessels, and keeps the tooth alive by its connection to the rest of the body. Cementum covers the dentine roots of a tooth within the gum. The enamel, dentine, pulp and cementum form distinct layers. One tooth which must be mentioned specifically is the canine of the male pig which is often called the boar's tusk. It is a large tooth which is open-rooted and continually growing (unlike most of the teeth considered here) and was frequently used as a pendant decoration (Hillson 1986, 9-20).

ENAMEL

Enamel is a very hard material which is substantially mineral in content (Waters 1980; Hillson 1986, 113-50) though there are gradual variations which take place in life and during growth. The mineral content of enamel increases absolutely with age, and the organic and water content decrease proportionately, and thus a large, old tooth may have less total organic and water content than a small young one. In order to understand the nature of this variation, it is necessary to take a detailed look at the formation and structure of enamel.

ENAMEL FORMATION

The formation of enamel cannot be separated from that of dentine. The first stage is for odontoblasts to begin the laying down of dentine near the internal gum surface. Once this has started, enamel formation by ameloblasts, which do not live within the enamel, commences on the dentinal surface (Halstead 1974, 87). This process continues till the tooth has fully formed and at this stage it erupts through the gum.

ENAMEL STRUCTURE

The inorganic phase in enamel is hydroxyapatite (Vincent 1982, 160), the same crystalline substance found in bone and antler. The organic phase is specific to enamel and called amelogenin. When enamel is deposited by ameloblasts it initially contains a large amount of water and protein, hence the high proportion of these substances in immature enamel. As the hydroxyapatite crystals grow, the water and protein are displaced (Halstead 1974, 87). In enamel, hydroxyapatite forms larger crystals than in bone, Wainwright et al. (1976, 224) suggesting that they are c 40 nm across and about 150 nm long. Waters (1982, 101) suggests that they are 25 nm thick, 40-120 nm wide and 160-1000 nm long; though if they are ribbon-like in form they may be much longer. These crystals are linked to make key-hole shaped prisms, about 5 microns wide within which they follow the line of the prism and it appears that there is an increase in organic content towards the boundary of each prism. The prisms, which combine to give enamel its bulk, fit together to form an interlocking pattern. The prisms are not totally regular in either shape or pattern and the boundaries of each prism form weak interfaces across which there is a marked change in orientation of the crystals (Vincent 1982, 161-62). As well as the enamel prisms there are tufts of enamel which appear to be thickened prism sheaths. These have a higher organic content than the prisms (Halstead 1974, 92).

Enamel is thus formed by a highly-oriented structure, largely inorganic in content. There is however a variation at the gross scale in terms of mineralisation. The outer surface of enamel tends to be more highly mineralised than the interior, especially after contact with oral fluids. As the boundary between the enamel and dentine is reached, therefore, the quantity of organic component increases. The enamel of teeth thus forms a hard mineralised capping or crown which covers the dentine and forms the contact surface for food.

DENTINE

Compared to enamel, dentine has a higher organic and water content and it is much closer to bone (Hillson 1986, 150-62). Enamel may be seen as a simple covering of the exposed surface of the dentine, and below the gum is a thin covering of cementum. The dentine in a tooth is thus completely enclosed by these two materials, enamel above the gum and cementum below. The dentine has embedded in it the pulp which is connected to the rest of the body through an opening at the root tip. Radiating from the pulp contact surface are dentinal tubules which run from the pulp completely through the dentine to its outer surfaces below both the cementum and enamel.

DENTINE STRUCTURE

Waters (1980, 101) records that the inorganic phase in dentine is, again, crystalline hydroxyapatite, the crystals having similar dimensions to those in bone i.e. c 3 nm in diameter and 64 nm long. The organic substance consists of collagen fibres c 0.3 microns thick and mucopolysaccharide. These fibres are generally aligned with the tubules i.e. radiating outwards from the pulp cavity. In contrast, the hydroxyapatite crystals are apparently not aligned along the axes of the collagenous structure as in bone, but have a more or less random orientation (Waters 1980, 103).

This complex of collagenous matrix and hydroxyapatite crystals is regularly pierced by dentinal tubules which carry tissue and cellular processes. These are linked to the dentine-forming cells (odontoblasts) which line the surface of the pulp. The total number of tubules decreases from the cavity surface to the outer surface of the dentine, there being c. 75,000 per mm^2 at the pulpal surface reducing to 20,000 per mm^2 at the outer surface because they link together. Surprisingly, although there is this fusion, the tubules also decrease in size, those at the pulpal surface being 4 microns in diameter reducing to 1 micron at the outer surface. Within the tubule is a layer similar to the lamella of bone osteones. This 'pertubular dentine' increases in thickness from the surface of the pulp cavity to the outer surface of the dentine (Waters 1980, 101). Another major difference between bone and dentine is that there are no odontoblasts within the dentine as there are osteoblasts within bone.

Dentine forms the basic shape of a tooth and though its components are very similar to bone, its morphology and the nature of its growth is distinct. It is dentine which forms what is usually called 'ivory'. This is important for special teeth such as walrus tusk.

CEMENTUM

The cementum forms a very thin layer on the surface of the tooth covered by the gum (Hillson 1986, 162-66). At its thinnest, near the cervix, it is 20-50 microns thick, increasing to 120-200 microns at the apex. Little is known of its structure, but it is composed of roughly equal amounts of inorganic material, and water and organic substance. The organic phase is collagen, some fibres of which continue into the bone of the mandible or maxilla. This allows for the tooth to be attached to the jaw, but also to move very slightly (Halstead 1974, 70). The inorganic phase is definitely an apatite structure which is probably in the form of hydroxyapatite crystals (Waters 1980, 101). There are two types of cementum (Halstead 1974, 70-71). The first is completely acellular and lies nearest the crown of the tooth. The second has cells within the cement (cementocytes) though there are very few cell processes in the cementum. This latter type occurs nearest the root apex. An important difference in the teeth of herbivores is that they have cementum not only within the gums but also on the crown.

In summary, teeth are made of four components: organic pulp, highly mineralised enamel and calcified dentine and cementum. Although there are areas of contact which enable blood supply and nutrition to pass from one component to another, there are quite distinct boundaries between each of the materials.

An important aspect of the structure of calcified materials is that in life they are growing materials. The method of growth is incremental and spasmodic and so there are distinct boundaries and thus enamel, dentine and cementum gain an increasing number of growth lines with age.

HORN

Horn is one of several structures of the body which are composed of keratinous tissue. Some are 'hard' - nails, claws, hair, wool, feathers, hooves, baleen and horn; others, such as mammalian skin, are 'soft'. By far the greatest amount of work undertaken on keratins has been on wool for textile research. This area dominates the literature and references to this particular form of keratin are ubiquitous. Relatively little study has been made of the visually bulky forms as opposed to the fibrous ones, though work by Makinson (1954, 1955) is an exception.

Only the horns of cattle, sheep and goats are considered here. Both males and females of these species are capable of growing horns though modern breeding has tended to remove this characteristic from female animals. Horns are used in defence and attack, to determine hierarchy within the herd/flock and as a sign of that position.

HORN FORMATION

Fig 3.11 shows a cross-section of a horn and the outline of the os cornu of a sheep. This is a bone which grows from the frontal plate of the skull and acts as the horn core - the solid structure over which the sheath of horn grows. The horn itself grows from an epidermal layer overlying and enclosing these horn cores (Halstead 1974, 98). Keratinous structures are different from other biomaterials discussed in that keratin is produced intracellularly i.e. keratinocytes deposit keratin within their own cells until so much is produced that the cell dies and the cell structure is incorporated into the keratin (Fraser & Macrae 1980, 211). Because of this there is a series of layers which may be distinguished in the region of growth of keratinous structures. Romer & Parsons (1977, 131) mention three layers above the dermis - the stratum germinativum, the stratum granulosum and the stratum corneum - each of which is a stage in increasing keratinisation. There may also be another layer - the stratum lucidum - between the horny and granulous layers. Additionally E H Mercer (1961, 211) has noted six zones which he claims represent stages of development separated in time and space, but these again emphasise the transition from cell formation to fully developed keratin. What have been identified here are simply stages in a gradual developmental process. Once the keratinocytes have died, they and the fibrils they have produced fuse into the horn material which has formed earlier. This means that the horn gradually grows upwards and/or outwards, the oldest part of the horn always being nearest its tip.

The rate of incremental growth varies according to nutrition and the time of year, resulting in 'annual' rings which are clearly visible on the horns of sheep, but less so on those of cattle (Thompson 1942, 875-76). The fact that horns are non-deciduous, continually growing structures means that the older an animal is, the larger the amount of horn it will carry. Whilst there is a general inter-species relationship between horn core size and horn size, this does not hold for individuals within a species since the horn core itself does not grow in proportion to the horn. The colour, shape and size of horns also varies greatly.

HORN STRUCTURE

Keratin is a protein and exists in two forms - a relaxed state and a sheet state (Wainwright et al. 1976, 189; Vincent 1982, 43). The relaxed state is the natural one for mammalian keratin. It can, however, be modified and manipulated by stretching in steam.

There is a microfibrillar structure, about 7.5 - 8 nm in diameter, which makes up about half the keratin bulk, the rest being a non-fibrous cross-linked matrix within which the fibres lie. This matrix consists of amorphous protein groups (Wainwright et al. 1976, 190). Some parts of the structure may also calcify slightly.

The structure of keratin has already been discussed in terms of intracellular production. The physical properties of horns, however, cannot be simply reduced to a discussion of keratin itself since within a horn there are the remains of the dead generative cells and the materials which hold them together.

One element of macrostructure which must be mentioned, however, is the plate-like orientation of horn. If viewed in cross-section, horn consists of a series of sheets of keratin, concentric on the longitudinal axis, which are relatively weakly joined together (Makinson 1955, 284), and this is a function of the incremental growth of a cone-like shape.

CETACEAN BONE

Since cetacean bone was exploited on a number of coastal archaeological sites it is worth mentioning something of its structure. Cetaceans are the Order of sea mammals which includes dolphins, porpoises and whales and cetacean bones are usually much larger and less dense than the bones of land mammals. The compact tissue contains a greater number of gaps and there is a large amount of cancellous tissue. Visually, its structure parallels antler, although greatly scaled up in size and particularly so in the case of the larger species. Some whale species are toothed and have provided large tusk-like teeth for use as pendants.

CHAPTER 4
THE PROPERTIES OF SKELETAL MATERIALS

In order to understand the behaviour of bone, antler, tooth and horn when they are worked or used as tools themselves, it is necessary to examine not only their structure, but also the properties they have as a result of that structure. By the term 'property' is meant something intrinsic to the object of study and which is observable in some way. This either takes the form of an attribute which may be present or absent, or it may be something quantifiable. The properties of a bone tool would include size, shape, colour, strength, brittleness, hardness etc. In this chapter, structure is examined in terms of its determinant relationship with mechanical and physical properties i.e. how the materials behave when subjected to particular forces and why this happens. This provides insight into the techniques used in tool manufacture and the ways in which the tools made were themselves utilised.

Two areas of study must be considered. The first is concerned with physical and mechanical properties and how these might be defined. The second deals with what actually happens in a material when it is subjected to a force or an impact. These two areas are closely related, since the former is simply a quantified and generalised statement of individual factors, and the latter is a result of the interplay between some or all of these factors in a specific set of circumstances. Some basic introductions will have to be given in both cases, since bone, antler, enamel, dentine and horn are very complex and their properties difficult to isolate and define, even in terms of present day materials science.

MATERIALS

Much of the information presented in this chapter is derived from the following texts: Benham & Crawford 1987, Gordon 1976, Gordon 1978, Gordon 1980, Granet 1980, Harris 1980, Herrmann & Liebowitz 1972, Hill 1981, Jones 1975, Vincent 1982, van Vlack 1980, Wainwright et al. 1976, Watson 1975. These are texts on the structure and properties of materials and none was written specifically to identify the fracture dynamics of bone or the effects of manufacturing techniques. The only published work parallel to the study presented here was undertaken by Johnson (1985).

A crystalline material consists of a number of particles of one or more elements, bonded to each other in a pattern which is usually repeated throughout the structure of that material. In non-crystalline materials the particles are bonded together, but in a non-regular array. In both types of material it is the relative quantity of different elements, the form of the particles and the properties of the bonds between those particles that makes one material structurally, chemically and physically different from another.

It is again important to return to structure and emphasise the nature of the skeletal materials discussed here. They are complex tissues which are organised at various levels and in differing ways. The detailed level of particles and inter-particle bonds is one which is literally so fundamental as to be an essential area of enquiry here.

BONDING & BOND BREAKAGE; TYPES OF BREAKAGE

Solid materials are held together by chemical bonds of various types - ionic, covalent, metallic, hydrogen, van der Waals etc. These terms are concerned with the particular mechanism whereby the particles are linked together and though they also give an indication of the strength of the bonds, it is unnecessary to investigate them in detail. The main point is that bonds do exist and if a solid is to be modified by cutting, breaking or grinding, then the bonds between the part which is to remain and that which is to be removed must be broken. This can happen in several ways depending on the relationship between the orientation of the bond to be broken, and that of the force applied to break it. If the force is applied in the same direction as the bond and breaks it by pulling the particles apart it is termed a 'tensile' force. The opposite of this is a 'compressive' force where the particles are pushed together so closely that, because of mutual repulsion, the stable relationship between them which previously obtained is disrupted and they break apart. Both shearing and torsion breakage are simply more complex forms of tensile breakage since the particles are pulled apart, not in these cases via a force parallel to the main axis of the bond, but at an angle to it in the case of shearing, and in torsion, with a twist.

Some general principles are worth stating:

1. Materials react to force in different ways, whether or not the force applied induces fracture.

2. A force applied to a material may cause some bonds to distort or even rupture. If bonds do rupture, i.e. a crack nucleus forms, that crack may then propagate through the material and it will follow the route that causes least loss of energy i.e. it will take the 'route of least effort'. The crucial factors that affect initial fracture and direction of crack propagation are strength of applied force, strength of applied force across a particular bond and strength of that bond relative to the force. Even in the very simplest structure, with all particles the same and with bonds of equal strength between them, it is very unlikely that all the bonds will be in the same orientation to the applied force. Those at right angles to the force will be unaffected, those parallel to the force will experience the greatest stress. If the force reaches the breaking strength of the bonds, these bonds will break first. The direction the crack then follows is determined by the next bonds that come to fracture, i.e. those most highly stressed and it is difficult to predict which these will be since, when the first bond breaks, the other bonds undergo a slight change in orientation relative to the applied force.

3. The structure in a real material is more complex as all bonds are unlikely to be of equal strength. Also the applied force is unlikely to be equally distributed across the

material because flaws or impurities within the material can act as stress concentrators.

Before elaborating on these themes and introducing some of the classes of materials which have been identified, it will be useful to discuss a number of properties - and how these properties are quantified.

STRENGTH, ELASTICITY, BRITTLENESS AND HARDNESS

When a force is applied to a material, a disturbance in the natural state of the bonds in that material will occur (Watson 1975, 64). The effect of this will be determined by the nature of both the force and the material. The force applied is called the 'stress' and may be defined as the 'load per unit cross-sectional area of the material' which is being stressed, and can be measured in N/m^2 (Watson 1975, 61). The resultant deformation of the material is called 'strain' and is expressed as a ratio between, for example, the original length of the piece concerned and the change in length whilst being stressed.

If stress is plotted against strain (Fig 4.1) a visual representation of the reaction of a material to loading is given. Fig 4.1a shows an idealised diagram of a material which was not loaded to fracture . The straight line shown demonstrates Hooke's law ut tensio, sic vis i.e. a simple proportional relationship between extension and load. Most materials which exhibit Hooke's law are also to some extent elastic i.e. when the load causing the deformation is removed, they return to their original shape. In other materials, once a threshold has been reached, but before fracture, other types of reaction are exhibited. Fig 4.1c represents a plastic material i.e. one in which all the deformation caused by loading is permanent if the stress is removed the piece is permanently deformed and does not return to its original size. Fig 4.1b shows an elastic-plastic material, in which the initial deformation is reversible, but further deformation beyond this threshold is permanent. Thus, if loaded to the limit of the Hookean reaction it will return to its original shape when the load is removed but will deform permanently if loaded above this limit. In Fig 4.1d is shown a viscoelastic material i.e. one which will return to its original size when the deforming load is removed but which has a time delay in this reaction. Many biomaterials have viscoelastic reactions.

Loading to a point before fracture gives information about the properties of a material, but for the purposes of this study it is more interesting to examine pieces loaded to fracture i.e. which are tested to their breaking points. Fig 4.2 shows a schematic representation of loading of steel, bone and rubber. Several features are worth noting. Firstly the angle of each curve is different. That for steel is steeper than that for rubber. In such a stress/strain diagram, the angle of the curve demonstrates the elasticity or (its antonym) stiffness of a material. One measure of this is given by the ratio of stress to strain measured in N/m^2 (Young's modulus). Thus, a material with a high Young's modulus (a steep line on a stress/strain diagram) is very stiff since it needs a large load to deform it and one with a low modulus is elastic since it requires a smaller load to deform it. Secondly, the area under each curve is different. This represents the toughness, or brittleness, of a material i.e. its propensity to breakage. A brittle material is one which is likely to fracture in conditions of loading. A tough one is likely to absorb the energy of loading, deform and finally return to its original shape if it is elastic, or flow if it is plastic. Thirdly, the height of the curve represents the ultimate stress to fracture of the object tested. This is the same as its strength. A strong material needs a high load per unit area to produce fracture. A weak one will break more easily.

It should be clear that strength, elasticity and brittleness are closely linked and interdependent. Together these three properties give a lot of information about the behaviour of a material, though they are easier to understand when considered in comparison to other materials rather than in isolation. The curve given for bone (Fig 4.2) shows that it is weaker than steel and stronger than rubber; under loading it has elastic properties which fail at point A. This is its elastic limit and after this point, bone exhibits a period of irreversible plastic flow before it fractures. Bone is more elastic than steel, but less so than rubber. Beyond its elastic limit, it shows a relatively simple plastic reaction. Steel on the other hand, exhibits a property called strain hardening since beyond its elastic limit it becomes plastic for a short time and then becomes stronger, finally fracturing only when the strain hardening effect is overcome. Bone does not show strain hardening and is overall less hard than steel. Hardness is very difficult to define because it can be assessed in different ways, e.g. Moh's hardness, scratch tests, but one standard method of assessment is the measurement of deformation by a specific load over a specific time (i.e. Vicker's hardness). This gives an indication of how pliable a material is, and in one value gives an overall impression of the combined effects of specific levels of hardness, elasticity and brittleness.

These properties are all quantifiable ones, values for which are obtained by testing pieces of the material concerned. It is necessary here to warn against over-reliance on the results of such tests without careful study of the circumstances and purpose of testing. Figs 4.1 and 4.2 were drawn solely to illustrate the static loading of test pieces to failure under tensile stress. Test pieces are usually machined, standard, rod-like shapes of material which may bear no relation to the original shapes of the objects from which they come. What is being tested is the material, not the object made with or formed from that material. In static loading, an increased force is gradually applied to the test piece until it fractures usually by increasing a weight attached to one end of the piece. Under such circumstances a test piece would be subject to as pure a tensile stress as it is possible to create. There are some circumstances in real life (in building, for example) where static loading occurs, but very frequently loads are dynamically applied and pure tensile loading is very rare. More often different parts of a real object will be subjected to tensile, compressive, shearing and torsion stress at the same time. In a study which deals with the fracture and cutting of certain skeletal materials to make artefacts which are subsequently utilised themselves, it is important to examine the relevance of static tests concerned with tensile strength. Their value will be discussed later, but they cannot be uncritically applied to studies of bone tool manufacture. It is also important to understand why particular tests were being undertaken, as the purpose of the test directly determines the methods of measurement and the qualities measured. Nor may the type of measuring equipment be ignored.

Natural variation amongst species, individual animals, bones of individuals and parts of those bones is unlikely to be adequately identified in such test work since the search is for the general rather than the particular. Finally, a large amount of the work recorded in the literature on bone etc. was not performed with any great interest in fracture mechanics as such, but rather to determine the natural boundaries of the flexibility and adaptability of in vivo skeletal materials. Interest in the intentional fracturing of antler for tool manufacture, for example, is usually peripheral in such studies.

CRACK PROPAGATION

Whilst the results of tests which have not taken materials to fracture are of interest, it is more important when dealing with bone to appreciate the reaction of materials in fracture. If a hypothetical material is taken which has equally-spaced particles with equal bonds in all directions and this material is put into tension by pulling it from both ends, it will distort so that the bonds in the direction of the force are stretched. The other bonds will, of course, stretch as well but the greatest strain will be in those which are most affected by the loading force i.e. those parallel to this force. When the stress to which the material is subject reaches the ultimate strength of that material (which is the same as the ultimate strength of some of the bonds of that material in the direction of maximum force), it will fracture. Initially one bond will break, and then a crack front will run through the material. The whole piece will fracture provided that, as the crack front reaches each bond in turn, its load is greater than or equal to the ultimate strength of that bond. The crack will stop running, however, if this not the case. The load may be reduced as a result of crack propagation itself because work is done to break the bonds themselves and in creating the new surfaces left behind by the crack front, and fracture will cease if the bond strength is greater than the force applied.

The compression strength of a material is different from its strength in tension and this also holds for shearing and torsion. Fig 4.3 shows a supported beam which is loaded centrally. From this figure it will be seen that such loading does not produce pure tensile or compressive stress in the beam. Because it is a solid three-dimensional object, there are a whole series of effects and counter-effects coming into play. Indeed, very few of the bonds in the beam are subject to pure compressive or tensile stress since they are far more likely to be in shear or torsion. When the load causes the beam to break it is likely to be a tensile breakage since most materials are far stronger in compression than in tension, and it is very difficult in practice to break anything in pure compression. The beam will break in tension, therefore, because the bonds have been pulled apart, but since few of the bonds are likely to be in line with that of loading, it is the more complex form of tension called shearing, and sometimes also torsion, which causes the breakage. Shear breakage requires more work to be done simply because the bonds broken are being pulled apart at an angle to the force rather than at the optimum pure tensile direction.

A similar effect is found with a load which is introduced at a single point and in a line respectively. Point loading produces distortion of the bonds away from the point. Some will be compressed and others stretched. When the shear stress (or whatever form of tensile stress occurs in the particular instance) reaches the ultimate strength of a bond, that bond will break and a crack will propagate in a direction starting from the initial bond breakage. Point loading to fracture initiates a crack which can propagate in any direction from the initial crack formation. The actual direction of propagation will depend on the direction of loading and the particular route of least effort through the material concerned. In an ideal, hypothetical material the bonds will be pulled apart in tension since this requires less energy than breakage in shear and the crack will propagate in a flat plane. A real material, such as flint, produces a more conchoidal fracture.

When a load is introduced in a line the effect is similar except that simultaneous breakage of bonds is likely along that line giving a linear directionality to the crack propagation which is not present in point loading. The actual work done to initiate a crack by line loading rather than point loading is distributed over a greater area and more bonds must be broken by that loading. This is essentially the difference between fracture using, for example, a hammer stone and a blade. Chopping a piece out of a bone, and fracturing it with an iron blade are two different techniques of manufacture using the same implement.

STRESS CONCENTRATION

So far the material used as an example has been a hypothetical one. Two features of real materials which are crucial to studies of their reactions under loading conditions are that on the gross level they are flawed, not perfect and on the microlevel not all bonds are of equal strength. Flaws often act as stress concentrators, so that cracks are initiated at flaws and cracks tend to propagate through them, and if all bonds are of different strength the weakest tend to rupture first.

It is not so much that stress seeks out weaker bonds, but that when bonds are subject to the same absolute stress, the weaker ones will break first. Thus a crack propagating through a material with bonds of varying strength will run through the weakest ones since this will be the route of least effort.

The effect of flaws is rather different. Fig 4.4 shows two pieces of the same material under tensile stress. Fig 4.4a is of a perfect piece and therefore the actual stress per bond in the material in line with the arrows will be the same for each bond. In Fig 4.4b, however, a load of the same magnitude will cause greater stress to the bond nearest the natural flaw in the material. This is because the flaw allows the material to move apart decreasing the cross-sectional area and increasing the load per unit area for this particular bond. Thus, even though the example shown in Fig 4.4b is as strong a material theoretically as that in Fig 4.4a, it is the former which will break first because of the stress concentrating effect of the flaw. In practice, natural cracks, irregularities and discontinuities in a material act as stress concentrators and these are particularly crucial when they occur on the surface of an object under load or are generated during loading e.g. if a surface is struck during working and small flakes removed.

TYPES OF MATERIAL

In order to understand how real materials fracture, it is necessary to examine the various types which exist, how they are structured and how these differing structures react to loading. To simplify discussion tensile loading is assumed, although any form of loading could serve as an example since what is being discussed here are the inherent properties and natural weaknesses of materials.

At the gross scale, materials can be single phase or multiphase. In a single phase material there is a uniform structure and composition, i.e. it is homogeneous, whereas a multiphase material contains two or more separate phases with different compositions and/or structures. These phases may form an intimate mixture, as is often the case with metals, may be visible as separate phases at the macrolevel e.g. temper and clay in ceramic bodies, or, in the most extreme case of composite materials, simply consist of separate phases separable at the gross level. The most important aspect of this for fracture studies is that the bonding between phases is likely to be weaker than within each individual phase. This is not to say that a single phase will necessarily be totally uniform, because, at the next level of organisation down, most solids are not single grain but multigrain. This can most easily be considered through the process of solidification.

When a liquid that will yield a crystalline, single phase solid is cooled to its freezing point, at least one solid nucleus forms. If there is only one nucleus, all further solidification will take place around that nucleus and it will grow to form a single crystal or grain. If more than one nucleus forms, solid growth will concentrate around these nuclei and each will grow out until they impinge and the liquid has solidified. These grains are likely to have different orientations. The net result is a series of crystals or grains with each grain having the same structure and composition but showing discontinuities between grains. The bonding within grains will be the same but that between grains, i.e. along grain boundaries, is likely to be weaker. In multigrain and multiphase materials the structure is, therefore, quite complex at this level, with networks of both grain boundaries and phase boundaries.

More complex still are composite materials, which consist of two or more single or multiphase materials in conjunction. The three basic types of composites are laminates, fibre-matrix composites (in a two-part laminate) and particle-matrix composites. Each is laid down as a layer and sandwiched between layers of the other material. In a fibre-matrix composite, fibres of one material lie at random or in an oriented manner within a matrix of the other. In a particle-matrix composite, particles are suspended within the ground matrix.

STRUCTURES OF MATERIALS

At the lower level of structural organisation in solids, i.e. at the particular level, there are also different forms of structure - crystalline and non-crystalline. The particles in crystalline structures (Watson 1975, 41-59) have a regular arrangement which is repeated across each grain, whereas in a non-crystalline material e.g. glass, the particles have a random arrangement. It will be easiest to begin with a discussion of the structure of metallic bonding and to examine how it reacts to stress.

METALS

Essentially, a pure metal consists of positively charged ions in a sea of electrons. The positively charged ions repel each other because of their similarity of electrical charge, but this repulsion is screened somewhat by the presence of the negatively charged electrons. The crystalline form adopted depends on the size of the protons and the spacing of the protons is determined by their size and the electrical charges.

Another important concept in metals is that of grain size. Pieces of metal are usually polycrystalline i.e. made up of many individual, contiguous crystals. The orientation of the particles in a single crystal will be consistent within that crystal, although various flaws and discontinuities will make the actual structure more complex. The orientation of the particles of one crystal need not, however, be the same as that of an adjacent crystal and is unlikely to be so. In such circumstances, therefore, a force applied to such a piece of metal is liable to cause slippage along the grain boundary itself rather than within crystals since, again, the strength of the bonding across the boundary will be less than that within the crystal. For the purposes of this discussion, the strain-hardening properties of metals mentioned above are set aside.

OTHER CRYSTALLINE MATERIALS

What has been said about natural propensities to slippage in metal crystals applies to all crystalline substances. The important differences are that:

a. the type of bonding in other crystals is not the same as that in metals (i.e. they do not cohere because of metal bonds) since they may be ionically bonded or, in organic materials, have covalently bonded carbon as well as some secondary bonding and

b. the size of crystal (grain size) and the nature of the grain boundary may vary dramatically.

CRYSTALLINE AND NON-CRYSTALLINE CERAMICS

The term 'ceramics' covers a range of materials which may be defined as compounds of metallic and non-metallic elements. Many of these are crystalline and their behaviour under stress will be comparable to those discussed for metals. Some, however, are non-crystalline and are referred to as glasses. They consist of a network of ions arranged randomly throughout the material with no individual grains visible.

A crystalline ceramic which is subject to stress will react differently from a metal crystal because the type of bonding which makes the solid cohere is ionic and very different from the metallic bond. It is a stronger bond and when subject to a load which attempts to make it slip, the particles will move but will bring ions of like charge closer to each other with the result that they repel and cause cleavage rather than slippage. Thus, whilst in metals slip planes within the crystals resulted in plastic deformation before fracture, in ceramic crystals cleavage is likely to occur far sooner. Hence crystal ceramics are brittle materials. Grain boundaries in crystal ceramics will also be prime areas for movement because they form greater anomalies than the other boundaries within the intra-crystal structure, but such movement will again tend towards brittle fracture rather than plastic deformation.

Glasses react in a different way. There are no slip planes in glasses nor grain boundaries simply because glasses are non-crystalline substances with no separate grains. There therefore will be no preferred direction of slippage within a glass apart from that determined by the direction of loading, faults within the structure and fracture will also be brittle. This is the way that flint fractures.

COMPOSITE MATERIALS

So far the materials discussed have all been single-phase. The basic reactions to loading have been indicated for both crystalline and non-crystalline materials. Composite materials fall into three basic categories - fibre-matrix laminates, fibre-matrix composites and particle-matrix composites.

Composite materials are useful ones since they can combine the properties of two materials without having to form a new compound. The advantage of this will be seen from a comparison of the discussion of metals, crystalline ceramics and non-crystalline ceramics. An ideal material might be one which is strong but also resilient i.e. it combines strength and toughness. Unfortunately, materials which are strong also tend to be stiff and brittle. Those which are tough and have a high elasticity also tend to be weak. In choosing a material in manufacturing industry a compromise has to be reached between its strength and resilience in a material. Composites are one way of making this compromise. By combining one material which is strong with another which is elastic, a composite which has both strength and resilience may be achieved and will be far stronger than the elastic material on its own, and far more flexible than the strong material on its own. Nevertheless, the new material is not a compound. The two phases which make up the composite continue to react individually in their own specific ways. It is simply that combined in close contact, they moderate each other's undesired characteristics.

FIBRE-MATRIX COMPOSITES

The components in a fibre-matrix composite are the fibres and the matrix in which they lie. The fibres are usually of a material different from that in which they lie, but occasionally they may be of the same substance. What is also important is the nature of the interface between the two. Fibres in themselves are stiffer and stronger than the same material in bulk (Jones 1975, 2). Several reasons account for this. In the fibre of a crystalline material, the crystals align along the fibre axis and there are fewer flaws than there would be in a bulk form. The very geometry of a fibre has physical and mechanical advantages over bulk form. It is usually the stronger and less elastic material which forms the fibres of a composite.

The nature and properties of a matrix enable it to function as a binding material to hold the fibres in place and give them support. It resists loading by transmitting the load and distributing it amongst the fibres. The matrix is usually the more elastic of the two materials and can act as a shock absorber and stress transferrer if fibres within the material break.

An example of a fibre-matrix composite, in this case a non-crystalline fibre, is fibreglass. This material combines the strength of glass with the elasticity of the resin matrix to produce a tough composite. The hull of a ship made of glass would be impractical since although it would be strong, it could not endure high strain and would undergo brittle fracture when struck with a wave. A hull made of resin would also be impractical since it would be so elastic and weak as to make the ship insubstantial and unable to support weight. In practice a hull composed of fibreglass reacts to both stress and high strain using the two parts of the composite. The glass fibres provide a strong rigid structure which resists stress and the resin acts to absorb large strains.

Another advantage of a fibre-matrix composite is that the fibres may act as crack stoppers under conditions of high strain. If a crack in the matrix runs towards a fibre a large amount of the energy of fracture may be dissipated when the crack front reaches a material of higher strength and runs up the interface between matrix and fibre (Wainwright et al. 1976, 154). A load which may break an individual fibre, may then be unable to cause further fracture in the matrix if the energy of work done is not high enough to overcome the elastic properties of the matrix.

Two overall types of fibre-matrix composites exist: with oriented and random-oriented fibres. As the names would suggest, the fibres in an oriented composite all tend to lie in the same direction and those in a random-oriented one lie at random. These two types both have advantages and disadvantages. If a material is likely to be consistently subject to tensile stress, fibres oriented along the axis of principal tensile stress will prove very effective. Their reaction to compression will depend on the nature of the fibres and the matrix. Such a composite will, however, be particularly susceptible to fracture by tensile loading perpendicular to the orientation, since the fibres can contribute little to the resistance of such loads (Wainwright et al. 1976, 150-51). One solution to this problem is to arrange the fibres in a random array and thus any stress applied will find resistance to it from some at least of the fibres. Its disadvantage is that attempted resistance to forces from all directions results in greater bulk. This theme will be developed further, but suffice it to say that the relationship between hydroxyapatite crystals and collagen has been likened to a fibre-matrix composite, as has that of collagen fibrils within the ground substance of bone. Woven-fibred bone is a type of random-oriented fibre-matrix composite and all other bone is oriented. The situation is of course more complex than this since a large amount of bone forms into laminae (e.g. lamellar and laminar bone as discussed above) and it will be useful to take brief look at this type of composite.

LAMINATES

A lamina can be defined as 'a flat (sometimes curved as in a shell) arrangement of unidirectional fibres or woven fibres in a matrix' – in other words a plate of a fibre-matrix composite. A laminate is 'a stack of laminae with various orientations of principal material directions in the laminae' (Jones 1975, 14,16). Thus each lamina will have its fibres oriented in a direction different from those in each contiguous lamina. Whilst there will be some sort of interface between two laminae, they are usually bound together by the same material which forms the matrix. Since this is so, no space need be given to examining the reaction of individual laminae. It is useful, however, to discuss the reaction of a laminate as a whole. The advantage of laminates is the same as that of random-oriented fibre-matrix composites in that <u>qua</u> composites they can resist stresses from several directions, depending on the number of different orientations in each lamina and their periodicity. Their problem is that they are susceptible to shear stress which may provoke delamination by causing movement in the interfacial matrix which bonds together two laminae of differing fibre orientation (Jones 1975, 17). This is one of the major features of bone and antler fracture.

Dentine, cementum and horn can also be considered as laminates, even though the fibre orientation of their layers does not seem to vary as much as that of bone. The prisms in enamel are certainly not laminae, but their reaction is not so different since they suffer fracture most easily along the interfaces of the prisms where adjacent enamel crystals are oriented in completely different directions. In terms of their incremental growth, all these materials may also be considered as laminates.

PARTICLE-MATRIX COMPOSITES

These composites may be a better analogy for the hydroxyapatite-collagen relationship in bone. Currey (1970) has drawn attention not only to fibre-glass as an illustration of the properties of bone, but also to vulcanised rubber. This is a particle-matrix composite which, as one would expect, consists of particles of a stiff and strong material suspended in a more elastic and tough matrix. Particle-matrix composites might simply be considered as fibre-matrix ones which have short, irregular fibres and they react in a similar manner. The particles are, however, non-oriented, though they may be arranged linearly, but they cannot modify the matrix properties to the same extent as can fibres in a matrix.

THE FRACTURE OF LAMINATE COMPOSITE MATERIALS

Any discussion of the reaction of composite materials is frustrated by generalisations not only in terms of the diverse reactions of different materials, but also because they are by nature very complex. This complexity of composite materials, particularly in terms of fracture mechanics, cannot be over-emphasised. They are both heterogeneous and anisotropic i.e. their properties vary throughout and are different in all directions from any point within them. Thus the properties of a particular part of a composite depend on its position within the object and on its orientation. Simplification of such variety is extremely difficult (Jones 1975, 10-11). Nevertheless, if any understanding is to be gained of what is actually happening in a skeletal material which is being cut or fractured, it is essential to realise how such materials react under stress to fracture. This emphasis on fracture is deliberately at the expense of study of loading of materials at stresses below their ultimate strength since the interest here is in modification of material by removal of that material. Reactions to stress below the ultimate strength is, however, subsumed in the study of a material as it reaches fracture. Needless to say, the quantitative study of fracture mechanics in composites is very complex. The approach taken here is of a more qualitative nature.

It is useful to recap on two general points made earlier. 'The strength of any material is inherently related to flaws which are always present' (Jones 1975, 291). 'Fracture is caused by higher stresses around flaws or cracks than in the surrounding material' (Jones 1975, 292). There are two possible approaches to this study. One is to examine the properties of the separable components in a laminate. Since, however, interest here is directed towards the reaction of composites qua composites, the alternative approach is taken, namely to treat structural complexity as a property rather than a problem which requires solution.

There are two major junctions in a laminate which form areas of stress concentration - the interfaces between fibre and matrix; and those between laminae. The effect of the fibre-matrix junction is rather similar to that of intra-crystal slip planes in that, though they are important in the study of individual crystal fracture, they are of less importance if a larger scale is being viewed where grain boundary dislocation has a greater role to play. The junction between laminae is far more important for consideration here.

Since the bulk of the material in bone consists of laminae whose individual orientation is broadly similar, the reaction of bone to stress varies dramatically according to the direction of application of that stress. Fig 4.5a represents a piece of laminar bone. The axes drawn show the relative tensile strength of that piece to loading in the direction of its x, y and z axes. This is firstly an illustration of anisotropy and secondly a statement about the effect of the fibre orientation and lamination in bone. The figure shows that bone is strongest in a longitudinal direction and progressively weaker in tangential and radial directions. If laminar bone consisted of a series of laminae whose sum fibre-orientation could be plotted as a random distribution, then its tensile strength in longitudinal and tangential directions would be equal. The fact that these values are not equal is a function of the preferential longitudinal orientation of fibres in bone - itself a function of the natural purpose which bones fulfil in the body and a reaction to the types of stress which affect living bones. In any laminate, high stress is likely to cause failure by lamina slippage. In a laminate with preferential fibre orientation, such stress applied at right angles to the fibre orientation will also cause failure within the laminae by separating the fibres within the laminae.

The relative strength of Haversian bone is shown in Fig 4.5b. All that need be said is that the longitudinal and tangential strength of Haversian bone is comparable to that of laminar bone. In the radial axis, however, it is stronger than laminar bone, but as strong tangentially as laminar bone. This is because the discontinuities and junctions in Haversian bone are comparable in the radial and tangential axes. Since fibre orientation in Haversian systems, and in the bone in which they form, also tends towards the longitudinal axis, it is stronger in this axis.

STATIC AND DYNAMIC LOADING

Many of the tests which have been performed on bone were concerned with the loading of test pieces. Such pieces take the form of standardly cut shapes designed to fit into test apparatus and usually consist of a cylinder with expanded ends. The cylinder is the primary test area and the expanded ends are simply to enable the piece to fit into the test apparatus. Usually such tests are static ones i.e. a measured load is gradually applied to the test piece and increased to failure if the fracture properties and ultimate strength are of interest, or to below fracture if the test is concerned with the behaviour of the material at lower stresses.

The difference between such tests as compared with results of impact fracture and the cutting of skeletal materials can be substantial. A piece of antler, cut by placing a knife on its surface and applying pressure is in some ways similar to a static loading test. Any technique, however, which involves movement of the impactor or cutting blade e.g. a hammer stone or a knife used in chopping, involves dynamic loading. The major difference between such practices is that static loading pressure is applied until some natural flaw or discontinuity in the material gives way. In dynamic loading, the impactor itself initiates notches and cracks which, if a great enough stress has been applied, will propagate through the material causing complete fracture. There is also a marked directionality to the force. Under such circumstances, the shape of the contact areas on both the impactor and the impacted surface are very important, as is the orientation of the input force in relation to the structural, and resultant mechanical, properties of the impacted material.

THE STRUCTURE, MECHANICAL AND FRACTURE PROPERTIES OF BONE, ANTLER, TOOTH AND HORN

The rest of this chapter is concerned with the application of the various principles already discussed to the skeletal materials which form the subject of this study. As has been demonstrated above, these materials are very complex. Modern materials science is only beginning to cope with such complexity, but it is possible to give indications of the major areas which contribute to the fracture patterns of the materials concerned.

There is a crucial relationship between working material and worked material. e.g. hammer stone and metapodial; iron saw and antler. The working of skeletal materials must be related back to their context of manufacture which involves at least two distinctly different types of materials with distinct properties. Such types of manufacture are two-way processes and the potentialities of what may be made from bone etc. depend both on the structure and properties of bone and on the structure and properties of the tools doing the work.

For the present, all the substances will be considered as they are when fresh from the animal.

BONE AND ANTLER

The easiest way to describe the mechanical properties of bone and antler is to begin with a brief summary of their structure in terms of materials science. At microscale, bone and antler consist of longitudinally aligned crystals of hydroxyapatite set on and in a matrix of crystalline tropocollagen. The whole lies within a non-crystalline matrix of polysaccharide with particles of calcium phosphate forming a ground substance. The hydroxyapatite-collagen arrangement forms a composite of a strong material and a tough one respectively, which appears to be similar to short length fibre-matrix composites, though perhaps a better analogy would be an aligned particle-matrix composite. The relationship of the collagen fibres and their hydroxyapatite crystals to the ground substance is that of a fibre-matrix composite.

Woven-fibred bone and woven bone are random-oriented fibre matrix structures. Lamellar bone is an oriented fibre-matrix composite with the orientation of the fibres organised at two levels; that of domains and that of the lamella itself. Laminae exist as almost discrete laminates whose boundaries are pierced only by occasional fibres.

At a higher level all types of bone have gaps within their structure caused by osteocyte lacunae, blood channels and the canaliculi. These act as stress concentrators. In woven bone they lie at random within the bone structure. In primary lamellar bone they follow and emphasise the general directional orientation of the collagen fibres.

Haversian bone is complex since a Haversian system consists of layers of lamellae concentric on a blood channel. There is a cement line around the outer edge of Haversian systems. The relationship between Haversian systems and lamellar bone is that of unidirectional, though branching, fibres in a matrix composed of the same material. They do not, however, result under normal types of loading in fibre pull-out as usually happens with fibre-matrix composites (Piekarski 1970)

Laminar bone is, as the name suggests, a laminated material consisting of layers of woven and lamellar bone. Between each layer is a 'Bright-line' which reacts as a distinct discontinuity between the layers and is a likely area for fracture.

In compact bone, any force applied will spread relatively easily through the bone. Cancellous tissue, however, is constructed to dissipate and absorb impacts and stresses. Its trabecular architecture is particularly apt for such stress distribution.

In fresh bone, the role played by fluids and soft tissue within the bone is one similar to that of hydraulic fluids in that they have a restricted area within which they may be compressed. They will cushion impacts and make bone more resilient by their ability to move within the channels of the bone.

Since antler primarily comprises woven-fibred bone, it consists of a randomly-oriented fibre-matrix which is, therefore, able to resist forces from all directions and is tougher than bone (MacGregor and Currey 1983) (Fig 4.6). Fully mature antler, which has lost its velvet, is, however, different from fresh bone. Its properties, as with those of bone, depend on whether it is wet or dry, wet antler being far more resilient than dry (Currey 1980) (Fig 4.7). When dry, bone and antler are more brittle and harder than when wet and it is likely that cetacean bone shows the same properties. All three effects are caused by the dehydration of the proteins in bone and antler (primarily the collagen fraction) removing part of the basis of its elasticity.

When bone and antler are dynamically loaded, they fail at the points of natural stress concentration. One primary area of natural flawing is the surface of any material since it is uneven and irregular. There is compensation for this in bone since the outer surface normally consists of woven bone. The further reaction of these highly oriented complex composite materials is a general disposition to longitudinal fracture i.e. fracture in the radial and tangential planes with marked visible stepping on the surface caused by the fracture of individual laminae and lamellae. Pace Herrmann & Liebowitz (1972) there does seem to be a tendency for fractures to run into osteocyte lacunae, the cement line and blood channels of Haversian systems, lamellar interfaces and the Bright-lines of laminar bone. The effect of these major discontinuities is, however, twofold. They are prime areas for crack propagation since they are weaker than surrounding material, but they may also act as crack stoppers by allowing the force of fracture to dissipate and change direction through them rather than continuing in the original direction. Blood channels and perhaps also osteocyte lacunae seem particularly advantageous for this.

Finally, the gross morphology of the particular bone or antler element under load will affect the route of shock waves of impact and the direction of the wave front of fracture. In relation to past techniques of bone working, it is primarily cylinders which were fractured - either of bone filled with marrow, or antler filled with cancellous tissue. The complications caused to a fracture front by cancellous tissue mean that fracture usually fails when it reaches such a structure since the force is dissipated in the voids. Fracture of antler is thus usually confined to the outer compact surface and fracture of bone to the compact tissue, if it has cancellous tissue below it. This results in long bone fracture being frequently confined to the diaphysis with avoidance of the cancellous-rich epiphyseal ends. These properties are directly related to the functions which the particular structures fulfilled in vivo. Cancellous tissue only reacts in this way to wave fronts. If it is directly loaded itself, it crushes easily.

Fibre pull-out of, for example, primary osteones or Haversian systems requires special conditions of very slow fracturing (Piekarski 1970) which are never normally present for a material as brittle as bone.

The structure and properties of bone and antler determine the ways they react and may be used as raw materials for tool manufacture. A fracture technique on cylindrical bones, generally produces long segments of bone which tend to split longitudinally and, when fresh, 'spirally' (cf. the independent study by Johnson 1985, 167-79). This is as a result of the longitudinal orientation of the various levels of structure in a bone. When segments or flakes break off a bone, they again tend to be longer in the longitudinal axis of the bone. Flakes can be struck from a bone using any suitable surface as a platform, and flake surfaces often show a slight 'stepping' which occurs when subsequent lamellae and laminae are breached.

Cutting, chopping and scraping techniques on bone are more effective 'with the grain' (longitudinally) than against it, particularly for brittle lithic tools. The more resilient metal blades are less restricted by the structure and physical properties of bone and can chop into or across a segment. Grinding and sawing are specific examples of micro-cutting, whereby very localised areas of bone are removed.

Although antler is composed of random-oriented bone, its macrostructure does have a longitudinal orientation and as a result, it also tends to fracture longitudinally. It is also more easily split and sawn in this direction.

Tools made from bone and antler tend to have their main axis in line with this orientation. For piercing tools, pins, spatulae, handled combs and any object on which pressure is likely to be exerted at one end, the maker uses the natural resilience of bone and antler to compression in this axis. When breakage happens, it is usually across an implement or at an angle to its main axis, for it is in the radial and tangential section of bone that it is most vulnerable.

TEETH

Since enamel, dentine and cementum are all composite materials, teeth are themselves composite composites.

Enamel consists of a complex of interleaving key-hole like prisms of large hydroxyapatite crystals with some amorphous organic material. The orientation of the crystals follows directly the morphology of the prisms. Each prism is surrounded by a sheath which has a higher organic content than the prism itself and the orientation of the prisms is primarily radial. The high mineral content of enamel makes it a strong but very brittle material, although the greater proportions of organic material in the prism sheaths provides some resilient cushioning. The orientation of the crystal and the interfaces between the sheaths are prime areas of stress concentration.

Dentine is primarily composed of radiating collagen fibres and a random distribution of hydroxyapatite crystals. This structure is regularly pierced by dentine tubules. Its properties are similar to those of bone except that the radiating tubules determine that the fracture pattern runs consistently through the diameter of the tooth. This orientation fits neatly with that of enamel.

The cementum layer is so thin that for practical purposes of fracture mechanics it can virtually be ignored. More important is the effect that the central pulp cavity has on the general breakage pattern and distribution of stress within a tooth. The elongated shape of the pulp cavity is a function of tooth shape, and has a similar effect to the central cavity in long bones.

As a whole, teeth are built to resist the compressive stress which is applied longitudinally in chewing. Waters 1983, Fig 13 illustrates a model of the natural stress patterns in a tooth. Such general orientation as has been described for enamel and dentine and the stress pattern of teeth results in them being susceptible to stresses applied tangentially and radially (Waters 1983, 125).

The most frequent use of teeth is as pendants and for making beads. The teeth themselves could be perforated and hung and the tooth root was sawn across and snapped to provide small beads. In such practices, virtually no advantageous use was being made of the physical properties of the teeth. Rather, the colour of the dentine and its ability to take a high polish was the feature sought after. All the techniques of manufacture used were ones ones of micro-cutting - grinding and sawing.

HORN

Horn has a far higher proportion of organic material than bone, tooth and antler and its properties are substantially different from the others. Makinson (1954; 1955) has shown that the structure of horn is approximately transversely isotropic about the radius. Keratin fibre orientation is longitudinal (the direction of growth, Wainwright et al. 1976, 189) but fibres account for only half the keratin structure. The rest consists of a matrix which cross links the fibres. Because of the incremental growth of horn it resembles in section a series of cones fitted one inside the other. Within the almost pure keratin structure are the remains of keratinocyte cell processes and walls.

The nature of the high organic content of horn suggests that it is a very tough material (Vincent 1982, 46). It can, however, be broken and cut, but a simple and traditional method of making horn tools is by roughing out a tool by cutting, placing it in a mould and then immersing it in boiling water or steaming until it takes the desired form.

The structure and physical properties of skeletal materials determine how they can be used and how effective the resulting tools are. Some techniques of manufacture, such as fracturing, and flaking, make use of these properties to rough out the shape of tools. Finishing techniques such as grinding and trimming, are micro-cutting techniques which are most easily undertaken 'with the grain', but can run against it. Cutting and chopping depend on effective bladed implements and considerable differences can be seen in the results obtained by using lithic blades and iron blades, the latter being far better at removing large pieces of bone. Any 'technology' will make use of natural properties, rather than work against them. It is in their resilience, and the common availability of skeletal materials, that their importance lies.

CHAPTER 5
RISGA, LOCH SUNART, ARDNAMURCHAN

INTRODUCTION

Risga is one of a number of locations on the coast of central West Scotland where a late Mesolithic population of hunters, gatherers and fishers settled, probably in the late sixth to fifth millennia BC. The sites are notable because of the shell middens present, their close relationship to the post-glacial maximum shoreline and the use of a distinctive range of bone and stone tools. As to the related sites, Mellars (1987) has begun full publication of those on Oronsay and this is the best source for the many references to his work on those sites, for the earlier excavations and the associated details relating to environment and site dating. The other major 'Obanian' sites are MacArthur Cave, Oban (Anderson, 1895) and Druimvargie rock shelter, Oban (Anderson, 1898). Material of similar cultural background has been found at other locations in the Oban area. The midden at Risga was found incidentally and was excavated and recorded in such a manner that interpretation is difficult. Nevertheless it has a large and important assemblage of objects made from bone and antler, in addition to a lithic assemblage of over 14 000 pieces. The fact that it is still the most poorly published of this group of 'Obanian' sites made a detailed analysis of the skeletal element of the artefact assemblage all the more interesting.

Objects from the site lie within collections in the Hunterian Museum, University of Glasgow and the Art Gallery & Museum, Glasgow. Although individual pieces have received some attention, there has been no previous complete survey of the skeletal material. Even Stevenson (1978) missed much of what came from the site. All the surviving animal bones and shell remains were examined. The 571 pieces of the former were recorded in detail and a general examination of the lithic component of the assemblage was undertaken.

SITE LOCATION AND DESCRIPTION

Risga is a very small, rocky island only 12 hectares in area and 650 m long by 400 m at its widest, which lies in the middle of Loch Sunart about eight kilometres from its mouth, on the Ardnamurchan side near the natural landing place of Glenborrodale (Figs 5.1, 5.2, 5.3). This is an area of very dramatic scenery and steeply rising mountains with only an occasional narrow strip of flat land by the water's edge or on the islands in the loch. If the dating of the Oronsay shell middens is comparable to that of Risga, as would seem likely, then the site was occupied during the Late Mesolithic period, some time between the late sixth and the fifth millennia BC. (Switsur & Mellars 1987). When it was first discovered, the mound or mounds (NGR NM 612 600) ran North-South for 24 m on the East side of the island, 18 m from the current shoreline and at a height of about 9 m above it. The archaeological deposit was about 0.9 m deep and comprised shell, stone and burnt soil in which were contained the excavated assemblages. Its location shelters the site from the prevailing winds and at the time of the local post-glacial maximum sea level (+5 m (Sissons 1981)), it would have been on the edge of a small bay just above high tide. The whole island would then have been slightly smaller.

Unpublished letters of 1921 and 1922 from D MacEwen to A Henderson Bishop give glimpses of the site itself. The letters are in the Hunterian Museum and were brought to the writer's attention by P A Mellars. At the core of the mound were a number of boulders; the mound itself comprising shells, burnt earth and heat-fractured stone. The shells formed a dense layer at the centre which thinned out to about 75 mm towards the edge. Underneath the shell layer was a 'sooty' layer about 0.3 m deep which lay on bedrock.

EXCAVATION HISTORY

Only a few contemporary documents give details of the excavations at Risga. Two reports appeared in the Glasgow Herald (1920, Sat 21 August, 6; 1920, Wed 8 September, 8) the former submitted by Ludovic McLellan Mann himself, a regular contributor to the Glasgow Herald, and the latter detailing a visit made to the excavation by the

Geological Survey and a number of archaeologists including Callander, then Director of the National Museum of Antiquities of Scotland. A third report appeared in the Oban Times (1920, Saturday 18 September, 2). This was the result of an interview with Mann after three weeks of excavation and in places cites the previous Glasgow Herald articles. From the correspondence between MacEwen and Bishop already referred to, it is clear that further excavation took place in 1921-22 at the hands of Mr. D MacEwen who was contracted to work on the site by Bishop, although Lacaille (1951, 115) only mentions 1920 as a year within which work took place. The dates on envelopes with the finds in Glasgow Art Gallery & Museum all refer to September 1920 and this relates to Mann's involvement with the site.

Mann travelled to Risga in August 1920 for two purposes - to investigate a shell midden deposit which had been discovered by chance and to examine what were then thought to be large cup-marks (Glasgow Herald 21 August). These latter would have been of considerable importance to Mann since throughout his life he showed a strong interest in prehistoric 'religion'. Current interpretation of the 'cups' pecked out of the rock favours them being associated with 'craigie seats' (Mann 1922, 121-22; Morris 1968, 53-5, 64 cat no 76; RCAHMS 1980, 10) i.e. they are hollows in which fishing bait, such as shellfish, were pounded and then thrown into the sea as ground bait. Their location is on rocks which jut out into the sea, providing a good position from which to fish. Mann was sent some worked bone from the midden, but it is not recorded who sent it nor how it came to be found on the uninhabited island (Glasgow Herald 21 August). He directed the excavations with assistance from Mr. Duncan of Lenzie (Oban Times 1920) but there is no reference to support the assumption that A Henderson Bishop was also present at that time.

The excavations took place from at least 21 August - 8 September, 1920; 2 October - 22 November 1921 and 11 June - 8 August 1922. In 1920 the excavators were based in Tobermory, Mull and travelled to work on Risga by boat. MacEwen stayed in Glenborrodale during the 1921 and 1922 seasons.

The site is a 'kitchen' or shell midden. In 1920 'Trial pits' were dug into the midden which was about 0.3 m thick, covered with turf and lying on bedrock. The midden (or, perhaps, middens (Oban Times 1920)) ran North-South for 24 m on the East side of the island. They were 18 m from the shore. No further details are known about the 1920 excavations apart from information on some envelopes in Glasgow Art Gallery and Museum which list finds recovered on three days in September 1920.

MacEwen's letters of 1921-2 suggest that the mound comprised a turf layer over a shell deposit which itself overlay a 'sooty' layer and bedrock. It was excavated by cutting back a section throughout the mound 24 m long North-South and later one at right angles to it at the South end. The maximum depth from ground surface to bedrock was 0.3 m. All the excavated soil was riddled, bone, flint and quartzite being removed, and then the soil was dumped behind a turf wall. Flints are recorded from the shell layer which was thicker at the centre of the mound and the sooty layer contained bevel-ended tools, the finer flints and certainly two of the barbed points. Despite the detail in MacEwen's letters, the material must be considered as a collection of unstratified objects which come from a single archaeological location. The finds from the 1920 excavations remained in the possession of L M Mann and were bequeathed to Glasgow Art Gallery & Museum on his death in 1955. MacEwen posted the material from the 1921-22 excavations to Bishop who bequeathed this part of his collection to the Hunterian Museum in 1951.

RANGE OF MATERIALS

Only artefacts made from lithic and skeletal materials were found at the site, as would be expected from one of Mesolithic date. There have been three detailed studies: Lacaille (1951, 1954), Coles (1963) and Stevenson (1978), all concentrating primarily on the large lithic assemblage. Lacaille (1951) initially published a general discussion of the technology of a range of finds of the different materials in a study of the lithic industries from Northern Argyll and Southern Inverness-shire. In The Stone Age in Scotland (1954) he summarised the information and related it to other Mesolithic shell midden sites, treating it as being one of the locations of Obanian settlement. Lacaille was interested in presenting all the aspects of the site in terms of resources and technology, although there is no quantification of the assemblage.

Coles (1963) examined the Risga lithic assemblage and presented the statistics of his categories of classification as compared to other known Mesolithic sites from the West coast of Scotland, both Obanian and non-Obanian. His assessment suggested that there were 11 800 'waste' flakes, 900 'utilised' ones and 957 retouched pieces, most of which were scrapers of various forms but there were also burins, awls, backed blades, bipolar forms, tanged points, a saw, a 'Bann' point as well as cores and core rejuvenation flakes.

Stevenson (1978) considered all the available artefacts, classifying and quantifying them in order to encompass lithic and skeletal materials. The aim of his study was to investigate the relationship between the objects from Risga and those from other Obanian sites on Oronsay in the light of excavation by J Mercer (1968; 1971) and to assess the coherency of the 'Obanian culture' with particular respect to Risga. In general, his analysis of the lithic assemblage confirms the range of pieces and the proportions identified by Coles (1963). He identified flint as the major raw material for the lithic assemblage, but also quartz and quartzite, schist, metamorphosed sandstone and bloodstone. Most would have been available locally. The island of Rhum, some 80 km away, is the major source for bloodstone in Scotland, but it is possible that there are localised beach deposits of it along the central West coast (pers comm A Clarke & C Wickham-Jones). Stevenson identified scrapers, chisels, awls, burins, microliths, miscellaneous retouch and waste. In addition there were two pieces of pumice and a number of rough pebble tools.

In interpreting the lithic assemblage, Stevenson's analysis draws on, and expands, that of Coles, making use of Mellars' (1976) approach to achieve an understanding of the general importance of particular activities through the functional identification of the assemblage. The question of what may be classified as "waste" upon only visual examination is a difficult one. This amalgamation of variously defined pieces including primary flakes and cores, suggests that manufacture at least took place on site. Stevenson (1978, 44) concludes in his discussion of seasonality, following Mellars (1976), that what is represented is most likely a winter/-autumn occupation, although he recognises the poorness of fit to Mellars' hypothesis. The basis of the argument are the activities which are thought to be represented by the objects found i.e. scrapers represent hide preparation and burins represent bone and antler working. Leaving aside the question of seasonality, it is necessary to look at these two assumptions since both categories relate to the exploitation of animal resources and are important to Mellars' argument.

Scrapers have long been associated with hide cleaning and working and a steep-edged scraper is far less likely to cut into hide than an acutely-angled flake. Although scrapers are thought of as made for the removal of subcutaneous fat from the hides and, perhaps, the surface hair, it will be argued below that many of the bone and antler bevel-ended tools would be best seen as hide working tools - for the removal of subcutaneous fat and the making of the hide more supple. Lithic scrapers may also have been used in this way, but they would have been better employed in the removal of hair from hide as a stage in the production of clothing, containers and roof coverings.

The idea of burins as bone and antler working tools is based on the presumption that these materials are worked by the groove and splinter technique following, in Britain, Clark's work at Star Carr (1954). It must be said that whilst groove and splinter is known as an antler working technique from Palaeolithic France (e.g. Allain et al. 1974) as well as Star Carr, there is no evidence for this as a bone-working technique, as was recognised by Clark (1956, 93) in his discussion of material from the "Obanian". The evidence from Risga shows that the majority of tools of bone and antler were made by fracture.

"Scrapers" and "burins" might be used for wood-working, vegetable and root preparation, descaling fish, bone-working, etc. and there is always the danger that we attribute single uses to artefact categories without any firm evidence from the site at which they originated. There is some doubt about the equations 'scraper = hide working' and 'burin = bone and antler working', but they cannot be totally discounted provided that other uses and multiple uses are borne in mind.

ANIMAL RESOURCES

Both articles by Lacaille give species lists for the site. Despite appearing to suggest that he undertook the identification himself or had it done for him (Lacaille, 1954, 229) it is unlikely that this was the case, i.e. it seems probable that Lacaille made use of secondary data rather than primary observations.

Care must be taken in assessing the animal resources exploited at Risga and it is worth quoting extensively from the sources used. In the article by Mann in the Glasgow Herald (21 August 1920, 6) he begins the discussion with a list of creatures - crabs, fish, shellfish, land and sea mammals and birds - which formed the diet of the people.

> " The prehistoric larder
>
> Oransay man had no knowledge of domestic animals, agriculture, pottery, textiles, or metals, but he was a skilled fisher, hunter and boatman. In Scotland his dietary consisted chiefly of products of the sea. His kitchen-middens contain remains of crabs, including the fidler crab, haddock, conger-eel, skate, grey mullet, bream (both sea and black), wrasse, angel-fish, tope, ray, and the now despised spiny dogfish. He ate limpets in large quantities also periwinkles, cockles, scallops, mussels and oysters. Before eating the dog-whelk he broke the shell upon little flat stones, which show traces of the abrasions thus made. Pecten valves he employed as scoops and spoons and pieces of antler he made into tools like shoe horns. Among the bones scattered about his dwelling places, as if thrown aside at his meals, are those of the marten, red deer, boar, otter, rorqual, common and grey seal and a large number of birds, which he perhaps snared or trapped, such as

the guillemot, gannet, razorbill, gull, tern, water-rail, goose, shag, cormorant, and red-breasted merganser.

Oransay man seems to have clothed himself in skins, for neatly made bone pins and piercers have been found at Risga, Oban, and Oransay. He, or his children, had necklaces of perforated cowrie shells, and he used a red pigment. Fire injured stones, char, and burned animal bones testify that he had fires and roasted his venison and other flesh secured in the chase. Some shell-fish he ate raw. With finger-like implements of bone, horn and stone he gouged the limpet mollusc from its shell, the peculiar contour of the inside of that shell giving the end of the gouge a characteristic facet."

He then mentions that he picked up the leg bone of a great auk from the midden at Risga.

Comparison of this species list with that in Lacaille (1951, 116) shows a remarkable similarity between the two. Lacaille added Latin names for the species, thus forcing him to emend the list slightly i.e. 'bream (both sea and black)' became 'black sea bream'; 'ray' became 'thornback ray' and the general shell species are further defined. The only real differences are the omission of wrasse from the list and the addition of razor shell. There are still pieces of razor shell in the collections in Glasgow Art Gallery & Museum. That there should be such a close correlation between what in one case is clearly a generalised list for what we would term "Obanian" sites, and what in the other is given as a list specific to Risga itself is felt remarkable in itself. The species list recorded in Lacaille (1954, 240, Table V) is very similar to that in Lacaille (1951), except that further definition of the molluscan remains is presented, references to oysters and razor shells are omitted and the mention of thornback ray is also omitted. Wrasse was unnoted in either of Lacaille's lists. If further examination of Mann's list is undertaken, it appears that this has been compiled by taking the list of marine mollusca and mammals known from Caisteal nan Gillean and adding the fish and birds from Cnoc Sligeach to present a range of creatures of air, water and land which were available for exploitation in Western Scotland and on the islands.

Whilst there are bones and shells preserved in Glasgow Art Gallery & Museum and the Hunterian Museum, the close similarity between the list of species given by Mann and those by Lacaille would suggest that Lacaille misinterpreted Mann's list as being a discussion of the material from Risga. He used it as the basis of the articles published in 1951 and 1954, emending it in areas in which he felt confident - firstly the attribution of Latin names for the species and secondly the identification of marine mollusca. The creatures named by Lacaille in relation to Risga should, therefore, be seen as indicating ones which <u>may</u> have been available to the inhabitants of the island, but not necessarily ones which <u>were</u> available <u>and</u> exploited. Until the existing remains are re-examined and identified, the only species which were certainly listed as present are great auk and red deer, (Glasgow Herald 21 August 1920) and limpet, winkle, mussel, oyster, whelk, razor and crab (identified by the writer). Labels attached to objects in the Hunterian Museum suggest that elk was present, but this is doubtful. Grigson (pers comm) has, however, recognised bones of <u>Bos</u> and pig in the assemblage.

There is therefore no firm foundation for discussing the creatures exploited on Risga, save the bones and shells themselves and final discussion of the way the island was used must await full publication of the fauna. Red deer are the only animals recognised in any quantity although, as already indicated, others may have been utilised for tool manufacture. Coles (1971, 314) comes to a similar conclusion regarding the material from Morton, Fife where both red deer and <u>Bos primigenius</u> were represented in the faunal material.

It is certain that Risga is now too small to support a viable deer population and during the period of habitation discussed here, the island would have been even smaller. Herds which inhabited the Ardnamurchan peninsula to the North and Morvern to the South could easily have been exploited from the island base of Risga. On a visit to the island in 1985, deer were often seen swimming between Ardnamurchan and Risga. Whether the animals were captured whilst swimming, or brought to the island in the form of large butchered joints is unclear, but the range of bones seen in the museum collections suggests a concentration on legs, ribs, vertebrae and scapulae, a group reminiscent of meat joints rather than complete animals. As to size of the animals, Grigson & Mellars (1987, 255-59) compare the small animals from Oronsay to mainland populations and the remains from Risga examined by them fit well within the range for mainland British populations of the period, including those found much farther south.

UTILISED MATERIALS

Red deer bones and antlers were available for the manufacture of tools, and these are the most frequently utilised sources identifiable in the collections. Some objects are made from pieces of bone which may be too thick to be red deer and may be from <u>Bos</u> sp. (pers comm A Young), but these are very few in number.

Since there are so few variations in the raw material, the simplest way of presenting information is in tabular form. Table R1 shows the identification of the 571 objects in terms of their material origins.

TABLE R1 : materials used in tool manufacture

	antler	antler/bone	bone	total
points	1	6	9	16
barbed points	12		1	13
point/barb		1		1
?barb	1			1
'fish hook'		1		1
point/hook			1	1
blunts	1		1	2
bladed tools	7		3	10
tongue-shaped objects			3	3
bevel-ended tools	42		481	523
total	63	6	502	571

Those pieces given as being antler/bone are difficult to identify because diagnostic features have been removed. Where identifiable, all the pieces of antler are from the beam, except for two of the bladed tools which are made from the beam and the junction with a tine.

Tables R2 and R3 show which elements and parts of those elements are represented. There is clearly preferential selection of long bones (almost 500 pieces) with only one jawbone (R 29, Fig 5.4,) and five pieces of rib (e.g. R 568, Fig 5.8) used. Many of the tools were made from split pieces of long bones but their exact origin in terms of species is difficult to ascertain as the diagnostic epiphyseal ends are not present. Only two objects (R 43, 44, Fig 5.6; both bladed tools) can be attributed with certainty as being red deer metapodia.

TABLE R2 : bone elements used in tool manufacture

	jaw	rib	long bone	?	total
points			4	8	12
barbed point	1				1
point/hook				1	1
blunt			1		1
bladed tools			3		3
tongue-shaped objects			2	1	3
bevel-ended tools		5	476		481
total	1	5	486	10	502

TABLE R3 : long bone segments used in tool manufacture (meta = metapodial; m.c. = marrow cavity; corn = corner; bl.ch. = blood channel; r&con = ridge and concavity)

	meta	m.c.	corn	bl.ch.	ridge	r&con	total
points		3			1		4
blunt					1		1
bladed tool	2	1					3
tongue-shaped object		2					2
bevel-ended tools		257	49	23	132	15	476
total	2	263	49	23	134	15	486

The other tools have been examined in terms of the part of the long bone used. The classes "ridge" and "ridge and concavity" refer to pieces made from the prominent ridge of red deer metapodia or involve the deep sulcus between the ridges on these bones (e.g.

R 96, Fig 5.7; R 522, 566, Fig 5.8). Several split red deer metapodia are in the collections in the Hunterian Museum and Glasgow Art Gallery & Museum and the long bevel-ended tools from MacArthur Cave and Druimvargie Rock shelter (Anderson 1895; 1898) are made from red deer metapodia.

The category "corner" (R 156, Fig 5.7; Pl 5.6, 5.8) distinguishes an object made from a bone which has a more angular section with one surface flat and the adjoining one curved and this identifies the metacarpal. Pieces classified as "blood channel" have a small sulcus or groove-like vascular channel in them probably also from the metacarpal. The majority of the pieces are, however (R 90, Fig 5.7; Pl 5.6), made from simple curving segments of long bone upon which no features other than the marrow cavity are identifiable. As mentioned above, two other objects are definitely made from red deer metapodia. At least 149 are very likely to be made from red deer metapodia and the rest are from long bones which would not be inconsistent with these bones or that species.

Apart from the jaw bone and ribs, which are not identifiable in terms of species, there is a concentration on red deer antler and metapodia, and, presumably, on other long bones of the animal. The metapodia would have been available for tool manufacture during the early stages of butchering and would probably have been split for marrow.

The majority of the pieces which show evidence of fracture have been fractured in a manner which is typical of "fresh" bone, i.e. that which has recently come from an animal. Fifty-two (10%) of them, however, have at least one straight side which has a squared section. Miller (1975) and particularly Morlan (1980, 33-34) have shown that this is characteristic of natural weathering cracks and it is likely that they are tools which have been made from bones which had begun to weather, and which, when fractured, split partly along natural weathering cracks, but also split as fresh bone. It is unfortunate that all the work on this topic has been undertaken in hot, desert environments but its results are useful to examine.

"weathering cracks in long bones begin to appear shortly after the bones become exposed ... After an animal has been dead for one year ... from two to three longitudinal cracks have appeared on the bones" (Miller 1975, 217)

The speed of weathering is related to environmental conditions and dessication is the prime weathering factor. Thus, it would be expected that post-glacial Risga would not produce such cracks as rapidly as contemporary Colorado Desert, California, although Olsen (1984a, 185-87) records that even at room temperature, the sounds of cracks forming because of dehydration after the removal of the periosteum are almost immediate. There is probably a greater time lag for full weathering cracks to appear in less hot and more humid environments. Despite uncertainty regarding the time-scale of the process, it is very likely that bone and antler used for tool manufacture, whilst mostly acquired from recently dead animals, was also collected in a weathered state - perhaps from the midden surface or from within the midden itself.

None of the antler present in the collections retains the burr and so it is impossible to know whether it had been shed before collection. It has been suggested that the majority of antler tools are made from segments of the beam and in the Hunterian Museum there are at least 48 chopped-off tines which may be debris from manufacture. In terms of the quantity of antler used, that required for the bladed tools roughly equals that for other classes and a maximum of only c. 5 single antlers would be a reasonable estimate for the quantity needed.

WORKING TECHNIQUES.

Clark (1956) discussed bone and antler objects from a number of "Obanian" sites, and since this article is still the fullest discussion of working techniques on these sites it is worth examining.

He identified red deer as being the major species from which tools were made. It had been generally accepted, and appears still to be, that bone and antler were worked by the groove and splinter technique despite the fact that there is no evidence that bone was ever worked in a manner which is more appropriate to antler, and elk antler in particular (pers. comm. M. Newcomer). It was with this in mind that Clark studied the Obanian material, including that from Risga, after his work at Star Carr. He noted, following Lacaille, that there were few burins from the site and that these were of such a form as to cast doubt about their "certain" use as grooving tools (1956, 93). He states that the bevel-ended tools were made:

> "... of nothing more than splinters broken out of the parent material ... they comprise in effect the residue from which other pieces have been detached." (1956, 92-3).

As regards groove and splinter technique:

> "The important point for our purposes is that in no case is there any trace of longitudinal grooving: the margins are formed by the fractures effected when the raw material was split up, save that in one or two rare instances they have been regularised by local working." (1956, 93)
>
> "...the most diligent examination of the antler and bone material from Obanian sites has failed to reveal any indication that burins were employed, at any rate in the task of detaching portions of raw material from their parent bones and antlers ... the Obanians managed to work these materials quite well without employing the groove and splinter technique ..." (1956,94)

He then notes, as indicated above, that various pieces of antler chopped off with lithic tools were found in the collections and that the bone was "split".

Why this fundamental study has not been more influential is a mystery. It seems clear from a reading of the previous literature (Anderson 1898, 302 ; Grieve 1923, Fig. 20; Lacaille 1951, 120-2; Breuil 1922, 267) that it was generally accepted that manufacture of both bone and antler tools - particularly the bevel-ended tools - was by "splitting", "splintering", or fracture. Some viewed this as performed with wedges (Lacaille 1951, 122) but are happy to state:

> "... it seems that prehistoric man flaked bone in much the same way as he did flint" (Lacaille 1951, 122).

Clark's study confirmed this, but what might be called the "Star Carr syndrome" replaced this understanding, in Britain at any rate, and since the publication of the Star Carr report, has influenced ideas concerning bone and antler working. The assumption of that report, despite contradiction in Clark (1956), was that the "norm" was to work both materials by groove and splinter. That this is accepted as the norm is a great step backwards in our understanding of the relationship between materials and laid the foundation for the concept 'burins = bone and antler working'. It cannot be said too often that groove-and-splinter is not an appropriate technique for working bone. As for the antler at Risga, as suggested by Clark, there is no evidence for the technique as part of a preliminary manufacturing process. The technique here called "cutting/sawing" does, however, bear some resemblance to grooving, but as has been stated below, this is a technique only used for the making of barbs.

PRELIMINARY TECHNIQUES

In terms of the initial stages of manufacture, <u>fracture</u> is most frequently used for bones, and chopping appears the technique used to remove tines from the beams of antler. Finer fracture was used to trim down the size of the split bones and also to break the antler shafts into smaller fragments. Further working cannot be treated at this general level, since the particular techniques used depend, naturally enough, on the object to be made.

The majority of the bone and antler tools were manufactured by a fracture technique, though it cannot be stated with certainty whether direct or indirect percussion was used. Long bones were split into utilisable segments (cf. Pl 5.1, 5.2, 5.3, 5.4), presumably during marrow extraction, and were subsequently finished by techniques such as grinding. Others, particularly those formed on a ridge, seem to have been deliberately driven off the bone by using the diaphysis as a core, sometimes producing a single flake (Pl 5.12). Some of these tools have been made on large single flakes struck from the proximal end of deer metapodia and using that end as a platform.

SECONDARY TECHNIQUES

Several of the objects were, however, more finely worked by the removal of small flakes which may have involved a pressure technique. There is slight evidence for pressure flaking on the sides of a small number of bevel-ended tools.

Lithic tools were used in a variety of ways - cutting/sawing, chopping and trimming. Cutting/sawing involves the use of a lithic tool to cut into the surface of antler or bone to make notches which have characteristic parallel grooves on the side of the notch and a right-angled base. The barbs on the barbed points were made with this technique (Fig 5.4). Groove and splinter working is a similar technique and although no visible remnants of this have been found at Risga, it is possible that it was used in the initial preparation of the barbed antler points.

Chopping is achieved by using a lithic tool with a steep or right-angled edge. It leaves a rough "nibbled" surface, and reduces the amount of material present. Only one object has evidence of this technique - the bladed tool R 39 (Fig 5.6). Since the tool is quite short, it may be that this was a roughening and reducing technique for socketing and the rough surface made the use of a resin glue more effective.

Trimming describes the removal of small amounts of the surface of a piece of bone or antler with a scraping motion and a steep-edged tool would achieve this result best (Pls 5.5, 5.9, 5.10). The technique produces roughly parallel striae which are irregular i.e. some are deep, others quite shallow and was used in shaping the surface of some of the bevel-ended tools and objects in virtually every other group.

Grinding is an abrading technique which involves using pieces of pumice or grainy sandstones in a grinding motion as abraders, or else using coarse siliceous sand as a medium for grinding on any stone. Two large pieces of pumice were recovered by Mann, neither, unfortunately, with signs of working. Small pieces of worked pumice are, however, regularly misidentified as fragments of burnt bone.

Pumice would have been available from Holocene raised beach deposits in the area.

Only one small tool (R 29, Fig 5.4) has been perforated. This broken, and possibly unfinished, barbed implement has a natural nutrient foramen beside a hole drilled from both sides using a lithic drill point.

Hollowing. All the antler tools have had some of the cancellous tissue removed. In most cases this was achieved by splitting the antler and then grinding the tissue away. In at least two cases (the "mattocks" R 36, 38, Fig 5.5), the compact tissue must have been crushed and then the cancellous tissue hollowed out with long lithic, bone or wooden points.

OBJECT CATEGORIES

POINTS (R 1-11, Fig 5.4)

POINTS/PINS (R 12-16, Fig 5.4)

The distinction between points and points/pins is purely one of quality of finish, in that pins have had a greater amount of effort invested in manufacture, resulting in careful trimming, rubbing and polishing. There are 11 points and 5 pins. Virtually all of the points are made from bone apart from one of antler and another of which it is difficult to be certain. Parts of the marrow cavity and, in one case, a deer metapodial ridge, are still recognisable. No firm decision either way can be taken about the points/pins. Apart from one tool, all have had the surfaces trimmed and rounded with lithic tools and have then been rubbed and polished. The working ends of the tools, where present, are roughly circular and taper to the point. All are broken transversely or obliquely across the shaft at the proximal end and 75% are additionally broken at the tip. All the breaks seem to be ancient ones. The tools called "points" are likely to have been piercing tools whereas the "pins" are fastening and decorative tools e.g. for clothing, bags, etc. both, presumably for use with hide or leather. In all cases the long, thin shape of the tool makes use of the longitudinal strength of the raw materials. The finishing techniques produce a round-sectioned point which is effective for piercing, and only likely to be damaged if subjected to angular pressure.

BARBED POINTS (R 17-29, Fig 5.4)
The objects here called barbed points are what are sometimes mistakenly called "harpoons". Only one of the thirteen pieces is unbroken and that - a tool with a rounded butt, a single barb and a point - is atypical. One is certainly made from a jaw bone and it is difficult to decide the origin of another, but despite previous identifications listing them all as bone, the rest are made from antler as can be seen by the remnant of cancellous tissue which runs along the length of most of them. Three groups can be distinguished - eleven barbed points apparently all biserial; one single barbed point and butt and one perforated, uniserially barbed bone implement.

Biserial points (R 17-19, 20-28, Fig 5.4) All are fragments of tools which are either pieces of shaft with barbs or else are the shaft and distal point with barbs. None of the butts survive. Blanks for these tools may have been made by either fracture or groove and splinter technique. The surfaces of the shafts have been trimmed with lithic tools, and ground with either pumice or large grained stone and then, in some cases, smoothed down. The barbs have been made by cutting or sawing into the shaft at an angle from both upper and lower surfaces of the points until the notches on both sides met. Usually a groove was sawn into the shaft on both sides following the line of the notch. The waste from such a technique would be in the form of very small fragments and dust. On all the implements which have this evidence present, the barbs are not set opposite each other, but slightly offset.

A feature of the tools which may indicate how they were used is the fact that the lateral edges tend to be rounded, even on the barbs, rather than narrow-angled. Such a design makes a more effective thrusting weapon than a throwing one, and perhaps these should be seen as the barbed heads of thrusting spears used at close range - e.g. fishing or sealing spears, rather than as javelins thrown at deer. On land they would be effective in the final kill of stunned or wounded or slow-moving animals. No estimate can be made on the basis of these tools as to their length save that they were at least 80 mm long. They all appear to belong to the same general group and to have been of similar size and form. Very close parallels come from Cnoc Sligeach, Oronsay as well as some of those from Caisteal-nan-Gillean and MacArthur Cave, though most have the barbs opposed. The same manufacturing technique has been used for them all.

Single-barbed point with butt end (R 20, Fig 5.4) This small antler object was made in the same way as the biserial points and is complete. It has a point, a single barb and a thick rounded, curving butt. It must have been inserted at the tip of a shaft as the butt seems too thick to have been placed anywhere else. It may have been used as a spear or arrow tip. A similar piece comes from MacArthur Cave, Oban (Anderson (1895), No. 11) though this has two barbs.

Perforated uniserial point (R 29, Fig 5.4) This is the only barbed point which is certainly made from bone - the jaw. Its trimmed proximal end includes some cancellous tissue with a nutrient foramen running through it. About halfway up on the thicker side there is a drilled perforation. Two notches have been cut on the more angular side defining one broken barb and a small part of a second barb. The surface was trimmed with lithic tools then ground, and the barbs were formed by sawing with lithic tools. Though the tool is broken, it bears a resemblance to the barbed uniserial points from Druimvargie rock shelter (Anderson (1898), 301, Figs. 1,2). Neither of these has its proximal end surviving, so it is impossible to say whether they too were perforated. This is not a perforation like that on the point from MacArthur Cave (Anderson 1895 Fig. 10). The hole in the Risga example is not elongated, but circular and the tool in which it is drilled does not look strong enough for use as a harpoon. The perforation may be a means of attachment whereby the point was secured to a shaft.

The great majority of the barbed points were made from antler. All would have been mounted in a shaft and been used as piercing weapons, whether thrown at a creature, or thrust into it. As has already been discussed, antler is more resilient than bone, and in the manufacture of tools which are subject to impact forces on their tips, antler has the more effective properties in resisting damage from such an impact. As would be expected, all the tools follow the linear orientation of the original raw material.

POINT/BARB (R 30, Fig 5.4)
This bone or antler tool is plano-convex in section and lithic trimmed to form a point at the distal end with a barb by the proximal end. To the left of the barb is a trimmed angular piece which is likely to be where the point was attached - perhaps to a thin shaft such as an arrow shaft.

?BARB (R 31, Fig 5.4)
This antler piece has been interpreted as a segment of waste from the cutting of barbs but it is far too large for such debris. It has however been made by cutting/sawing on two sides and trimming on the third, forming a scalene triangle and it may be itself a barb for mounting in a wooden haft.

"FISH HOOK" (R 32, Fig 5.4)
A well-known item from the Risga collection is a "fish hook". It is made of bone or antler and has been trimmed with lithic tools on all its surfaces. Its proximal end is a point which is rounded in section. At its distal end there is also a point with the "hook" coming off at an angle. The notch between the shaft and the hook was originally smaller as a piece of the shaft has broken off. Whilst it would be an important find to have a fish hook from a British coastal Mesolithic site, this piece is probably not one, although it does look like a modern fish hook. The tip is very thick and rather short and it would be better viewed as a form of barbed point.

POINT/HOOK (R 33, Fig 5.4)
Having suggested that one tool is not a hook, there is one piece which could be part of a composite mounting as a fish hook. Lacaille (1951, 124-5, Fig 9.21) discusses this as "an armature for tipping a shaft". It is made from a piece of long bone, flattened on the lower surface and slightly hollow on the two upper surfaces. It is roughly triangular in cross-section and whilst broken at both proximal and

distal ends, it seems to have had a pointed tip and a rounded butt with an expansion on the shaft. It would have been mounted, perhaps as an arrow tip, as one of several points in a composite spear point or as a single hook fitted at an angle as a fish hook.

BLUNTS (R 34-35, Fig 5.4)
One bone and one antler tool are blunt-tipped points. Both are broken and have been trimmed with lithic tools on the surface and then partly polished. The antler tool (R 34) is flattened on the lower surface and rounded on the top. The bone tool (R 35) is made from a ridge and therefore has a roughly triangular cross-section. Both have an amount of erosion and wear at the tips. These may have been used as pressure flaking tools or, depending on the form of the missing proximal end, arrowheads which might have been used for stunning.

Whether used as projectile tips or pressure flaking tools, these implements rely on their ability to resist pressure (by dynamic or static loading) on their distal ends. As with other pointed implements, their longitudinal axis is in line with the natural long axis of the bone or antler.

BLADED TOOLS (R 36-45, Figs 5.5, 5.6)
This term refers to two groups of antler and bone tools which differ in the angle of the working edge, some of which were mounted like mattocks or axes, and others hand held like chisels. These may be termed acute-angled and steep-angled.

<u>Acute-angled blades (R 36-39, Figs 5.5, 5.6)</u> Four antler tools have acute-angled blades of which the largest and best known is an antler-beam mattock (Smith, C nd and pers comm) (R 36, Fig 5.5), made from the beam and one tine of an antler. The cancellous tissue was hollowed out, and opposite the junction of the tine and beam, a hole was cut/chopped in the surface of the beam. The tool is broken across this perforation. The working end of the "mattock" is a tongue-shaped blade with a curving end, one surface of the blade being the natural outer surface of the antler which has been worked and used so that it forms a slight curve. The other surface has been

made by splitting or cutting into the antler beam at an angle, removing the cancellous tissue and trimming with a large lithic blade. The surface was then ground. It now is very polished and has two small flakes removed from the tip. Presumably the tool was hafted with a wooden shaft which would make it axe-like rather than adze-like. Very close parallels are known from Meiklewood, Stirlingshire and from Maglemose and Ertebolle contexts (Clark 1956, 105). The association of some of the Forth Valley tools with whale carcasses has been used to suggest their use in removing whale flesh. Whilst it is just possible that the sort of wear and damage seen on this object might not be inconsistent with such a use, it would only be useful for flesh and not for chopping through bones. Digging through sand or soil would certainly produce this type of wear. As with most of the beam mattocks, it is axe-shaped and could not be used like a mattock.

R 37 is a fragmentary part of a tool like R 36 with an acute-angled blade and part of the original ground and polished blade surface surviving. Again the cancellous tissue has been hollowed out and the outer surface of the antler cut and trimmed with lithic tools. Lacaille (1951, 124, Fig 9.17) illustrates it in the wrong position and over-emphasises the flakes which are either due to breakage of the original tool or a form of flaking to narrow the edge. It may not have been a hafted tool in itself but perhaps a mounted blade or even a sleeve for mounting a lithic tool.

The two other acute-angled pieces are fragments of blades similar to R 37. R 38 (Fig 5.6) is an almost complete, curved tool made from the beam of an antler. The working, distal end is highly polished and there are heavy striae from use proximal to it. The proximal end itself is the only part of the tool with the cancellous tissue removed. This, again, seems to be part of a haft or socket which should be seen as sleeve-like. The use of antler to make hafted digging implements, and sleeves for mounting other tools, shows deliberate selection of a raw material which is resistant to direct impact and can act as a shock absorber in indirect impact. Bone can be used to make mattocks but is likely to suffer the type of edge flake damage seen on polished stone axes and on the metapodial implements from Skara Brae (SB 766-821). Bone tends to be too brittle to make effective sleeves for holding other objects. Antler has the advantage that the cancellous tissue can grip a lithic implement in a way that even the tissue in the end of a long bone diaphysis shaft cannot.

R 39 (Fig 5.6) is one half of the original hollow-bladed shaft. The proximal end has been thinned down by chopping with a lithic tool and the distal end split, then ground and polished. The blade edge is rounded on its outer surface and polished by use and there are four large chop marks on the outer surface which seem to have been made by a lithic tool. The latter three tools could have been mounted as either axes or adzes.

Steep-angled blades (R 40-45, Fig 5.6) R 40-41 are simply the tips of two antler steep-bladed tools. The natural antler surface has been smoothed and polished and the blades themselves are formed by the junction between this surface and the split antler which was ground and polished. Again these would be best seen as gouging or scraping tools. R 42 is a long segment of antler shaft which has a flattened, polished surface at a steep angle to the longitudinal axis of the tool. It is, however, badly broken and it is difficult to tell whether it was mounted or hand-held.

Both bone and antler were used to make tools with steep angles. Enough of two of the bone tools survives to identify them as deer metapodia which have been split and then had the split surfaces trimmed and ground. R 44 (Fig 5.6) is very much a chisel-ended tool - elongated with a finely sharpened blade. There is, however, no evidence of striking on the proximal end, so it was presumably a hand-held tool used in a scraping or gouging way. R 43 is similar, though it is only a fragment of such a tool. A further fragment (R 45) may be from the shaft of a similar deer metapodial tool. These implements may be beaming tools.

The fact that they have been made in both bone and antler, implies that the differential properties of these raw materials are less significant than for points or tools with steep-angled blades. This would suggest that they were not being used in a manner that created impact and that the blade edge itself was an area of more gentle contact. Scraping and cleaning of hides would be just such a practice.

TONGUE-SHAPED TOOLS (R 46-48, Fig 5.6)
These three broken tools all have rounded ends with at least one flattened surface which seems to have been polished and they may be fragments of small polishers. Their broken nature makes interpretation difficult.

BEVEL-ENDED TOOLS (R 49-571, Figs 5.6, 5.7, 5.8; Pl 5.5, 5.6, 5.7, 5.8, 5.9, 5.10, 5.11, 5.12, 5.13)
There are 523 bevel-ended tools from the site and generally these are elongated, finger-like segments which have had one or both ends bevelled, partly by manufacture and partly in use. Traditionally these tools are known as 'limpet scoops'. The tools were examined in terms of the origin of the raw material, method of manufacture and subsequent modification. Raw material has already been discussed at a general level, and it was emphasised that the great majority of the tools were made from the leg bones of, probably, red deer. 42 are of antler (R 49, 102-42; Fig 5.7; Pl 5.11) and five of rib (R 567-71; Fig 5.8). This would suggest that for these tools the natural properties of antler as opposed to bone are not being exploited. The leg bone tools (R 50-101, 143-566; Figs 5.6, 5.7, 5.8; Pls 5.6, 5.7, 5.8, 5.9, 5.10, 5.12, 5.13) were made from segments which had been split from the shaft of long bones or deliberately struck from part of the bone, either the ridge of a metatarsal or using the proximal end of the bone as a platform. Some of the tools are double-ended (R 50-101; Figs 5.6, 5.7; Pl 5.6, 5.7, 5.8, 5.9, 5.10) and some have blunt, rather than the more common broad, tips. Of the latter, one surface of the tool edge is usually slightly more heavily worn although some are equally bevelled.

53 of the tools are double-ended (R 49-101; Figs 5.6, 5.7; Pl 5.6, 5.7, 5.8, 5.9, 5.10), only one of which is made of antler (R 49). Of the others, one has two blunt ends (R 50; Fig 5.6) and 16 have one end blunt and one broad (R 51-66; Figs 5.6, 5.7; Pl 5.7). Four

(R 98-101, Pl 5.9) have one bevelled end and the other one pointed, although one of these is broken (R 101). They have had their whole surface scraped and trimmed using lithic tools (Pl 5.10). The rest of the double-ended tools have broad ends at both ends (R 67-97; Fig 5.7; Pls 5.6, 5.8). Of the single-ended tools, 41 are of antler (R 101-42; Fig 5.7), five are of rib (R 567-71; Fig 5.8; Pl 5.11) and the rest are from parts of long bones (R 143-566; Fig 5.7; Pls 5.12, 5.13). 55 (11.7% of the single-ended tools) are blunt (R 143-96; Fig 5.7; Pl 5.12) and a high proportion of these are made from the ridge of metapodials. In both the single- and double-ended tools the shaping of the tip probably reflects the natural form of the segment of bone, the ridge being suited to blunt tips (e.g. Pl 5.7), and other segments of shaft, with their convex-concave profile, being more appropriate for broad ones, whether this be a simple segment of the bone which only shows the marrow cavity, or one which carries other diagnostic features such as the corner of the metacarpal, or the blood channel.

These variations represent at one level the nature of the raw materials used, but at another the choices made regarding which material to use. What seems to be shown by this analysis is that whilst various groupings can be distinguished, and particular parts of a bone are more often selected for some classes than others, there is a general similarity which cross-cuts these groups i.e. as a class bevel-ended tools do seem to be a coherent group in terms of manufacture.

In terms of usage, there are a number of problems in defining which modifications are the result of manufacture and which the result of use. Clark (1956, 92) wrote concerning these tools:

> "What is common ground is that the characteristic rubbing was due to use."

This writer does not accept this 'common ground'. The techniques used to make the blanks for the tools have been discussed and would have resulted in a piece of bone with a flat or angular edge. On some of the tools there is evidence that they had been flaked, perhaps by pressure flaking, before the bevel was made (e.g. R 199; Pl 5.13) or developed in order to remove an unwanted protuberance or to thin the blade. This sharp or flat edge was subsequently shaped into the characteristically bevelled facet and the question is whether this was made as part of the manufacturing process, is the result of use or a little of each. Others certainly show signs of having had flakes removed after the bevel had formed. The distinction between those which are bevelled and those which are bevelled and flaked is one which has been recognised by others in different terms - the former interpreted as hide-working tools and the latter as flint-flaking, or in other words rubbers and punches.

Some of the objects no longer show any sign of use or wear other than the flakes. Most have a bevel with an even, flat surface, usually with greater emphasis on the upper or lower surface of the working end (in roughly equal quantities), though some have equal upper and lower bevelling and a small number are more rounded at the tip than bevelled. The blunt ends tend to be almost circular in section and have no bevel as such, but rather a blunt, rounded tip.

Both those which are bevelled and those which have blunt tips have been striated by some large-grained stone or pumice (Pl 5.7). There is a range from the deeply striated to those whose marks are virtually worn away and the question of whether these are marks of manufacture or use is central to the problem. There are two possible explanations which are not mutually exclusive. Blanks for these tools would require modification of the working end before they could be used. This would easily be achieved by grinding down the end on pumice or a large-grained stone which would mean that those which have these striations worn down are more used (or have not been re-surfaced). An alternative explanation is that this second level of shaping is achieved through the use of an abrasive. Both may in part be true. The striations are, however, parallel and usually at about 20 degrees from the longitudinal axis of the tool. The blunt-tipped tools tend to have radial striae with a worn tip. Under such circumstances the striated surface is likely to be the result of secondary working by grinding which is then gradually worn away, or partially maintained through the use of abrasives. Considering the range of activities which may have taken place on Risga, the most likely one to involve such tools is the cleaning, rubbing and softening of hide. Reference has already been made to the illustrations and discussion by Semenov (1964, 175-179), and the two types of implement shown by him are very close to the blunt and broad-ended classes from Risga.

What, then, of the flakes, some of which are certainly the result of use and which have removed the bevelling? They have broken off from the tip and therefore pressure must have been applied longitudinally from the end. Contact with large abrasive grains would not produce such breakage, but a more violent striking of some hard material would. Breuil may have been right in suggesting that some of the tools have been used as flakers or intermediate punches. Whatever the case, most which exhibit this feature have also been used as rubbing tools. Presumably, then, these were used in more than one way.

Other tools appear to be multipurpose. There are the four objects (R 98-101; Pl 5.9) which have a distinctly pointed end, though one is broken. These would seem to be piercing tools, deliberately sharpened with lithic tools. Only nine bevel-ended tools have further modification by trimming, usually on one side or surface. Those which have points, however, are trimmed on every surface.

One other feature is worthy of mention. It was noticed that many of the tools were much smoother on the sides of the tool or on only one side at the working end (Pl 5.8). This area was frequently more rubbed than the rest of the surface of these tools and in some cases the whole side was rubbed smooth. Of the 569 surviving ends from the site (double-ended tools counting twice), 192 (34%) show this feature. Occasionally the surface of the tools has deteriorated to such an extent that it is in too poor a condition for rubbing to survive. The location and nature of the rubbing would suggest that it is the result of holding and handling. If this is so, then the method of use illustrated by Semenov (1964, p 178 Fig. 93, 4&5) is not appropriate. Apart from the tools being too short for use in this manner, they could hardly have been held in both hands. What is suggested, then, is that they were held between thumb and index or middle finger and rubbed backwards and forwards.

The bevel-ended tools have a long history of controversy about their purpose. In discussing the objects from Caisteal-nan-Gillean, Oronsay, Grieve (1882 and 1885) recognised variations within the group which included ones of bone and antler as well as some of stone:

> "... but most likely they were used for different purposes, as those rubbed flat only on one side are larger, and made of selected pieces of the bones of Red Deer, while some of those with the rubbing on both sides, so as to form an edge, are made of the same material; portions of smaller bones have been used." (1885, 52)

He examined the other type of stone tool and suggested that they are "limpet hammers". The distinction made is between tools which have a rubbed, bevel end and those which have roughened, abraded ends with flakes struck from them. This is a distinction which is still maintained.

Anderson (1898) discussed those from Druimvargie rock-shelter and MacArthur cave, arguing for a number of uses according to the features visible on them. He suggested "a punching or scraping purpose" (1898, 302-4), but did not detail what might have been punched or scraped.

Bishop (1914) excavated at Cnoc Sligeach, Oronsay, and suggested that the bone, antler and smaller bevel-ended stone tools were for scooping the limpet flesh from its shell. The neatness of such an explanation can only be admired. All the tools found in the middens were now explained in terms of the content of the middens themselves. Flint tools were found as were 'harpoons' but these did not cause consternation. What did cause problems were the objects of bone and stone (other than flint). After an initial suggestion by Grieve, based on an interpretation by one of the local workmen to whom he talked, some of the tools were identified as limpet punches. Thanks to Bishop, the rest of the enigmatic tools could also be understood. The neatness is in the removal of any need to think beyond the middens themselves for explanations of objects within them. They are shell middens, substantially composed of limpets. What better use for the tools than for limpet exploitation, despite the fact that others had recognised differences amongst the objects grouped together? The term 'limpet scoops' entered archaeological parlance and was, and is, used as shorthand for e.g. bevel-ended tools. Despite this 'knowledgeable' use of the term, the concept of these tools as genuine limpet scoops has gained acceptance.

Mann (Glasgow Herald 21 August 1920) comments on this attribution as follows:

> "With finger-like implements of bone, horn and stone he (Oransay man) gouged the limpet mollusc from its shell, the peculiar contour of that shell giving the end of the gouge a characteristic facet. The function of these tools was obscure until, in 1912, Mr. A. Henderson Bishop put forward the explanation of its use, which has not met with general acceptance."

Grieve (1923, 54-5), a great critic of Bishop and his excavation at Caisteal-nan-Gillean, was himself unhappy with the idea. He believed that they were used in rubbing skins in the preparation of leather and bone harpoons to make them smooth and one presumes that here he is primarily concerned with the stone ones. He mentions Bishop's suggestion and rejects it, realising that his rejection is not strong, since it argues that if they are limpet scoops, why are there none found on the duns of Colonsay and Oronsay which also have limpet shells.

Breuil (1922) examined the tools and states:

> "This scrutiny compels me absolutely to reject the proposed interpretation (as limpet scoops)." (1922, 267).

He recognised two groups, one used for hard and repeated rubbing, and the other as intermediate punches. Both groups were seen by him as used in flint working, the former being pressure flakers and the latter punches for indirect percussion. In this argument Breuil is including both groups of tools i.e. the former are "limpet scoops" and the latter "punches".

Movius (1942, 183-5) seems to have taken many of the ideas on board and suggested that the tools were rubbers for animal skins as well as limpet punches and wood working tools but rejected the hypothesis that they are flaking tools.

It seems that Bishop's suggestion gained dominance until Lacaille summarised the information from the coastal sites (1951, 1954). He states, as if quoting the accepted view, that they are used to scoop limpets from their shells, but then goes on to suggest that they may have been tools for working hides to make leather (1951, 122). In 1954, however, he seems reluctantly willing to accept their use as scoops, concluding :

> "It is possible, therefore, that among so many enigmatic components the Obanian groups may include yet another category of elementary implements." (1954, 224)

Clark (1956, 92-3) also rejected the flint working theory, cast doubt on wood working, but did not seem to make a final decision. He discussed Lacaille thus:

> "Lacaille clings to the idea that they were used in part as scrapers, rubbers and polishers in the treatment of skins, and in part for the traditional function of detaching limpets." (1956, 92)

The use of the term "clings" however, suggests that Clark favoured the "traditional" interpretation - which was, in fact, only forty years old. Clark goes on to state:

> "What is common ground is that the characteristic rubbing was due to use" (1956, 92)

A comment which has been challenged above.

More recently, Coles (1971) described 38 bone tools recovered from Morton. Although he does not mention the tools from "Obanian" sites and the illustrations given by him (ibid. 318, Fig 15) are not as detailed as one would like, it seems that they may be the same type of object. Coles (1971, 314) suggests that they may have been skin working tools and draws a parallel with the same illustrations by Semenov (1964, 175-179) as are mentioned above. Mellars (pers comm) argues for their use as limpet scoops on the basis of personal observation and an undergraduate study of relevant material (T Reynolds 1983).

What, then, is the evidence for discussing the use or uses to which these tools were put? Clearly the only ones which can be discussed in detail here are those from Risga. Nor is it the intention that this discussion should be applied to the various pebble tools of which only thirteen are known from Risga, although some of what is said is relevant to these tools. It seems likely that the bevel on the tools was produced as part of the manufacturing process and maintained during use. There is considerable variation in the shape, angle and sharpness of the edge, however, and this would suggest that it is the bevel surfaces which are important rather than the edge formed at the junction of those surfaces. During use, the bevel surface is smoothed and flattened and, in a number of cases damaged by flaking. These two types of wear are not consistent. Whilst flaking could result from the use of the tools as intermediate punches in working lithics, the smoothing of the bevel surface could be achieved by their use with abrasives in the cleaning and working of skins, though certainly not in the way that a bladed tool would be used. The pointed tools are likely to have been used as piercers. Certainty is impossible, but there does seem a strong case for arguing that this group of objects had diverse uses and that they may have been general purpose tools made use of at times because they were to hand. The writer's judgement is that they were more frequently used in working hides and occasionally acted as punches and, indeed, perhaps also for removing shellfish. They nevertheless cohere because of the consistency in techniques of manufacture and the wear to the facet rather than the edge. The multifunctional aspect of them, however, distinguishes them from most of the other material examined for this thesis.

CONCLUSION

Little can be said about the distribution of material on the site at Risga since this information was not clearly recorded, except to say that most of the finds seem to have come from a sooty earth deposit under a shell midden rather than from the shell midden itself.

The location of the settlement of Risga is similar to that of a number of contemporary sites in that they are coastal and able to make use of a range of resources from the sea and land. Risga is particularly well placed for easy access to mainland herds of deer the members of which were more substantial in size than those on the Inner Hebrides (Grigson & Mellars 1987). The bone and shell remains from the site are difficult to interpret and appear to have been mispublished by Lacaille (1951; 1954). Nevertheless there are the remains of a range of species of shellfish, as well as deer and some cattle and pig bones. It is from mammalian sources that the bone and antler tools were made and, where identifiable, these come from red deer bone and antler. It is likely that herds of the animals lived by Loch Sunart and on the islands within it and that bone (and perhaps the antler also) was freed for use when the animals were killed for food. The Mesolithic people would not have had to journey far to exploit these animals. Many other creatures could have been caught from this island - fish, shellfish, birds and seals. It is still not clear which creatures were trapped and killed, but red deer and *Bos* sp. would seem to have played and important part.

The technology used in tool manufacture is based on fracture followed by the use of lithic tools and some grinding. This required simple hammerstones, a few lithic knives or scrapers and some pumice or sandstone. There is a very large assemblage of lithic material from the site which is dominated by 'waste' but contains a good number of retouched pieces, particularly scrapers. The skeletal assemblage is itself dominated by bevel-ended tools, for which a number of purposes are argued and it is possible that they were made to be multifunctional. Barbed points, bladed tools and simple points could have been used in hunting and hide processing and this is the main purpose argued for the bevel-ended ones. There is some overlap with lithic materials in the manufacture of pebble bevel-ended tools, but on this site very few of the latter were found. For those same tools, it seems to have made little difference whether bone or antler was used and this confirms that the natural properties of the raw materials were of little significance. For the points, however, and particularly for the bladed tools, raw material was far more important, and careful selection was made to produce objects which resilient to the pressures and stresses they underwent.

Despite its lack of stratigraphy the site at Risga offers interesting insights into the Late Mesolithic settlement of Scotland and is presumably one of a number of 'camps' in the immediate area which was occupied because of the safety which living on islands provides and the ready access the island gave to marine and land-based resources. Given the range of remains and material found on the site, it may be that this was a camp maintained for the exploitation of red deer in particular, and the processing of their meat and hides. The shell layer, however, if near contemporary, shows that the molluscan resources were also valued.

The skeletal objects from Risga form a large component of the artefact record that has survived. Whilst it is impossible to be certain what the role would have been of soft animal tissues, wood and other organics, a community making use of this accessible site, safely located on an island close to the mainland, would be expected to gather resources from the area around. The island is a natural location for the exploitation of deer, other land mammals, fish and shellfish, and may have given shelter in the past to seals, although their bones are not known from the site. The settlement on Risga seems carefully located to make use of these resources and, in its bone and antler working, to present an approach to animals which uses the hard tissue to its limits: long bones and pieces of antler were split up into small pieces and used as tools. Apart from a few points/pins which may be interpreted as clothes fasteners, all the material is utilitarian and fashioned in a simple manner. The most complex items are the bladed tools and the barbed points, all of which are part of composite implements. It seems likely that most of the hard skeletal materials were exploited in order to make better use of the whole range of resources which killed animals could supply i.e. they formed part of a tool kit for animal kill, hide processing and perhaps in the manufacture of flint tools, also for animal processing. The exceptions are the antler tools with acute-angled blades which may well have been digging implements.

It is unfortunate that nothing is added to the picture of Risga from the recorded archaeological context of the finds made, since so little information about it survives. As a Mesolithic site, the skeletal assemblage raises questions about coastal Mesolithic exploitation in general, and that of Late Mesolithic settlement in central West Scotland in particular. The domination of an assemblage by a single artefact class does seem to be repeated at other sites, as does the occurrence of piercing tools, barbed points, mattocks and a number of other, less clearly defined implements. It seems likely that what is seen at Risga is part of a lithic and skeletal tool kit, specialised for the exploitation of a rich coastal and marine environment at which red deer and perhaps other land mammals are present. As such, there is no particular season which such a tool kit would favour. From the presence of chopped antler tines and a little debris, there is no doubt that bone and antler were worked on the site, though it is unclear whether the animals came to it live or dead, or even as joints of meat.

With some butchery practices, the presence of metapodia would suggest that skinning and primary butchering were taking place on site. Too little information survives about butchery practice on Risga to be certain of its significance, since the metapodia may have remained on the carcass to be split carefully and used for marrow.

In broader terms, the study of the assemblage from Risga is important for our understanding of the Mesolithic settlement of coastal Scotland. The connections which can be made in the forms of barbed implements and the bladed antler tools, makes links with Mesolithic sites in other parts of Britain and Western Europe, and the absence of bevel-ended tools from the repertoire of other population groups becomes noticeable. Were other groups using different materials, such as wood, to make equivalent implements? At Risga, there should have been no shortage of suitable timber so this cannot be the whole explanation. What is suggested is that this group of tools does define a distinctive cultural tradition which may have some links with other Scottish coastal sites and tenuous links with European traditions, but which is effectively locally specialised and isolated.

CHAPTER 6
SKARA BRAE, ORKNEY

INTRODUCTION

The skeletal assemblage from Skara Brae is one of the best known in Western Europe because of its general publication (e.g. Childe 1931b) the quality of its survival and the ambiguity of its 'uniqueness' which has enabled it to be considered exceptional as well as being the basis of a 'typical' Neolithic collection. Nonetheless, the assemblage has remained unpublished in detail and as a result the impression given has tended to over-emphasise unusual objects. For the study of the manufacture and utilisation of skeletal materials in Neolithic Britain, Skara Brae is the richest site, although another Grooved Ware settlement with probably as rich an assemblage has undergone partial excavation at the Links of Noltland, Westray, Orkney.

Given that Skara Brae was an obvious choice for study here, it came as a surprise just how much material there was from the site once the dispersed collections in the three locations in Orkney, the National collections in Edinburgh and the British Museum in London had been assessed. 1209 objects or groups of objects were examined and recorded in detail. Most of the groups comprised strings of beads and when counted individually, this produces an object total of 6270 pieces for the site. Non-artefactual material was also examined to determine likely butchery practices and techniques. With only Childe's published work to go on, a vague idea of the concentrations and distributions could have been given. C Richards' rediscovery in the Institute of Archaeology, London, of the excavation diaries and finds numbers from Childe's excavations have meant that faint numbers written in ink, or more often pencil, in Childe's irregular hand, can be used to identify which objects came from where, and this means that much more refined questions can be asked of the material.

The objects from Clarke's excavations of 1972-73 and 1977 were not detailed for this study, though most were examined, since the full results of the sieving of these deposits were not available and it is these in particular which will be most important in future assessment of the site assemblages.

In interpreting the distributions at Skara Brae, the work has been influenced by an awareness of the diversity and complexity of the nature of 'midden' and midden composition learned at Links of Noltland, Westray and other Grooved Ware sites at Pool, Sanday and Barnhouse, Stenness.

SITE LOCATION AND DESCRIPTION

The settlement site of Skara Brae is situated on the South side of the Bay of Skaill in the parish of Sandwick on the West coast of the Orkney mainland (Fig 5.1, 6.1, 6.2, NGR HY 231 187) There are only four natural landing places on this coast of the mainland and the Bay of Skaill is by far the most sheltered. It is now a bay of about 1 km at its broadest with sheets of flagstone exposed at its North and South edge and with a broad sweep of shell sand in the southern half gradually becoming more full of cobbles to the North. About 600 m to the South-East is the freshwater Loch of Skaill. The land around the site is now a rich shell sand pasture with rough grazing and moorland to the South on Ward Hill. It is difficult to be sure what the environs of the site were during its occupation. We do not know exactly where the coastline was at the time when Skara Brae was occupied, but it is certain that it has changed within recorded time, largely as a result of movements of the shell sand and cobbles during particularly violent storms (such as that which uncovered the site in the 1850's) and during the high equinoctial tides. MacKie (1977, 185, Fig 27) illustrates the difference between the coastlines at the Bay of Skaill in 1772 and 1975, showing that in the eighteenth century Skara Brae would have been at the edge of an inlet which led from a bay with most of its coast 100-200 m further out to sea. Recent years have also seen the sea encroaching further and further inland and the redistribution of the sand and cobbles.

The name Skara Brae (or Skerrabrae) refers to the high, sloping dune which formerly covered the site before its rediscovery in the midnineteenth century. Initially, buildings which were being actively eroded by the sea, and parts of others to landward of them, were explored. After some 'excavation' during the nineteenth and early twentieth centuries (Petrie 1868; Traill 1868; Stewart 1914) the major work on the site was undertaken under the eye of V Gordon Childe in the late 1920's and 1930 in advance of the site being consolidated for public presentation (Childe & Paterson 1929; Childe 1930a, 1931a, 1931b). Since that date excavation has taken place within the guardianship area in 1972-73 and in an adjacent area in 1977, both under the direction of David V Clarke (Clarke 1976a, 1976b, 1977). It is Childe's assessment of the history of the site, modified by Clarke's studies (Childe & Clarke 1983, Clarke & Sharples 1985) which is presented here.

Before Childe's excavations, investigation of the site consisted of the exploration of a number of individual rooms or chambers without any real understanding of their interrelationship. It was really only with the work undertaken in 1927-30 that any impression of the scale of the site was gained (Fig 6.3: the periods 1 and 2 marked are those identified by Clarke). Childe (1931b, 61-95) argued for five periods of development at Skara Brae. Before settlement took place there was a slight build up of sand over the natural clay surface which overlies the flagstone bedrock. In period I, a substantial midden was laid down across the site and possibly a few wall foundations. Whether the settlement which produced the debris for the midden was on the same site or some distance away is uncertain. Period II saw the use of this midden as a foundation layer in which the first village was built. The remains of houses 4', 6', 9 and 10 belong to this period and show features which, in modified form, were repeated through the whole history of the site. Buried under the later houses are presumably traces of other structures contemporary with these. Houses were built of dry stone walling, were sub-square in shape with a single entrance, which could be barred, leading from a courtyard or passageway. Each had a square, central hearth and usually a small cell in one of the corners. Within the house was furniture made from large flagstone slabs which formed bed areas and dressers. In period II bed areas were recessed into the house walls.

In Period III the focus of the village moved to the long passage A with its short string of houses. To the North was house 1, with houses 2 and 3 on either side of it, and to the South was house 5, with houses 4 and 6 to either side of it. Building 7 was built at this time down its own small passage B and the workshop 8 was placed slightly separate from the rest of the buildings. All the constructions were firmly set into midden and at least partially covered by it, either by digging into preexisting mounds or by deliberately bringing it in as a building material. The buildings of Period III were larger and had higher and thicker walls than those of II. The internal furnishings were more elaborate; bed areas being built out into the room rather than recessed, with clay-luted tanks and other features being set into the floor, and an increased number of cupboards set into the walls. By the end of Period III, buildings 1-8 would have been the main structures.

Period IV is represented by minor changes to house 8 and some of the additional walling around the site. House 6 was infilled and the midden covering of the site was increased in size and depth. The whole site was subsequently overwhelmed with sand, though perhaps not in such a dramatic and catastrophic manner as Childe envisaged, but there are traces of hearths and occupation within the sand infill, higher up in some of the houses. This forms a 're-occupation' period by people using the same range of tools as the previous occupants.

Clarke (1976a, 17-18; 1983, 5-6) simplifies this sequence to two major phases of occupation as shown in Fig 6.3: Period 1 - an earlier village roughly equivalent to Childe's Periods I and II and Period 2 - the later village (Childe's Period III with its subsequent alterations). These two phases do, therefore, represent major design changes in the organisation of the village and of its houses. This break is also seen in the midden deposition (Clarke 1976a, 18), but is not necessarily coincident with any other type of change, since there seems to be little discontinuity in the range of resources exploited or tools used and made.

The detailed history and stratigraphy of the site is made more complex by the use and reuse of midden deposits as a constructional material. It is still difficult to be certain how 'midden' is formed, but its constituent parts seem to be the debris of everyday life - the cleanings from the house, ash, dung, food refuse, manufacturing debris, broken tools etc.,which amalgamated in various proportions to form a an 'earth', more solid than the loose shell sand from around the houses. It is likely that this midden was being accumulated at the same time as it was being used as a building material. Under such circumstances the stratigraphy at Skara Brae should be expected to be reworked. Midden used as a wall lining was probably 'mature' and stable rather than fresh. Some parts of the midden were deliberately piled up over the houses, but other structures were dug into it in order to lay their foundations. At least two of the houses (10 and 6) were infilled with midden to provide a stable base for other later developments. In summarising the history of Skara Brae, therefore, it is relatively easy to concentrate on the main building phases and ignore the implications for the associated deposits. This is a site which saw a steadily increasing vertical accumulation of deposits, at a gross level. At the level of detail things were far more complex.

Originally Skara Brae was felt to be a unique site, but the discovery of a similar village settlement on the Braes of Rinyo, Rousay (Childe & Grant 1939, 1947) showed that there was at least one other site within the Orkney archipelago. Since that time, other villages with a parallel material culture have been rediscovered - Links of Noltland, Westray (Clarke, Hope & Wickham-Jones 1978; Clarke 1980, 1981); Pool, Sanday (Hunter 1985, 1987); Barnhouse, Stenness (Richards 1986, 1987).

EXCAVATION HISTORY

The history of the exploration of Skara Brae is quite closely tied to the ownership and tenancy of Skaill House, a large mansion from which the site and the Bay of Skaill can be viewed. Petrie (1868) provides the best summary of the rediscovery and early excavations at Skara Brae. Some time between 1850 and 1852 a great storm undermined a large sand dune, resulting in the exposure of a midden section 2.5-3m high and containing bone, shell and charcoal. William Watt, who was living at Skaill, found various implements of bone and stone and noticed buildings eroding there. He contacted George Petrie, Sheriff Substitute for Orkney and a corresponding member of the Society of Antiquaries of Scotland, who passed on information about the site to other antiquarians in Britain. Various objects were collected by Watt until, in 1861, James Farrer, a member of parliament who came from Yorkshire, opened up part of the mound and explored some of the structures. Farrer spent several summers in Orkney 'exploring' sites but unfortunately left very few records of his work. Following Farrer, Watt undertook excavation more seriously, and by 1867 had proceeded to empty houses 1, 3 and 4, the part of passage A linking them, and parts of the entrances to other houses. We must be very grateful that someone of Petrie's knowledge and quality of observation visited the site whilst Watt was excavating, particularly since his record is the only written source of information about what was excavated in an area where some of the buildings were later destroyed by other storms. After this time Dr William Traill (1868), also a corresponding member of the Society of Antiquaries of Scotland, joined Watt in his exploration of the site and offered some general discussion about the age and affinities of the 'chambered mound' of Skara Brae. By April 1868 Watt had 'entirely cleared out the rubbish from four houses [i.e. 1, 3, 4 and 5] and ... hopes to find a fifth' (Traill 1868, 431). Some of the finds from this set of excavations were donated to the NMS at that time (<u>Proc Soc Antiq Scot</u> 6 (1864-66), 419-20 by Mrs Cairns; 7 (1866-68), 422 by Watt; 7 (1866-68), 459-60 by Traill). Most of the rest, including many of those listed and illustrated by Petrie (1868, 218-19, Fig opposite 218) being kept by Watt at Skaill House, to be later moved to the Kirkwall Library Museum of the Orkney Antiquarian Society and thence split between the latter (now within the collections of Tankerness House Museum) and Stromness Museum in 1934. Others were sent straight to the British Museum in 1866.

Little further serious work took place at the site until after Watt's death. In August 1913 Balfour Stewart was summer tenant at Skaill House and explored part of house 2. One of his house guests was Professor Boyd Dawkins, who examined the site and commented on the finds, but the records and plans left of the site are less than helpful, and Dawkins comments on the finds are not based on experience of similar material (Stewart 1914). Most of the objects found were donated to the NMS (Proc Soc Antiq Scot 48 (1913-14), 270-71).

In 1924 the site was taken into state care (or guardianship) through the action of Watt's trustees, and late in the year was yet again damaged by severe storms. To protect the site from further damage, a sea wall was built during the summers of 1925 and 1926. Now a site in state care, it was important to expose and consolidate the remains for public view, and make an accurate record and plan of the buildings. To this end work began in 1927 to clear out the vegetation and sand which had encroached on the site since the previous work. This was overseen and recorded for the Office of Works by J W Paterson, Architect in Charge of Ancient Monuments in Scotland (Childe & Paterson 1929, 225-39; Childe 1931b, 4). Houses 1, 2, 3 and 4 were cleared out, and the rest of house 2 and a further part of passage A were excavated for the first time. Only a little additional information was gained about the houses already excavated, but detailed plans were made of the newly opened buildings and the location of finds made was plotted, although the stratigraphy in house 2 appeared to have been disturbed by the work in 1913 (Childe & Paterson 1929, 229).

As a result of the 1927 excavations it was realised by the Chief Inspector that large amounts of midden would need to be removed in order to allow the consolidation of the whole site. As a result, V Gordon Childe, the first Abercromby Professor of Archaeology at the University of Edinburgh, was invited to supervise that part of the work and did so during the seasons of 1928, 1929 and 1930. Childe had only moved to Scotland in September 1927 (Green 1981, 75) so his involvement in the project was probably his first contact with excavation in Scotland. His carefully phrased description of this involvement suggests that his role was that of an observer and that he wished to distance himself slightly from responsibility for all the work done and decisions taken about the site:

'By courtesy of H.M. Office of Works I was privileged to be present during the operations undertaken by them for the conservation of the remarkable prehistoric village of Skara Brae and to supervise the incidental archaeological results on behalf of the Society of Antiquaries of Scotland.' (Childe 1931b, v).

'Once again I was afforded facilities for observing and recording the archaeological remains that might incidentally come to light.' (Childe 1930a, 158).

Childe saw to the prompt publication of these excavations in annual reports (Childe & Paterson 1929; Childe 1930a; Childe 1931a) and in a monograph report of all the work at Skara Brae (Childe 1931b). Each report detailed the work undertaken for the year and the range of finds made. The monograph examined the village as a whole, detailing its structure, history, material and spiritual culture and, finally, the thorny question of its date and affinities. Excavation seems to have proceeded by removing overlying sand, cutting trenches through the midden and then defining and exploring such structures as were uncovered. The physical work of excavation and restoration had been contracted to a local firm (J Firth of Kirkwall) and was undertaken by local labourers under a foreman (Childe 1930a, 158). In 1928 passage B, house 6 and house 7 were excavated. In 1929 the west end of passage A was further explored, uncovering building 8, the 'market place', the walls to its south, passage C and some of the details around house 7, and the stratigraphic relationships between 6, 6' and 5'. The final season in 1930 involved the excavation of the earlier buildings 4', 9 and 10 and the full delineation of 7. Ten deep shafts were also sunk across the site to assess the feasibility of roofing over the whole village, and as a result the depth of stratigraphy was further examined. Childe's classification of the finds will be discussed below. After excavation and study they went formally on loan from Mr. Scarth of Skaill and Breckness to the NMS in 1933. Representative collections had been returned in January 1933 to Orkney for display in the Kirkwall Museum. Others were sent to Stromness Museum (reg no A262), to the small museum at the site itself and in 1938 to the British Museum. For the reopening of Tankerness House Museum in the 1970's further objects were loaned for display by the NMS. The recent relocation by Colin Richards of Childe's excavation notebooks in the Institute of Archaeology, London means that added detail can be given to the excavation reports and particularly to the finds' distribution.

Childe's excavations had resolved many of the questions about the nature of the site and went some way to exploring the everyday lives of its inhabitants. One question which had not been firmly resolved was the date of the site. Traill (1868) referred to the distinction between the broch and the chambered mound or 'Picts' house' and by extension called Skara Brae a Pictish village, since there was more than one house. He argued that the chambered mounds were earlier in date than the brochs and that Skara Brae was more closely related to the former. Childe (Childe & Paterson 1929, 277-79) was able to find parallels for material from the site in both pre-broch and post-broch contexts and clearly swithered between a Neolithic/Bronze Age date and a much later post-broch Iron Age. What was clear to him was that the site and its material culture were paralleled in other parts of Orkney. By 1929 (Childe 1930a, 191; 1930b) he felt more confident about an early date. It was J G Callander, Director of the National Museum, who sowed seeds of doubt in Childe's mind about the antiquity of the site, emphasising that there were strong parallels between some of the material from brochs and those found at Skara Brae. This led Childe to argue that whilst the Skara Brae culture was different from that of the brochs and souterrains, and had more archaic features than it:

> '...The agreements may accordingly mean either that the Iron Age culture took over certain elements from an earlier one, exemplified at Skara Brae, or that the builders of Skara Brae borrowed from the broch people.' (Childe 1931a, 72).

In a piece of careful argument, he later suggested that it was earlier than the use of the brochs but that an upper limit of 500 BC. should be given for the foundation of the village, which would place it, according to the then accepted chronology, in the Late Bronze Age (Childe 1931b, 155-84).

It was only with Piggott's study of the Grooved Ware pottery from Essex that the true context for Skara Brae was established as being in the later Neolithic (Piggott in Warren et al. 1936, 201). This dating was confirmed by later discoveries at Rinyo, Rousay (Childe & Grant 1939, 1945). By 1954 Piggott (321-46, 379-81) was writing of the Rinyo-Clacton culture and giving it an absolute date of 1750-1500 BC., dates which were to be radically revised with the increase in radio-carbon dating.

One of the reasons for Clarke's excavations of 1972-73 was to establish a radiocarbon chronology for the site, and answer a series of related issues which could not be dealt with by reference to the existing archives (Clarke 1976a 7-8; 1976b 243). There were other important questions about animal husbandry and exploitation of marine and plant resources which were impossible to answer because material had not been kept, or was irrecoverable, because of the excavation techniques which had been used. In the excavations of the 1970's sieving and flotation techniques meant that fish bone, grain and other plant remains were saved and available for analysis.

Two trenches were opened within the area under state care. Trench I, dug into a surviving area of midden between passages A, B, F and house 7, uncovered a complex history of midden deposition, building, infilling and sand drifting. The remains of an earlier and a later house were found, and a series of middens contained a rich collection of objects. Trench II was placed to the East of 4' and had a waterlogged midden at its base with layers of midden and sand higher up. No detailed analysis of these excavations has been possible. Some parts of the material collected have been studied in depth (e.g. Chaplin nd; Noddle nd), but no discussion of the site and its stratigraphy is available other than in Clarke (1976a; 1976b) and Clarke & Sharples (1985). That the site was of Late Neolithic date was confirmed by a series of 23 dates which ranged from 2520 bc $\pm$ 120 (Birm 795) to 1830 bc $\pm$ 110 (Birm 437) a time span of somewhere between 1500 and 475 calendar years (calibrated and at 95% level of probability (Renfrew & Buteux 1985)).

One piece of subsequent work has begun to put Skara Brae into its landscape context. In 1977 Clarke directed excavations immediately to the West of the settlement to discover the nature of an eroding piece of walling. These excavations suggested that there were various field or stock walls associated with the occupation of the village and that the area to the West and South of the site should be seen as having been farmed (Clarke 1977).

RANGE OF MATERIALS USED

As with many of the archaeological sites in the North of Scotland and the Northern and Western Isles, the principal raw material used was stone. The outcrops of flagstone which were used for the dry-stone construction of walls, the provision of hearths and the thin sheets of stone which could be used for the internal furnishings of the houses - the bed areas, the tanks sunk into the ground, decorated slabs and the dressers - were a rich source of building material, ensuring that the settlement at Skara Brae survived in such detail. It is wrong to take an apologist's stand over this and argue, as Piggott and others have that:

> 'Lack of suitable timber led to the use of flagstone where wood would have been more appropriate..' (Piggott, 1982, 33).

The Neolithic inhabitants of Orkney were well aware of the properties of materials, and in terms of durability, ease of construction and, certainly, availability of materials, stone was much preferable to wood in these constructions.

Objects were also made by pecking and hollowing out pieces of flagstone and gritty sandstone. From the site have been recovered a wide variety of small containers, larger mortars and probable knocking stones and saddle querns. Some of the small containers held red ochre and other colouring materials (Childe 1931b, 134) and some of the early finds of mortars are recorded as having contained pounded fish bones (Petrie, 1868, 213). A large number of hand-sized flakes struck from small beach cobbles (Skaill knives) were found and a few distinctive axe-shaped, pear-shaped, T-shaped and serrated tools were made by grinding. Andesite and camptonite, which outcrop nearby, were used to make axeheads, a number of unusual tools similar to those in flagstone, as well as carved stone balls and a macehead in the style of the stone balls. Most of these cannot be seen as utilitarian objects, but are rather more ceremonial or religious in purpose. A small number of stone beads were also made. Pieces of haematite, probably obtained from the island of Hoy or from other outcrops nearby, were ground flat to form rubbers and polishers and, perhaps, to provide some of the colouring material.

Apart from the Skaill knives, most the everyday tools were made from flint and chert. With the exception of one small axehead, they are virtually all small tools in a series of scrapers, knives and utilised flakes. Flint would have been available as small nodules from some of the beaches and from eroding deposits. The chert was certainly a local material and there is some reason for believing that it was being collected and then heat pre-treated on site in building 8 (Wickham-Jones 1977, 29). Excavations at Links of Noltland, Westray have recovered a similar range of flint tools and, in addition, very small flint points which can be interpreted as drill points (pers comm Wickham-Jones). Pumice was recovered by all the excavations, but was cryptically referred to by Traill (1868, 433), and never published by Childe, although noted in the diaries for 1928, (find no 12). Clarke (1976a, 20), however, identified many pieces of pumice, (collected from the local beaches in Neolithic times), which have flattened, concave and grooved surfaces as a result of grinding and shaping bone objects. Pumice would have floated across the North Atlantic from Iceland well before Skara Brae was occupied.

No record of plant materials was made in excavations before 1972. Because of the care of modern excavation techniques, the use of sieving of spoil and the availability of on-site conservation, Clarke (1977, 24-25) was able to recover a range of cut pieces of wood, including fragments of handles and heather root rope. This shows a use of plants and small trees which were locally available at that time, but also timber which must have come as driftwood from the North American continent, and may have been substantial in size. Other plant remains, such as puff-ball, show that we can only begin to grasp how these organic materials were used. That they were available is important in our understanding of the range of goods made at the site and the type of handles, hafts and composite tools which might have been used.

The pottery found at Skara Brae has been one of the main subjects of scholarly attention, but no attempt will be made here to try and summarise the history of its study and classification. Suffice it to say that there are a wide range of vessel sizes represented, from small cups to pots with a rim diameter of about 500 mm. Almost all were flat-based 'flower pot' forms which were coil built. The firing, and size of the pots, meant that very few survived intact and most are known only from fragments which were carefully recovered from the middens. Some are plain, others decorated with applied strips or pellets (Class A), with strips which have been incised (Class B) or with incisions made into a thick slip (Class C). It was believed that there was a chronological distinction in the distribution of the different classes at Skara Brae (Childe 1931b, 130-31) but this may also reflect 'social' distinctions in the pattern of deposition (pers comm C Richards).

As has already been mentioned, a number of the small stone vessels contained powdered ochre. This would have been available as coloured earth from eroding soils nearby and, given the size of the vessels, may have been used as a paint for face, body or clothing rather than for anything larger, though it is possible that some of the decorated stones had their peckings and incisions enhanced by the use of colourants. Petrie (1868, 210) records discovery of a lump of white pigment as well. Shells were an abundant find in the excavation at Skara Brae. Apart from food, some shellfish also provided containers for pigment (limpets), and the raw materials for beads (winkles). At Links of Noltland, Westray, oysters were also used as pigment containers and cowrie shells for beads.

In a general discussion of the economics of the site, Childe argues for a picture of self-sufficiency, with all the exploited resources being locally available and this is a picture very much confirmed by subsequent study.

ANIMAL RESOURCES

The large mammal species of Orkney were not, and are not, native to it. Cattle and sheep were certainly brought over from the Scottish mainland and it has been argued that red deer must have been introduced by human settlers on Orkney (Clutton-Brock 1979, 120). How long before the first settlement at Skara Brae they were introduced, is impossible to say, but it may not have been more than a few centuries earlier judging by the oldest radiocarbon dates for a Neolithic settlement (Ritchie, A 1983, 117-18). Before the excavations of 1972-73, most references to the faunal remains from Skara Brae were as comments on the use of bones for tool manufacture or because of unusual finds (e.g. the discovery of 26 sheep metapodia found together; (Traill 1868, 436)). As a result, only a species list can be gleaned from incidental remarks made in the reports, which do not see animal husbandry or the detailing of faunal remains in any way as important as the listing of structural and artefact sequences. The exceptions to this are the two reports by Watson included by Childe (1931a, 74-75; 1931b 198-204), the latter being an expanded version of the former; and Childe's discussion of economy (1931b, 96). Watson, Professor of Zoology at University College, London, was sent the bones and identified them as, primarily, the bones of animals killed for food i.e. butchering debris. What was sent to Watson were a selection of bones found during the 1929-30 excavations (Childe 1931b, 96-97), so his conclusions regarding the importance of particular species is difficult to assess. In order of frequency he recognised cattle and sheep, with pig being rare and red deer noted by antlers and a few bones. Some bird and rabbit bones he dismissed as modern. Watson emphasised that it was difficult to draw parallels with known sites in England because Orkney's distinctive environment would result in local variations.

In the cattle, he recognised a single domesticated, large breed and a distribution in size which suggested bulls, cows and bullocks with a large number of animals being young. They were not <u>Bos primigenius</u>. The number of young animals was interpreted as representing deliberate autumn kill because of the lack of fodder for overwintering. Legge (1981, 180) has argued that this pattern actually represents a system of cattle management for dairy production. The animals had been slaughtered by pole-axing and most of the long bones had been split, probably to extract marrow. Considerable variety was visible in the sheep remains but they were still probably of one breed. It was impossible to tell whether the pigs were domesticated. The red deer were principally represented by six antlers which he had seen, four of which were shed, two of which had been removed from the skull, and a few further fragments and bones.

The earlier writers had recognised parts of cattle and wondered whether they were Bos primigenius. Sheep and deer were identified and Petrie (1868, 211) notes that despite many bones having been found split open, those of deer were recovered unbroken. Parts of cetaceans were recognised, principally those parts made into implements - vertebrae, teeth and ribs. Walrus tooth was identified and (contra Childe 1930b, 96), large quantities of fish bones, from sillocks and cod (Petrie 1866, 211). Childe was the first to identify pig (1928, 266, 277). The shells of shellfish including limpets and oysters were frequently found in the middens along with occasional bird bones (Traill, 1866, 438; Childe 1930b, 96). The two identifications which neither Childe nor Watson were able to support from the 19th century excavations are those of horse which Petrie describes as 'frequent' (1866, 211) and seal. It may be that those of horse were misidentified or the result of the deposition of horse remains at a later date in the overburden of the site.

Childe's review of the economy (1931b, 96-97), attempts to work through the implications of Watson's report, and his own observations of the faunal remains, in terms of the uses and availability of resources and their implications for the inhabitants of Skara Brae. He emphasises stock rearing of cattle and sheep and the quantity of meat produced. Hunting for deer (and perhaps also for pig) was an occasional thing. The collection of shellfish must have been an important part of life whether they were for human consumption or for bait (Clarke 1976b, 243-44) and sea birds and crabs were occasionally exploited. The amount of cetacean remains found could be accounted for by exploitation of stranded creatures.

Childe saw no evidence of crop growing and assumed that meat was the staple diet. Clarke's work has revealed the carbonised remains of barley from an early phase of the site.

Noddle (nd) has studied the larger faunal remains from the 1972-73 excavations and it is worth mentioning briefly the results obtained, as this can expand our understanding of the species exploited at Skara Brae. She was able to confirm the dominance of cattle and sheep in the faunal assemblage with cattle contributing significantly more meat than sheep, particularly during the earlier use of the site. There were occasional finds of pig, which was more common in the later use of the site, as well as red deer bones and the very rare remains of dog, otter, seal, dolphin, whale and cat (presumably wild cat). There may also have been a few goats. Amongst the cattle, there was a larger number of neonatal and mature animals than of those in between, but a more even representation in the age ranges for sheep. Pigs of all ages had been killed, but red deer tended to be new born, immature and mature, with juvenile animals rare. The cattle were considered a large breed, even approaching the size of Bos primigenius. The sheep, possibly wool-bearing, were of a type close in size to the current North Ronaldsay breed, though it may have been a little larger. The pigs were slightly smaller than wild boar and the deer were larger than those of modern Highland animals.

Identifications for the species of cetacean represented are not available, but examination of the teeth found on the site suggest a range of dolphins and pilot whales is present and the tooth of a killer whale. Untoothed whales are therefore unrepresented in this list because their remains could not be identified. Walrus has been recognised by its tusk and the os penis. There was certainly a wide range of fish of both inshore and offshore, including sillocks and cod and virtually every shellfish still available in Orkney. Bird bones were occasional finds and represent land, shore and sea species.

UTILISED MATERIALS

Given the very large quantity of objects made from skeletal materials at Skara Brae, it is impossible to list them here in detail. Nonetheless it is interesting to note that the same bone elements from particular species are consistently used to make tools of the same class. This is a pattern seen to a certain extent on the other sites studied here, but not to the same degree as at Skara Brae. Thus, rather than simply talking of bone points, we may refer to sheep metapodial (Fig 6.4; Pl 6.5) and cattle metapodial (Fig 6.5; Pl 6.6) points, because the vast majority of these are made from those bones. The main reason it is possible to ascertain the origin of the tools manufactured, is because the range of tools made makes great use of the natural shape and properties of the bones themselves and the articular ends are often modified only a little. This is a fact which has been recognised at Skara Brae from the early excavations:

> 'I have endeavoured to find out if any principle of selection was shown in the choice of certain bones for making particular implements, and I found that in general such bones were chosen as, in their natural form, most nearly resemble the shape of the article required; however, in the case of one kind of sharp implement, like a quill pen without a split, it appeared that they were always made of a bone from the wing of some large bird.' (Traill, 1868, 438).

CATTLE

All the bones of cattle used for tool manufacture are ones which would have been disposed of as part of the initial stages of butchery and most of those used were from mature animals. Many metapodials (Pls 6.2, 6.3) were used with only minor modification (from the point of view of the original shape of the bone, e.g. Fig 6.11; Pl 6.14) taking advantage of the distal articulations, though segments of split metapodial were shaped into other implements (e.g. bone slices, Figs 6.9, 6.10; Pl 6.13). Since they contain a large quantity of marrow, metapodials are usually split in order to remove it and it was presumably at this stage that such segments became available. Where it is possible to tell, there is a preference for the metacarpal. The astragali of cattle were used without modification (Fig 6.14). The scapulae would have had to have been cut from the meat and left to allow the band of cartilage on the vertebral edge to decay (Figs 6.12, 6.13; Pls 6.1, 6.15). The other main parts of cattle anatomy to be used, were the mandible and teeth (Pl 6.4), the former being split for the bone to make mandible blunts (Figs 6.8, 6.9), and presumably also for the marrow, the latter used for the dentine or ivory in the tooth roots (Pls 6.16 bottom right, 6.18, 6.19).

SHEEP

The vast majority of the bones of sheep used were metapodials, mainly from mature animals and most of them split to make use of the distal articulation (Fig 6.4, Pl 6.5) so that it is impossible to say whether there was a preference for metacarpals or metatarsals. Others were used as whole lengths of bone to be notched and turned into beads (Pls 6.18, 6.19) and these sometimes include those of immature individuals. A small number of tibiae were split and used (SB 704 Fig 6.9) and a very few unmodified astragali.

PIG

The only parts of the pig confirmed as utilised were pig tusks and teeth, used whole or split (Pl 6.16).

RED DEER

Chaplin (nd) has examined the antler surviving from all the excavations at Skara Brae. All were from red deer and of the thirty which retained the base of the antler, half were shed and half unshed. Some of the antlers were quite massive and others from young stags. A few whole antlers were used but otherwise antler was little used for implements, though occasionally the tips of the tines and segments of the beam were cut and modified (e.g. SB 893 Pl 6.16, SB 1098, 1127 Pl 6.16). Few bones were utilised but, where identifiable, it is only the metapodial which is represented. Petrie noted long bones in the middens, but commented that of the species seen, only those of the red deer were unsplit (1868, 211).

CETACEANS

Both the bones and teeth of cetaceans were used. Most of the objects were made from hollowed vertebrae (SB 885 Fig 6.14), although one disc had been made from an unfused vertebral epiphysis (SB 1184 Fig 6.15). Segments and lengths of unidentifiable paddle bones were also used (SB 572, 578 Fig 6.7). Petrie refers to the use of ribs as providing a roofing framework (1868, 207-08) although commenting on the same material, Traill writes of whale jaw bones (1868, 432). Whole teeth were perforated and used as pendants and the dentine or ivory of others was turned into beads (e.g. SB 1092, 1102 Fig 6.15, SB 1112, 1109, Pl 6.16; SB 1135, 1136, 1119, 1141, 1100 Pl 6.18).

FISH

The vertebrae of large fish were used to make containers. Because of the improved levels of recovery during the 1972-73 excavations, beads made from small fish vertebrae were also discovered.

BIRD

The bulk of the bird bones used were the humeri of gannets (SB 488 Fig 6.6 Pl 6.8) though a few ulnae were also used. Occasionally the radii and humeri of other species were also used.

WALRUS

Childe suggested that the <u>os penis</u> of walrus may have been used for the manufacture of large pins (Childe 1929, 264) and again (Childe 1931b, 146) that walrus tusk was a major source of ivory. The NMS displays agree that walrus tusk was a source for large pins, but it is felt here that few, if any, of the pins can have been made from this material and that there has been a misattribution of objects made from cetacean bone. Certainly tusks were found on the site and a trimmed <u>os penis</u> may have been used.

A very high proportion of the tools from Skara Brae are identifiable to species and to bone element. This results primarily from the fact that most of the tools made retain some features which are diagnostic of the part of the animal used. It will have been seen from the range of cattle bones used that these are bones released early in the stages of butchery. Simply from the point of view of recovering the marrow from those bones which contained it, it is likely that at least the preliminary working of these tools was performed at this stage and bones were probably split to extract the marrow with the intention of also providing raw materials for tool manufacture. Scapulae are likely to have been left to allow the cartilage to decay (Pl 6.1) before being used, and the rest could have been kept back during butchering, deliberately stored till they were cleaner and less greasy, or even dumped within the midden to be recovered when a suitable piece of bone was needed.

The bones of sheep suggest the same strategy, although it is difficult to understand the exact significance of Traill's observation of a bundle of 26 sheep metapodia found together (1868, 436) which he acknowledges as being the raw material for both bone points and beads. It is impossible to be sure whether these were fresh bones about to be split for marrow and turned into points, or bones soaked and ready for notching to make into beads. Whatever the explanation, this pattern shows a high degree of skill and competence in the exploitation of animals as resources for materials in addition to food and hide.

TECHNIQUES OF MANUFACTURE

The range of techniques of manufacture used to make the tools at Skara Brae is larger than that at Risga, but decidedly smaller than at the Iron Age sites discussed below. The major reason for this is the absence of large-bladed chopping tools. Certainly there were stone axeheads available and the best interpretation of the Skaill knives is for their use in butchery (pers comm A Clarke) but the latter are much better as knives for cutting meat than for chopping or sawing through joints and bone. In general, the skeletal remains suggest that joints were cut through, rather than chopped. As a result, bones such as metapodia would have been available as individual elements, and even those with a only a little meat on them would have been relatively easily available. As already mentioned, the scapulae would have had to have the meat cut from them. Apart from these the bulk of the bones used were released at an early stage in butchering and contain a large quantity of marrow.

PRELIMINARY TECHNIQUES

Fracture is really the only preliminary manufacturing technique used on the site. The other techniques used are finishing techniques or so closely identified with particular object classes that they were not generally used.

Because of the marrow content of the metapodials, ulnae and jaw, most of these bones at Skara Brae were broken open in order to remove it and this fracture technique is the most frequently used preliminary manufacturing technique seen on the site. Akin to the initial stages of flint knapping it relies on the fact that bone is a brittle material and, when struck with, for example, a hammerstone, will split open. The articular ends of long bones contain more porous and cancellous tissue than the compact shafts and therefore when a blow is struck to the bone it is the shaft itself that splits, usually leaving the articular ends with a splinter of bone attached. Thus fracture is both the way that marrow for the diet was obtained, and the way that the initial stage of tool manufacture was begun. It seems reasonable to assume that butchery and marrow extraction took place to enable as much as possible to be got from each animal killed. The techniques used to split bones would therefore rely on the fact that there are similarities in morphology which mean that all cattle metapodials will break in a roughly similar, though not exact, manner, and that sequences for the butchering of animals and the production of tools can proceed together.

Fracture was also used as a second stage in manufacture since flakes and unwanted segments can be driven off with blows. The exact extent to which fracture was used is difficult to assess from the finished objects because most of them were completed in such a way as to remove the remnant of the fractured surface, but some of the sheep and cattle metapodial awls show remnant fracture scars (e.g. SB 430 Fig 6.5) and the easiest way of producing blanks for bone slices is by this method (e.g. Pl 5.3). Unfortunately very few blanks for the production of any of the tools were recognised, probably because they were taken simply to be part of the butchering debris, which indeed is what what they also are. The most effective tools to fracture bones are hammerstones, in a range of sizes and shapes (Pl 5.2), all of which would have been easily available at Skara Brae and which would also have been of use in flint knapping.

The use of blunt implements, probably of stone, in a pounding action was the way in which whale vertebrae were hollowed (SB 885 Fig 6.14; SB 886 Fig 6.15). This was a means of crushing the cancellous tissue which would then be removed, producing distinctive shallow containers. Examination of the holes in the cattle metapodial mattocks, shows evidence of a crushed area around the markedly hour-glass shaped hole, which also suggests that these perforations were begun by striking blows with a blunt hammerstone at right angles to the surface of the bone immediately below the distal articular end (SB 778, 780 Figs 6.10, 6.11; Pl 6.14). This is also the most likely technique for the removal of one of the condylar processes on sheep and cattle metapodia in the production of points (Figs 6.4, 6.5; Pls 6.5, 6.6). Pounding is a very rough technique which can only work where there is a high concentration of cancellous tissue and is more effective if the bone has been soaked in water in advance.

The term notching is used to describe the use of a cutting/sawing action with a lithic knife or blade. This results in a groove in the bone surface which has an almost right-angled base. As a preliminary technique it was confined to the production of beads from bones and teeth (SB 1051 Fig 6.15 Pl 6.17), though it may have been used as an occasional secondary process in the completion of metapodial points (e.g. SB 441 Fig 6.4; SB 444 Fig 6.5; SB 577, 582 Fig 6.7; SB 440, 441, 438 Pl 6.5). The use of lithic tools in cutting bone to shape has not been observed.

SECONDARY TECHNIQUES

Once the roughing out had been finished, a range of secondary techniques was used to achieve the fine detail of shaping. Just as fracture is dominant as a preliminary technique, so grinding is the most common secondary technique. On many of the coasts of Northern and Western Scotland, pumice was available which had eroded from post-glacial sources in Iceland and had floated across the North Atlantic. This was used at Skara Brae as the main material for grinding bone objects to shape. Although a very few pieces had been collected, but unrecognised, before Clarke's excavations in 1972-73, it was only with the sieving of excavated spoil that pumice was noticed and recovered in any quantity. When found in a dark, sticky midden layer, pumice is almost unrecognisable and without careful cleaning may be mistaken for small fragments of burnt bone. Many of the pieces have flattened or slightly concave surfaces, and some have small grooves which were worn as a result of their use in shaping the shafts of bone points. Pumice naturally comes in different grades, in that the size of gas holes varies. Coarse work could, therefore, be undertaken with pumice which had large gas holes, and finer shaping and smoothing using pumice of a finer grade. Other locally available rocks, such as the coarser grained sandstones, would have acted as grinding stones, but are nowhere near as effective as pumice used in small lumps, fitting easily into the hand and producing an excellent abrasive action. That pumice was used in the shaping of most of the bone tools made, is shown by the characteristic closely parallel grooves which are found over broad areas of flattened surfaces e.g. the blades of mattocks or the surfaces of bone slices, and from the longitudinal striations on the rounded bone points. Transverse and oblique striations on other parts of the tools will have removed flake scars and unwanted protuberances (Pl 6.9).

Some of the pins in particular have a very high polish which has resulted from the abrasion of the surface until it is exceptionally smooth. This would have been achieved by grinding the surface smooth with pumice and then using leather, and perhaps a fine ash powder, to produce a very smooth surface. Human handling will have enhanced the polish but the long, smooth circular section of some of the finest bone pins could not have been produced by handling alone, even after having been shaped with the finest of pumice (Pl 6.12).

The use of lithic tools to scrape or trim the surface of bone tools is only very rarely seen. The marks left are different from those of grinding, since the irregular blade surface of the flint, chert or stone flake leaves a more uneven pattern on the bone surface. It was likely to have been used to make a fine adjustment to the shape of a tool only when a piece of pumice was not to hand.

The use of notching has already been discussed as a preliminary technique in the production of bone and tooth beads. Since beads and pendants form a substantial part of the assemblage at Skara Brae, it is worth examining the other techniques associated with bead production. A bone or the root of a tooth was notched until the marrow or pulp cavity were reached. Because these cavities are present no perforation was necessary. The beads were snapped off and then finely ground, to remove any protruding tissue, and polished. This was probably achieved, as discussed above, with the use of pumice, leather and fine powder, the tooth roots usually having the cementum removed so as to expose the coloured dentine below. Since some of the tooth root beads are less than 4 mm long, the dexterity of the bead makers is worth noting. Notching was also used on some of the whale teeth to make larger beads which had a small natural perforation in them. There are, however, a large number of disc beads of bone and ivory, some pendants of tusk and bone, a small number of segments of boar's tusk, and a few bone points which did require perforation (SB 1092, 1101, 1102 Fig 6.15; SB 1109, 1112, 1119, 1140, 1141 Pl 6.16; SB 572, 573, 577, 578, 593 Fig 6.7; SB 568, 570, 574, 576, 580, 587, 595 Pl 6.10; SB 434 Fig 6.4; SB 434, 436, 437 Pl 6.5; Pl 6.7, 6.11). The holes themselves are markedly biconical and have irregular concentric striations which would suggest the use of flint tools. Nothing suitable was recognised at Skara Brae, but at a comparable site at Links of Noltland, Westray, one of the flint types which was distinctive of an area which contained bead making debris, was the 'Grobust pick' which has been identified as a drill point (pers comm C R Wickham-Jones; N Card). Whether this was mounted in a spindle and turned by hand, or used with a bow or pump drill is uncertain. Given the small size of some of the perforated pieces it is difficult to believe that the perforations were made using a hand-held point.

The bulk of the tools used in the manufacture of objects from skeletal materials are therefore of stone. Hammerstones were used to fracture most bones and pound others, and pumice provided the most frequently used grinding substance. Flint and chert blades and knives were commonly only used in the initial stages of bead production.

OBJECT CATEGORIES: CHILDE

Petrie (1868), Traill (1868) and Stewart (1914) make it clear they were well aware that a range of objects were being consistently made from the faunal material available to the inhabitants at Skara Brae, but it was only with Childe's involvement at the site that the description of the objects became systematic. It is worth examining the development of his classification and then revising it is terms of the classes identified in this study.

Childe's scheme was developed over the years during which he was involved at the site, but the principles of it remained consistent throughout. As initially conceived (Childe & Paterson 1929, 261-66) it recognised three main groups of implements - piercing tools (Group A);

'a miscellaneous series of cutting or polishing implements whose exact use is really unknown' (ibid., 264) (Group B); and picks and shovels (Group C). Each group had sub-groups. Such a classification is functionally based, but has problems of definition since one of the groups created in the analysis (Group B) is not fully understood. Throughout Childe's classification and its further detailing there are the problems of confusion between classifications defined principally on morphological, technological and functional grounds. These are far from easy to resolve but a step forward is taken simply by recognising and defining the problem fully. In addition to groups A, B and C Childe included separate classes for cetacean bone vessels, other cetacean objects, and beads, pendants and the debris from their manufacture.

Group A comprised A1 (A1a, A1b, A1c, AC1, AC1a, AC1b, AC1c), A2 (A2a), A3 and A4. A1 can be described as borers or pins made from a split sheep or deer metapodial leaving part of the articular end to form the head of the implement (Childe & Paterson 1929, 261). The different variants were only fully detailed in the Skara Brae monograph where A1a and A1b retain part of the distal end of a sheep metapodial, but in A1b the condylar head is heavily ground. A1c has part of the proximal end of a sheep metapodial as its head and all other small pins and splinters are classified under the general heading of A1 without further division. (Childe 1931b, 115-17). Those classified as AC1 were defined as being larger tools made from the metapodials of red deer or young cattle and could be divided into similar categories of: AC1a, which have half of the distal articulation present and unmodified, AC1b which also retain half of the distal articulation but on which it has been heavily rubbed down and AC1c which were made from the proximal end of the bone. Those which showed too little of the articular end were simply classified as AC1 (Childe 1931b, 115-17).

A2 are awls, initially described as only made from sheep metapodials (Childe & Paterson 1929, 263), but later defined as including ones made from a sheep ulna or bird bone as well. Rather than being split down the centre as in A1, the diaphysis was split obliquely and then ground to a point leaving the articular end, which formed the head of the awl, intact. Generally these were made retaining the distal end of a sheep metapodial, though it has sometimes been ground, but occasionally it was the proximal end which formed the head (Childe 1931b, 118). A2a are only mentioned in Childe & Paterson (1929, 263) where they are described as having had the articular end shaped to produce a squarish section (i.e. they have heavily ground heads). The term CA2 is used only once, to describe a large awl made like A2 but from a cattle metapodial. The only illustration of it by Childe (1931b, 126, Plate XLIV.2) has a caption which mistakenly identifies it as 'CA1'.

A3 was a 'needle', a very rare find, with a flattened head and simple perforation (1931b, 119).

A4 is a class of pins which is tightly defined. They were initially described as laterally perforated, bulbed pins (Childe & Paterson 1929, 264). Some from the 1930 excavations were unperforated (Childe 1931a 64-65) and in the monograph, the form of the head is described as usually being a conical bulb, slightly wider than the shaft (Childe 1931b, 120). All were thought to have been made from some form of ivory. This seems to exclude from any of Childe's categories the other pins he mentions - one with a flat paddle-shaped head (Childe 1931a, 64) and giant pins from earlier excavations (Childe 1931b, 120-21). The term CA4 is used to describe piercing tools made from ruminant ulnae (Childe 1931b, 126).

Originally listed as a 'miscellaneous series of cutting or polishing implements whose exact use is really unknown' (Childe & Paterson 1929, 264), those objects comprising Group B were later described as 'cutting or smoothing tools' (Childe 1931b, 121). B1 is a 'celtiform' implement (Childe & Paterson 1929, 264), or slice of bone, from the metapodia or other long bones of cattle, polished on both faces and having a ground edge at one end (Childe 1931b, 121).

B2 is described in 1931 as being an isolated spatuliform or blunt-edged implement, but the illustration of it shows an object which is a segment of long bone eroded by the wind and sand (Childe 1931b, 123, 122 Fig 13). This and the other objects in B2 are pseudotools.

B3 was made from a cattle mandible which had been split below the teeth, the front part of the bone being ground to a blunt-nosed end. It was interpreted as a 'fabricator' for flint i.e. a retouching tool (Childe 1931b, 123). Childe (1930, 188-89, Fig 27.1) refers to Group B3b as being blunted marrow bones, e.g. the proximal end of a sheep radius. These are objects later classified as 'B6' but unfortunately that illustrated is probably a humanly split, but naturally eroded, pig fibula.

Both B4 and B5 were recognised as unique implements which can broadly be described as spatulae (Childe & Paterson 1929, 266, 265 Fig 29). B4 is, however, an unworked, but eroded, rib.

B6 covers a range of implements made by splitting sheep tibiae and bird legs obliquely and grinding the tip to form a blunted nose (Childe 1931b, 123). Childe (1931a, 64) refers to two objects found in 1930 which are listed as being of group B6b, but this is not further defined nor is it mentioned anywhere else in his writing. It may simply be a typographic error for B6.

Originally listed as 'picks and shovels' (Childe & Paterson, 1929, 266) this group was later termed 'heavy tools' (Childe 1931b, 124); hence the use of the letter 'C' for the large bone points AC1. Tools of group C1 are made from cattle metapodials which have had the proximal end removed and the diaphysis sharpened to an acute blade edge usually on the dorsal surface, but occasionally on the plantar. Just below the distal epiphysis was made an oval perforation. Childe (1931b, 124) describes this as a perforated adze. Two variants were identified, although the descriptions of them make their identification very difficult. C1a seems to have the blade parallel to the shaft hole, making an axehead rather than an adzehead, but it is unclear whether it is the blade or the shaft hole which is in a different place from usual (Childe & Paterson 1929, 266; Childe 1931b, 124). Tools of the type C1b have the blade formed on the lateral surface of the bone, but it is not clear whether they would be axeheads or adzeheads (Childe 1930, 189; Childe 1931b, 124). CB1 is made by splitting a cattle metapodial from the proximal end to make a 'spatuliform chisel-like tool' (Childe 1931b, 126).

C2 covers cattle scapulae which have been used as shovels and had the spine worn down (Childe 1931b, 127). In one publication, Childe (1930, 189) classes these wrongly as C3. Later, C3 is used to identify a bladed tool like C1 but retaining the proximal end of the cattle metapodial, unperforated (Childe 1931a, 65).

Childe recognised that bone was used for other items. Large and small whale vertebrae were hollowed out to provide containers, the latter frequently being used to hold pigment, and there were a number of other pieces of worked whale bone (Childe 1931b, 136-37). The majority of the items made from bone and tooth, however, were beads and pendants. Beads were made from segments of sheep metapodials, bird long bones and cattle teeth, from discs of ivory and fish vertebrae. Pendants were made from a range of perforated teeth and tusks, principally those of whales and boars (Childe 1931b, 144-49). Additionally, mention was made of the perforated antler mount for an adzehead and the decorated cubes of bone (Childe 1931a, 61; 1931b, 154).

OBJECT CATEGORIES: FOXON

The categories devised for the study presented here are ones based on morphology and technology (though some of the names used are functional ones), and as a result there is some overlap, but some disagreement, with the scheme used by Childe. At Skara Brae there is generally a very strong correspondence between the shape of an original bone and the finished object. Only in a few categories (e.g. slices, fine pins and beads) are skeletal elements used as a form of bulk raw material rather than almost naturally half-finished tools. This means that the people of Skara Brae were making use of the natural properties of bone and of individual bone elements. Some of the range of items made on Iron Age sites would, however, have been virtually impossible to produce with such a repertoire of lithic and skeletal tools, and so some of this correspondence is the result of a technology which, in the light of the later development of iron-bladed tools, must be viewed as more restrictive. There is, however, a very wide range of objects made and a wealth of skill displayed over several centuries.

All the objects of bone, antler and tooth which were locatable in the various recipient museums were examined. As a result, the collections in Tankerness House Museum, Stromness Museum, Skara Brae site museum, the National Museums of Scotland and the British Museum were studied. The collections from Skara Brae are vast, and whilst it was possible to examine most of the collections on two occasions, the work had to be undertaken over a long period of time with breaks between. Detailed comparisons between collections holds some difficulties, as like objects could not be examined together. Standardised formulae for description were devised, and it is because of this that the large, dispersed collections can be discussed in general terms. For the purposes of this discussion the material collected and excavated under the auspices of Watt, Stewart, Paterson and Childe are discussed together since, as will be seen from the catalogue, the range of objects recovered is consistent across these excavations.

POINTED IMPLEMENTS

A very large number of the implements from Skara Brae are pointed tools, with sharp thin tips, round-ended stubby tips or straight shafts and rounded tips. As with most bonework, distinctions can be made on the basis of raw material origin, modification and morphology. The categories used here reflect this. The distinction between points and large points is simply on the size of the animal species utilised. 'Awls' and bird bone points are distinctive in their raw material and method of manufacture. Points/pins are morphologically distinct and qualitatively different from other points in the finish achieved. Pins form a varied group of objects which have elements of decoration or fineness of finish which set them apart. As to function, it is likely that the pins and points/pins are items of dress and adornment in clothing, hair etc. The awls and bird bone points seem suited as small strong piercing tools. Within the large category of points it is difficult to identify a single use to which they were put and additional to those already mentioned, they may have been used as needles, straw working implements, pottery decorators etc.

All make use of the natural strength of long bones in their longitudinal axis. the thickness of the tip varies from the thinnest bird bone, to the thickest cattle metapodial. Though the bone is as strong in one as it is in the other, the thicker the bone tool, the more resistant to a specific stress it is since the area of the tip will usually be greater on the larger bones. A fine thin sheep metapodial point will, however, be as vulnerable to breakage as any other of the same fineness, and be more vulnerable than shorter, stumpy tips which form a less acute angle. Breakage is most likely to occur when the point is subject to a force at an angle to the longitudinal axis of the tool.

POINTS (SB 1-374, Fig 6.4, Pl 6.5; All included by Childe within A1)

The great majority of the points are made from sheep metapodia which have been split to leave part of the articular end as the head of the tool, and a ground tapering length of the split diaphysis as the shaft and tip. Such a split follows the natural longitudinal axis of the bone and its direction of weakness. The removal of one half of the articular end, however, must have been a skilled piece of work as a fracture would normally terminate before it rather than run through it. It is likely that any surviving parts of the second condyle were removed by crushing and grinding. Because of the modifications, it is impossible to assess the extent to which the bones used were metatarsals or metacarpals.

Whilst a few were made from the bones of immature animals, the vast majority were those of mature animals. Of these, there was a marked preference for retaining one of the two condyles of the distal end as the implement head, although a few have been made using part of the split proximal end as the head. The traces of impact marks on a few of the tools and occasional remnants of the second condyle, show that a blow had been struck to the anterior/posterior surface of the bone where it expands below the articular end, in order to leave a lateral splinter of the diaphysis. With a pumice block, the rough edges were then ground away, the shaft being smoothed and the tip sharpened using a grooved piece of pumice. Occasionally the head was left unmodified, but more often the split side was ground to produce a flat or rounded surface and the sagittal ridge was made less sharp, presumably to make the point more comfortable to hold. The extent to which the head was ground forms a spectrum from the completely unground to the head which was heavily ground to produce a circular- or square-section, almost entirely comprised of cancellous bone. Some of the points had only the anterior and posterior surfaces of the condyle ground, resulting in a very thin head, which retains the full profile of the condyle and sagittal ridge.

There is quite a variation in length in those which are still complete, but the fact that a few show signs of having been broken and reground makes one wary of any general statistical conclusions based on this, since the short stubby points may once have been much longer, more acutely-angled ones which have been reground on several occasions. A few of the points are described as being of compact bone, but most of these are probably also made from sheep metapodia, on which so much of the identifiable features has been removed or broken, that it is impossible to be certain, although the thickness of the bone as measured from outer surface to marrow cavity would be consistent with that of sheep metapodia.

LARGE POINTS (SB 375-433, Figs 6.4, 6.5, 6.6)
(Included in Childe AC1)
The technique of manufacture of large points is an exact parallel to that of the small points, most the large ones also being made from metapodia. Whilst the majority of the large points are certainly made from the metapodia of cattle, there are a number of slender ones with modified heads about which it is difficult to be sure whether they come from small, slender (?female) cattle metatarsals or from deer metapodials. Because of the size of the condylar head of most of the large points, it has often been modified by grinding down in facets rather than in a complete curve. In addition to cattle and deer metapodia and unidentifiable segments of long bone, the radii and tibiae of sheep were also used, the shaft having been split and then ground to a point. The tips of the large implements are much thicker than their smaller counterparts and often somewhat blunter.

PERFORATED POINTS (SB 434-37, Fig 6.4, Pls 6.5, 6.7) (Childe A3)
There are only four perforated points, or 'needles'. Three are made from small split sheep metapodial points on which the lateral faces of the head have been ground flat and then a hole drilled in from both sides using a flint drill bit. The fourth is made from a segment of compact bone, the perforation having been made in a flattened area of the diaphysis. All are simply modified versions of the more common points, rather than being distinctive in other ways.

GROOVED POINTS (SB 438-41, Fig 6.4, Pl 6.5) (included in Childe A1)
Three sheep, and one ?deer, metapodial points have had a groove notched or cut into the completed point just below the remains of the articular head, which is the distal end in three cases and the proximal end in the other. The groove is only millimetres deep and it is difficult to assess whether this is a form of decoration or a

means of attaching thread or string for their use as some sort of needle. As with the perforated points, the grooved points are like their more common counterparts in all other respects.

DECORATED POINTS (SB 442-45, Fig 6.5) (included in Childe A1)
Of the four decorated points, two are made from sheep metapodials and two from cattle/deer metapodials. All are decorated by grooving on the external surface of the shaft with simple geometric patterns - horizontal lines, herring bone, horizontal and oblique lines and oblique lines.

AWLS (SB 446-79, Fig 6.6) (included in Childe A2)
Whilst the objects termed 'awls' here are indeed likely to have been strong piercing tools, they are also definable in terms of their raw material - metapodia - and method of manufacture. The bone was struck almost mid-shaft in order to leave the articular end complete, and to produce a length of attached diaphysis which was then ground and shaped into a point tip which is usually stouter than those of the points discussed above. This is a simpler tool to produce than a point, since less of the bone is removed. The tip and shaft may lie laterally or in the anterior or posterior plane. The sources of material are parallel to those used to make points, in that most are those of mature sheep and retain the distal end as the tool's head. A few were made from bones of immature animals or use the proximal end as the head, and a number are 'large awls' made from cattle metapodia. Some also have their heads ground.

BIRD BONE POINTS (SB 480-516, Fig 6.6, Pl 6.8)
(included in Childe A2)
Bird bone points are very similar to awls in that they were made by splitting diagonally across the diaphysis shaft rather than along its longest axis, to produce a length of bone which was ground to a fine, sharp and thin point; usually only about 1 mm in thickness. In the majority of cases, the articular end was retained unmodified, but on some of the pieces it has been ground a little. Most were made from the humeri of gannets (pers comm A S Clarke), but the ulnae and humeri of other birds were also used in the same way. The gannet is a bird of the cliff and open sea and, now, by no means a

common bird of the shore. Its habits are very unlikely to have changed to such a great extent since Neolithic times. This deliberate selection of gannet humeri, may be the result of the Neolithic appreciation of mechanical properties whose subtleties have escaped modern researchers, or it may also be related to more symbolic approaches to the role and strength of the bird and, by analogy, of its bones. It is easier to believe that the bones were obtained from carcasses washed up on the beach, rather than from birds which were specifically hunted or netted. The strength and fineness of the point will have made excellent piercing tools for precision work, presumably in piercing hide or leather for sewing.

POINTS/PINS (SB 517-58, Fig 6.6, Pls 6.6, 6.9)
(included in Childe A1)
This is a group of implements made from split sheep metapodia (in one case a cattle or deer metapodial) or a thin segment of compact bone from a diaphysis, which tend to have long, thin shafts which are as narrow just below the head as they are at the tip. The surface of the shaft has been ground smooth and highly polished and the tip is usually sharp. These are so long and fine that they are unlikely to have made good piercing implements and might better be seen as decorative pins perhaps for the hair or clothing. Such thin long shafts are dangerously breakable and one would presume that bone has been selected for its colour, ability to take a polish and the decorative feature of the cancellous tissue in the epiphyses, rather than the physical properties discussed in earlier chapters.

PINS (SB 559-606, Fig 6.7, Pls 6.10, 6.11, 6.12)
(including Childe A4)
There is considerable variety in the types of pins identified. Childe's category A4 was restricted to pins with lateral bulbs and sometimes loops. Here the group is expanded to include a range of giant pins and unperforated objects, as well as those which are perforated and/or bulbed. The main criterion for inclusion is the quality of finish and polish which the shaft has received. Most of the pieces have circular-sectioned shafts with a very high polish, although a number are flatter. Although they have been described as made of walrus tusk and ivory, the majority are made from compact

bone, probably long thin segments from cattle long bones, or from pieces of more solid cetacean bone. The head shapes include ball heads, conical heads, mushroom heads, square and spade-shaped heads and simple rounded ones. Some of the shafts are perforated and there is group which has a distinctive additional knobbed or bulbed expansion carved on the shaft which is sometimes perforated. Some of the giant pins are particularly distinctive and elaborate. Most of the pins have thick, circular-sectioned shafts and, as with the points/pins, the raw material seems to have been chosen for aesthetic reasons as much as for its physical properties. Such attractive pieces are likely to have been used as decorative fastenings for clothing or in the hair.

SPATULAE (SB 607-23, Fig 6.8) (including Childe B5)
This is a term which covers a range of implements of various materials all of which have some form of flattened tip. A number were made from cattle or deer metapodials which were split and ground to provide a long flat shaft with curving edges leading to a polished, tongue-like tip. A few make use of a segment of compact bone which has been ground completely to form a long flat piece of bone with a rounded end, in two cases with a point at the other end. A broken one made of cetacean bone is waisted and has a rounded nose. Generally they are all heavily ground, but by no means do they form a coherent group either in terms of raw material or morphology. Some may be smoothing or potting tools (like the slices discussed below) and those with a tongue-shaped tip must have been used in the same, as yet unidentified, way. All have been made from fractured long bone segments which have then been ground and sometimes polished. Their distinction is in the length of the worked area and its blade-like appearance.

MANDIBLE BLUNTS (SB 624-76, Fig 6.8, 6.9) (Childe B3)
About 60% of the tools with deliberate blunt ends are made from the mandible (or lower jaw) of cattle. The bone was split longitudinally to remove the teeth and marrow, and broken transversely just behind where the molars lie or closer to the processus angularis. This latter area was ground smooth and rounded to be held in the hand. The working area was formed on the U-shaped piece of compact bone

which formed the base of the mandible, by grinding to a rounded end with a flattish surface for an area about 7-8 mm by 4 mm. This part of the tool shows signs of having been further modified by use to give a roughened, crushed and striated surface, the appearance of which is paralleled by pressure flaking tools (pers comm C R Wickham-Jones) and the view of previous writers that these are 'fabricators' or implements for working lithics is supported. Two were made with blunt tips at both ends. The selection of the mandible for such tools, makes use of a very thick area of bone which required little modification to produce something easily held in the hand. It was the thickness and stability of such a working end that made it suitable for pressure flaking.

LONG BONE BLUNTS (SB 677-709, Fig 6.9) (Childe B6)
Other blunt-ended tools from the site show the same features on the tips but are made from long bones rather than mandibles. One group utilises sheep tibiae which retain the proximal articulation but have been split transversely across the shaft, the blunt tip being formed by part of the split compact surface of the shaft. The other major group makes use of segments of cattle or deer metapodials or similar long bones which have the tip formed by blunting the end of the segment which contains least cancellous tissue. From Watt's excavations were found two blunts, made from cetacean bone. Sheep tibiae supply a similar thickness of bone to that in the jaw and require no modification at the proximal end of the tool since the diaphysis of the bone fits easily into the hand. Long segments of shaft from other animals can range from simply split lengths of shaft to ones which have had their whole surfaces ground (e.g. SB 708 Fig 6.9). As with the mandible blunts, these sources of bone were chosen for their thickness and ability to take a flattened/blunted tip which could withstand the stress of pressure flaking.

SLICES (SB 710-65, Figs 6.9, 6.10, Pl 6.13) (Childe B1)
Bone slices are simply made from roughly rectangular segments split from long bones such as cattle metapodia. The whole surface of the segment was heavily ground to produce one blade-like edge either at the base of a square or an elongated triangle with rounded corners.

The blade can be at right angles to the axis of the piece or oblique to it. In section, slices are plano-convex, the upper surface being completely ground to shape and the lower one occasionally retaining part of the marrow cavity centrally. The blade edge is rarely sharp but more frequently rounded though not highly polished. These are hand-held tools and would be effective in potting and decorating pottery. Selection of the raw material for bone slices was determined by the size and thickness desired for the finished piece. Few bones, beyond the principal limb bones of cattle, could furnish a solid piece of bone of such a size which could be ground to produce stable edges.

METAPODIAL MATTOCKS (SB 766-821, Figs 6.10, 6.11, Pl 6.14)
(Childe C1)
These are bladed tools, usually made from adult cattle metacarpals, though also from metatarsals, which retain the condyles at the distal end but have had the proximal articulation fractured off and ground to form a blade on the volar or plantar surface. The blade is rounded or slightly flattened at the tip and has the split surface ground flat or slightly convex. The back of the blade is formed from the flatter surface of the bone and usually has had the shallow channel or sulcus ground away. Below the articulations is a perforation frequently more oval in plan than circular, and markedly hour glass-shaped. As is shown by the crushing of the thin compact surface at this point on some of the implements, this hole was not drilled, but made by striking the two surfaces of the bone to break the compact surface and then crush and hollow out the cancellous tissue which underlies it.

A single example in process of manufacture, with the perforation complete but no other modification made to the bone (SB 817), shows that this operation, which might completely split the whole bone in an uncontrolled way, was carried out before the blade end was formed. Comparison of an unused example (SB 789 Fig 6.11) with any of the others, shows how long they might originally have been and suggests that for this one at least, the blade may have been made simply by grinding the proximal articulation away, rather than fracturing it off. There are fragments of blades broken off and split during use and showing severe invasive flaking from the blade edge, which is as a result of the use of the implements. Many of the short implements may well be reworked tools which have been reground and this would explain some of the noticeable breaks in angle seen on some of the blades. Such damage is not caused by use as a beamer or hide cleaner, but would be consistent with digging implements, perhaps used to loosen soil, sand or dig out roots, the damage being caused by striking stone or very hard earth. A few have slightly polished areas by the perforation and some grinding of the sagittal ridge of the condyles which may be the effect of hafting the implements like a mattock hoe or adze. Two of the implements have the perforation through the lateral face of the bone with the blade edge still on the volar or plantar surface to make 'axeheads', one retains the proximal end of the bone (SB 807) and one is made on a metatarsal with the blade on the lateral surface but the perforation in its usual place (SB 796).

As with many of the tools at Skara Brae, there is a very close relationship between the selection of bones and the final implement. Metacarpals and metatarsals of cattle of cattle are the only cattle bones which show such marked symmetry as to be centrally perforated. These are also some of the few bones to provide a thick, flat area of bone to form a blade edge. If mounted as a mattock, the natural longitudinal resistance of the bone to compressive forces would be tested dynamically every time it struck the ground. Most of the soils around Skara Brae are light, sandy ones, and such bone mattocks would have worked such soils well.

SCAPULA SHOVELS (SB 822-59, Figs 6.12, 6.13, Pl 6.15) (Childe C2)
The use of slightly modified scapulae to make small hand shovels is well known from various sites throughout Britain (Curwen & Curwen 1926). Some modification of the scapula is necessary, since once it has been cut free of meat, the natural broad band of cartilage at the blade edge must either be removed, or, more easily left to decay a little and broken free. This leaves a flat edge up to 10 mm thick where the blade is to be formed, and it is likely that this and part of the spine would have been ground down to produce a sharp blade edge. Use of the shovel would have been by holding it at the collum

with the spine downwards and the blade edge towards the user. Most of the shaping and grinding on the blades and spines are the result of use but occasionally traces of initial shaping of these areas can be seen. Two shapes of blade edge were recognised at Skara Brae. Blades with a U-shaped edge are simply ordinary scapulae which have worn, rounded edges (SB 838 Fig 6.13). Those that are described as W-shaped (SB 828 Fig 6.12), have not been noted as distinct before, but are the result of the use of a scapula which has weathered heavily before use or begun to wear down over prolonged use.

The central area of the scapula blade is the thinnest part of the bone, and it is here that carnivores most often gnaw them and that they break if they are trampled upon. Equally, a well used tool will damage most easily at this part of the bone. Most of the scapula shovels were additionally damaged during excavation and so it is sometimes difficult to be sure of what breakages are attributable to which cause, but modern fractures are distinguishable by their different colour and ancient ones by the roughness of the edge. Gnawing and animal breakage leave their own traces and taking all these features into account, there are still a large number of shovels which show an original, utilised W-shaped blade edge. Whilst it is impossible to be sure whether this was the result of heavy use or not, it has been already suggested that scapulae may have been left after butchery to allow the cartilage to decay a little. Under such circumstances, it may be that scapulae for use as shovels were recovered from middens even after some of the bone had been damaged, rather than being used fresh.

Of the bones in the body, the scapula is the only one which presents a naturally broad, flat edge which gradually thickens away from that edge. It has a 'shovel' shape and, as with many of the bone tool classes from Skara Brae, shows a very clear link between bone morphology and tool classes. Repeated usage would wear the bone down quite rapidly, but when replacements were necessary, new scapulae would have been relatively easy to take from butchered animals. Unlike long bones, there was no reason to split them up for marrow since they contain none.

ASTRAGALUS POLISHERS (SB 860-83, Fig 6.14)
Exactly what these implements were used for is uncertain. Almost all are the astragali of cattle, though a few of those of deer and sheep were also found. They are unmodified, but shows signs of slight to very heavy wear on the four raised condyles of the posterior surface, in the form of a very high polish. No extraneous material is incorporated in the surface and such a polish is best explained as being the result of the heavy rubbing of hide, perhaps to make it more supple, though a similar polish would result from its use on plant material.

Astragalus polishers are hand-held tools and the size and shape of the bone must have made it immediately attractive. It would have been freed at an early stage in the butchering of animals, and the thickness of the outer compact tissue must have been part of the reason for its selection. It may be that the four points of contact (or double lines in the case of heavily worn examples) made a more effective rubbing tool, giving two, lines of pressure in one implement, rather like modern double-bladed razors.

CUPS & VESSELS (SB 884-92, Figs 6.14, 6.15)
A small number of vessels were made from the vertebrae of cetaceans, from large fish vertebrae, and from an unfused epiphysis. The vertebrae had the epiphyseal surface removed, if it were present in the first place, and the interior cancellous tissue broken and hollowed out to give a smooth surface. The small vessels have traces of red colouring material in them and served as paint or cosmetic pots. A similar range of vessels was made from hollowed stones. At least one much larger vessel made from a block of cetacean bone was also found which was made from a very large, hollowed whale vertebra and must have stored dry goods.

It is again the size and shape of the original bone which have made these elements attractive. It seems likely that the pounded cancellous tissue at the bottom of the cups acted as an abrasive area for crushing earth and making it into a paste, rather like the bottom of a pestle. This would make a good parallel with the pecked bases of the stone cups.

ANTLER SOCKETS (SB 893-94, Fig 6.15)
One certain and one possible antler socket were found at Skara Brae. The fragmentary one may have been a perforated antler macehead rather than a socket, but is in too broken a condition to be sure. The complete one is an adze sleeve, made from a segment of beam which has been hollowed out to take a stone blade and perforated for the insertion of haft. No traces of the original marks of manufacture now survive, but the outer surface of the antler appears to have been smoothed. The perforation has straight sides.

This is the largest piece of antler beam to have been used at Skara Brae. Earlier discussion of the resilient properties of antler producing a more effective shock absorber than bone, indicates that making an adze sleeve in which to fit the stone tool and which would then be mounted on a wooden shaft, is a creative use of those properties. The hollowed cancellous tissue provides a good area in which to sit the stone blade and can be shaped to suit it. Such antler adze and axe sleeves are, however, very rare in Britain.

ANTLER PICK (SB 895)
Several almost complete antlers have come from Skara Brae, some with the bez tine removed and the brow tine showing some signs of wear, but only one can confidently be described as an antler pick with a heavily worn brow tine.

Antler picks form effective tools for prising out stones in the soil, rather than as digging sticks or picks in the way we now think of them. The resilient properties of the raw material make them the natural choice from the whole range of skeletal hard tissue for such implements. Antler picks are known from many Neolithic contexts in Britain and Europe.

ANTLER (SB 896-912)
Other pieces of antler were recovered from the excavations, some with polished, hollowed or worn facets on the tips of the tines. Chaplin believes that some of them should be considered as artefacts and most of those identified by him are tines with worn tips which could have been used as pressure flaking tools. Nevertheless, the

studies undertaken by Olsen (1984b) make one very wary of even these features.

BEADS (SB 913-1044 Pls 6.16, 6.17, 6.18, 6.19)
BEADS IN PROCESS OF MANUFACTURE (SB 1045-59 Fig 6.15)
BEAD MAKING DEBRIS (SB 1060-75)

A vast number of beads of various shapes and sizes were found at Skara Brae. We are lucky that from the start of excavations there, pieces were recognised which are beads in the process of manufacture and the debris left from manufacture. The use of wet sieving techniques by Clarke at Skara Brae in 1972-73 and 1977 and at Links of Noltland 1978-1981, has confirmed these sequences and additionally filled in some of the gaps which require the recovery of very small pieces of debris. Whilst beads on the site were found well distributed, there were some distinct concentrations in parts of passages B and C, at the threshold of house 7 and particularly in Cell 3 of house 1 in which Paterson found over 3260 beads and many pendants in an exceptional cache of decorative material. The significance of these concentrations will be discussed further below. Whether the beads were strung as necklaces, bracelets and girdles or sewn to clothing is uncertain. The pendants would hang better from strings or thongs and their regular association with the beads may suggest that they formed decorative collars and necklaces.

By far the majority of the beads are made from the tooth roots of cattle incisors and canines. The tooth was notched all round with a lithic blade so as to produce two or three beads, leaving behind the crown as debris and sometimes also the very apex of the tooth, although this was sometimes simply ground away. Once the root had been notched, the beads were snapped off and had the rough surfaces and edges ground smooth and then polished. This removed the dull cementum surface to reveal the dentine or ivory below and it was for its colour and the quantity of polish it takes that tooth roots were selected. The pulp cavity formed a natural means of stringing. Some of the beads are tiny, being only a few millimetres in size and one cannot help but wonder at the dexterity involved and the length of time taken in their manufacture. There are a small but recurring number of segmented tooth root beads made by notching the root, but not snapping the beads off, and polishing the notched root as a whole. The commonest number of segments is two, but ones with three and even five segments are known. A very small number of tooth root beads have an additional transverse perforation drilled in at right angles to the natural hole and are likely to have been junctions in the stringing of complex sections of bead decoration.

The next most common group of beads was made from the shafts of sheep metapodia and metatarsals in particular. In a manner similar to the tooth root beads, the diaphysis was notched using a lithic blade to mark out up to eight beads which were then snapped off, ground and polished, leaving the proximal and distal ends of the shaft as debris. Similar beads were made from the shafts of bird bones, but were not commonly recovered. Tooth root, sheep metapodial and bird bone beads made use of raw materials which would take a good surface polish, and were naturally perforated up the centre of the shaft.

Apart from a few beads recorded by Childe as having been made from fish vertebrae (1931b, 145), but which have not survived, most of the rest of the beads were various forms of disc beads, all of which were perforated with lithic drill bits. Both bone and dentine were used for these beads. The small disc beads are mainly made from thin segments of bone which were heavily ground flat and then notched to form small squares which could be detached (SB 1051 Fig 6.15). It seems likely that perforation took place at this stage whilst a segment could still be held securely for drilling to be undertaken. The perforated squares were then snapped off and ground and polished to finish the beads. The larger disc beads, some of them up to about 15 mm in each dimension, seem to be made by notching segments of cetacean tusk and then increasing the size of the natural perforation by drilling. A small number of other beads were made from ribs or are doubly or trebly perforated cylinders. Some large bone beads may have been made from deer or cattle metapodia and these are certainly the source for the heavily ground cubic or parallelepiped beads and blocks. It seems clear that the beads and pendants formed part of a decorative costume, whether worn as necklaces and bracelets, or stitched to clothing. Large amounts of time went into the preparation of these items which are far from utilitarian.

PENDANTS (SB 1076-1145, Fig 6.15, Pls 6.16, 6.18)
It has been assumed in past discussions of the pendants from Skara Brae that they are all made from cetacean teeth or tusks. Whilst just the majority are made from the teeth of a range of species of toothed whales, a few are also made from otter teeth, and others, made from bone, cetacean bone and the tips of antler tines, have been shaped to imitate cetacean teeth. Most of the objects included here are genuine pendants i.e. once the tooth or tusk had had its root apex removed, it was perforated with a lithic drill point transversely from both sides, often linking into the natural pulp cavity. Most of the bone and antler ones are also perforated, but six are unperforated pieces shaped as pendants. It is difficult to know if these are unfinished pendants or whether there was a group of items which were somehow strung without perforation. It is interesting to see what must have been prized tusks imitated in other materials, but it should be noted that some of the antler and bone pieces resemble cetacean tusks less than they do eagle claws or first phalanges. Given that other items which could be used as pendants were made from segments of boars' tusks, it is interesting to note that such pendants, in other contexts thought of as 'trophies of the hunt', should be made from the powerful, wild and hunted creatures of the sea, land and sky or imitate their features. Even the copies of eagle talons are made from the tips of stag antlers. Many peoples believe that the meat, bones and hides of an animal carry its characteristics and strength and this use of tusks and tusk-like pendants must have been part of an explicit display of the power of their wearer by analogy.

Given that there was a regular association of pendants and beads, particularly in the cache found in Cell 3 of House 1, it is reasonable to assume that they were worn together and that they may have symbolised the status of the wearer. As is discussed below, beads were found underneath thresholds and in the passageways, and it is tempting to suggest that they were at times being used in some ritual way.

BOARS' TUSK SEGMENTS (SB 1146-58)

A small number of objects have been made by taking the triangular-sectioned boar's tusk and splitting it into three segments which were then ground, perforated, notched at the end or decorated with geometric incisions. Some are only ground but the others must have formed part of the decorative range of beads and pendants and worn with them.

MISCELLANEOUS OBJECTS (SB 1159-78)

There are some tool categories which are represented by single finds at Skara Brae and these have been put together to form a miscellaneous category. A two-pronged object illustrated by Petrie (1868, 219 no.38; SB 1159) is a cattle nasal bone probably unmodified, though the double pointed sheep metatarsal (1868, 219 no 36; SB 1164) is a genuine and very unusual piece. Two rough cubes of bone were found decorated with incised lines and dots and these and the biconical, decorated piece found by Paterson suggest that they may be playing pieces or perhaps part of the symbolic aspects of Skara Brae life which are more opaque to us (Fig 6.15). A small ground plaque and the ground molar might also be playing pieces. The rest of the items included here are parts of tools or complete ones which are difficult to understand, or simply show worked areas.

CETACEAN BONE (SB 1179-88)

From the excavations were recovered some pieces of cetacean bone which had been sawn or worked in some way. There was a small vertebra which had been perforated and decorated with a simple geometric design. Other items were also perforated including a large rectangular plate of cancellous cetacean bone with a central perforation, a perforated unfused epiphyseal plate and a perforated round block. A walrus baculum appears to have been trimmed along its whole length with lithic tools and had one end slightly modified. It may have been used as a haft for mounting an axehead or adzehead in a sleeve. Mention must again be made of references to the discovery of ribs etc., apparently used as the framework for roofing construction (Petrie 1868, 207-08; Traill 1868, 432). In general, however, little cetacean bone was used and it is unlikely that the bones of many individuals are represented here, even when cetacean teeth are taken into account. As far as ribs and vertebrae are concerned, their size and form are most significant, though the strength of the ribs is very important.

NATURALLY POLISHED PIECES OF BONE (SB 1189-209)
(including Childe B2)
There were 19 segments of compact long bone, which had been split and weathered by wind and sand recovered from the site during the early excavations and those of Childe and Childe's class B2 is simply one of these.

DISTRIBUTION AND INTERPRETATION
It is impossible to discuss the distribution and location of all the objects from Skara Brae simply because of their sheer number. The rediscovery of Childe's excavation diaries and the detailed listing undertaken here of numbers which had been written on the artefacts and whose significance had been long forgotten, does, however, allow us to identify many of the objects from a number of locations and contexts within the site. It is clearly of interest to see whether there is variation in artefact categories and forms through time and to examine distributions and concentrations within the site. For this reason, early and late examples of particular categories are identified here and particular locations studied to try to establish the nature of the generative principles for these patterns. Care must always be taken in considering a site which has midden deposits and shows signs of rebuilding and reworking of those deposits. The earliest layers, those incorporated in the ruins of buildings and those which form the latest deposits are, however, likely to be the most secure.

VARIATION THROUGH TIME
From his first involvement at Skara Brae, Childe was at pains to emphasise that objects found in the earliest layers were of the same tradition as those in later contexts (1930a, 167; 1931a, 52), and that finds made in the buildings were 'culturally' the same as those from the midden overlying the passages (Childe & Paterson 1929,

242-43) and some of the resettlement within infilled buildings. As a result, he was able to identify early examples of a range of tools which are also found in the late phases of the site and these are compared below. Childe did believe in chronological variation in the pottery styles on the basis of style of decoration (1931a, 38, 52; 1931b, 130) but since the 'early', more elaborately decorated styles of pottery are from slighted and infilled buildings (e.g. Houses 9 and 10) it may be that we are seeing a social rather than chronological pattern related to practices associated with abandonment of buildings.

In his summary and quantification of the bone material, Childe (1931b, 85, 115-27) identified the earliest contexts for particular object classes. From his period I and II (Clarke period 1) came points (SB 276 and unidentified), an awl or bird bone point (unidentified), a mandible blunt (SB 663) and a scapula shovel (unidentified). From the floors of houses 9 and 10 (Childe Period II) were the earliest examples of slices (SB 754), metapodial mattocks (SB 806), laterally bulbed pins (SB 590-91), beads and bead-making debris (SB 952, 1071). The latest contexts excavated by Childe were in the upper midden layers above Passages A and B and House 6 (= Trenches I, II and III, Childe & Paterson, 1928, 239-243) and from these layers came points (SB 98-99), a bird bone point (SB 491), a slice (SB 730), beads (SB 925), beads in process of manufacture (SB 1062) and a pendant (SB 1097).

Objects from the same class found in the early and late contexts and within the middens and buildings between are indistinguishable and attest a very mature, but conservative, approach to the technology of skeletal materials. This range of objects made, but within quite tight groupings, presumably reflects a very stable range of activities, both utilitarian and more symbolic. It may be considered unreasonable to compare distributions of objects from midden contexts, house 'floors' and infilled, slighted buildings, since the deposits are likely to have been generated in different ways and so we should not expect, for example, caches of beads or pendants to occur throughout all the deposits, or for any set of material to have a completely random distribution. For this reason the absence of particular categories from early or late deposits can in some cases be attributed the type of context which is being examined.

DISTRIBUTION

In order to examine the various types of distributions, a number of contexts has been identified. The areas chosen for study are the infilled early houses (nos 9 and 10), houses 2 and 7, passage B, building 8, the remarkable cell in House 1 and a few contrasting areas of midden.

House 9

Both houses 9 and 10 are early buildings which had been partially demolished, infilled and levelled before later construction work on the site. Childe describes the floor surfaces as containing objects left at the time of the houses' 'deliberate desertion' (1931a, 38). Parts of both houses underlie the South walls of houses 4, 5 and 6. House 9 had an entrance on the West which had been blocked up in the construction of Cell 2, a central hearth, two bed areas recessed into the wall, a circular cell in the South-West corner and a dresser, also recessed into the wall. When excavated, the walls were standing to an average height of about 0.6 m. There was an 'occupation deposit' on the house floor, above which was a thin layer of sand and on the South-West side some midden packing. Throughout the rest of the building was further midden, mixed with collapsed walling. From the floor surface came: between the South bed slab and the hearth, a spatula or metapodial mattock and two points (unidentified); between the North bed slab and the hearth was the antler mount (SB 893) and a grooved stone slightly to the North; in the South-West corner a cetacean bone vessel (unidentified); in the cell, a point (unidentified); under the dresser a metapodial mattock (SB 802) with, nearby it, a carved stone object, points (SB 246, 249, unidentified), a long bone blunt (SB 698), a red deer tine (unidentified) and decorated pottery, some of which was paralleled by finds made under the floors of houses 3 and 6. Additionally there were broken bones, shells and heat-fractured stones (Childe 1931a, 34-37; 1931b 75-76).

House 10

Only part of the structure of house 10 survived. There were no traces left of a doorway or hearth, but there were the lowest stones of the dresser, the bed areas, a cell and sections of walling. The floor was covered with a layer of sand and within it were found: near the South wall, 2 stone axeheads, a slice (SB 754), a mandible blunt (SB 658) and a highly decorated pot with another near the cell and a third in the cell itself decorated in manner similar to one found on the floor of house 7; also in front of the cell were the head of a pin with a lateral bulb (SB 590), a large point (unidentified), an awl or bird bone point (unidentified) and to the East of the cell another pin with a lateral bulb (SB 550); around the West end of the South bed slab were another stone axehead, a worked bone (unidentified) and a blunt (unidentified); by the West wall was a large and highly decorated pot. Flakes and scrapers of flint were found over the whole floor as were sherds of decorated pottery, bones, shells and heat-fractured stones. Immediately above these finds were other objects including a cetacean vertebra dish (SB 545), a metapodial mattock (SB 806), a 'spatula' (unidentified) and other worked bone. Within the upper filling of the rest of the house were points (SB 255, 256, 257, 258 and unidentified), two pins (SB 588, 589), a mandible blunt (SB 656), beads (SB 952 and unidentified) and teeth notched for beads (unidentified), a slice (unidentified) and a scapula shovel (SB 840) (Childe 1931a, 34, 37-38; 1931b, 76-77).

House 2

After passing through a cell-like entrance area, house 2 shows the usual central hearth with the dresser beyond. To the West and East are flagstone bed areas with other boxes and areas set into the floor. Underneath and behind the dresser is a cell with another one to its East. The house was partly dug into by Stewart, though he did not understand the detail of what he was excavating and may have disturbed upper levels within the building. Paterson reports only a single floor level. In front of the East bed area, and probably above it were found 120 cattle astragali and 8 astragali of red deer. In the entrance area by the threshold were found beads (SB 922 and unidentified) and a slice (SB 728); a little further into the room were, on the East, a mattock and by the South enclosure another slice (both unidentified) and in the South enclosure a decorated point (SB 444). In front of the East bed area were beads (unidentified), a playing piece (SB 1168) and two mattocks (unidentified); in front of the West bed area were four points (unidentified) and a piece of walrus tusk (SB 1167). Within the cell behind the dresser was a large point (SB 396). This forms an interesting pattern with mattocks and beads beside the furniture on the right hand side of the house as one enters and points in front of the left hand area. Other points were found at the front and back of the house with beads being found inside the threshold and a slice around the entrance area (Stewart 1914; Childe 1931b, 31-33; Childe & Paterson 1928, 229-33).

Cell 3 in House 1

Whilst most of house 1 had been excavated by Watt and re-examined by Stewart, it was in 1927 that the deeply recessed cell 3, which lies in the wall between houses 1 and 2, was found. Originally access to the cell was from passage A or from house 1 itself, but the former entrance was blocked off. From the interior wall of house 1, a passage which had filled with sand leads to the cell and takes a dog-leg to the left where it becomes narrower and goes up two steps. The cell itself is only just over 1.2 m square and about 1 m high. The entrance is only 0.53 m wide. Yet within the cell were found over 3200 beads, at least 18 pendants and a number of other implements. They were deposited in what seem to have been discrete piles: just over the threshold was a group of beads and pendants with some points and other implements (SB 95, 96, 398, 399, 689, 1050, unidentified); where the cell widens out were 16 pendants and ornaments (SB 1082-96, unidentified), a point and bead (SB 97, 921) and 800 beads (unidentified); across the centre of the cell were 2400 beads (unidentified) and behind this group were a cetacean vertebra dish containing red pigment (unidentified), a block of cetacean bone (SB 1179), teeth (unidentified) and a decorated boar's tusk segment (SB 1146). Whether beads were worn as strings of necklaces and bracelets, or sewn onto clothes it is clear that the cell contains a store or cache of objects for personal decoration. Not only are there the beads and pendants, but also decorated segments of boars' tusk and a container for red pigment. Of the three bone points identifiable, one (SB 96) is broken but the other two have heavily ground heads, such that the condyle has been completely ground away to leave a flat square-sectioned head and it may be assumed that such heavily ground points are also items of personal decoration (Childe 1931b 29-31; Paterson & Childe 1928, 225-29).

House 7

This is the most complete of all the buildings at Skara Brae and it has the features one expects from such a building - an entrance way leading into a sub-square room with a central hearth, bed areas to the left and right, a dresser opposite the door and another enclosure beside the door, boxes and tanks in the floor, a cell and wall storage. Nonetheless there are a number of features about house 7 which set it apart. Its foundations are set very low down into a midden deposit with no earlier structural remains below. The style of the building is much closer to those of the later period and this probably means that it was deliberately made semi-subterranean. It has a passageway which leads only to it and which partly circles the wall of the building; it is the only structure at Skara Brae whose door is barred from the outside and not the inside; it has foundation burials of two old women, the cists for whom are partly visible under the right hand bed which has a decorated slab as its side stone. Childe believed that house 7 gives a snapshot view of a building in general use which had been overwhelmed by a sandstorm and thus all the objects were in their usual place. Without debating the reasons for the abandonment of house 7, it appears that it was not an ordinary building, but a special and separate place. When found, the structure was infilled with sand in which were found the antlers and bones of red deer and signs of temporary occupation within the building as it filled with sand. The floor level was of a waterlogged reddish clay 12-20 cm thick, which merged into the sand above to form a deposit which was treated as a single layer, but was only a thin deposit. Only the upper part of the floor surface contained objects. Throughout there were fragments of bone, shell and pottery.

In passage C outside the entrance to house 7 is a threshold beyond which were found, beneath the paving stones, some pendants and a boar's tusk segment (SB 1113, 1114, 1149, 1150). Between this threshold and the door of house 7 was a ground plaque (SB 1170), a bone implement (unidentified), a point with a heavily ground head (SB 405), a ?pendant (unidentified), a mandible blunt (SB 641), a point/pin (SB 540), some decorated pottery and a flint scraper. Beads (SB 929) and a pendant lay on either side of the threshold to house 7, outside which a fire had been set which had burnt some of the beads.

To the left of the door was an enclosure in which was a stone pick and outside which were a broken mattock (SB 791), a mandible blunt (SB 639), three heavily ground points (SB 171, 172, 173), beads (SB 922, 925), a tusk pendant (unidentified) and a cetacean vertebra cup containing pigment (SB 885).

In the left-hand bed area were the skull and horns of an ox and some stone and flint objects. Between the left-hand bed area and the cell were tusk pendants (SB 1111, unidentified), bone pendants (SB 1114, 1115, 1117), beads (SB 922, 924, 925, 932, unidentified), a point (unidentified), a large point (SB 407), a slice (SB 741), two mattocks (SB 789, 790) and a scapula shovel (SB 829), a mortar and some other stone objects. In the cell itself were many beads (SB 923, 930, 931) and pendants of tusk, bone and antler (SB 1106, 1107, 1108, 1109, unidentified).

To the North-East of the hearth were a stone axehead, 2 broken mattocks (SB 793, unidentified), a slice (SB 744) and some worked and weathered bone (unidentified, SB 1202). On the East side of the hearth were an awl (SB 465) and a large pottery vessel.

In or beside the right-hand bed area which overlay the cist burials were beads (SB 933), a scapula shovel (unidentified), a slice (SB 742), a bone flake (SB 1171), a point with a heavily ground head (SB 170), a bone notched for making beads (SB 1051), a small cetacean vertebra cup containing pigment (SB 886), a point (SB 331), a large cetacean bone vessel (unidentified) and some flint objects.

The layer which most of this material came from was a hard red clayish one which was distinct from the rest of the deposit in house 7. To the North of this bed area were another cetacean bone vessel (unidentified), an unusual whale bone spatula (SB 617), a tusk pendant (SB 1112), part of a mattock (SB 792), a stone mortar and some pottery.

There is again a very strong emphasis on items for personal decoration. It would appear that a cache of ornaments had been kept within the cell, but was found extending from its mouth into the room. Throughout the room were pendants of various types and a large number of cetacean vertebra cups containing pigment. All the identifiable points had heavily ground heads. Several mattocks and shovels were found, mostly to the left hand side of the room and so the distributions and concentrations in house 7 are not immediately paralleled by those in house 2. Whilst the spread of some of the beads and pendants might result from having been dropped when trying to rescue them from the building, their existence under the paving in the passage suggests that they were deliberately placed there and that perhaps some of the others are likewise deliberate deposits. The fact that some of those at the threshold had been burnt in situ would suggest that they had not simply been lost during evacuation. The unusual structural features of the building have been mentioned. It is clear that in this building, unlike house 2, the 'beds' were no cleaner than the rest of the house floor and indeed in the left hand one there appeared to be some excreta as well as the bull's skull already mentioned. It is tempting to see in this building evidence of separateness within the community - a place which drew from the daily life of the village but was apart and special, perhaps a place for communing with the ancestors, moving from one status within society to another, or for people of special standing within the community (Childe & Paterson 1929, 246-61; Childe 1931b, 37-41).

Passage B

Closely related to house 7 is passage B which leads towards it from the main corridor of the village, passage A. The passage is partially paved and where it joins passage A it lies c. 0.45 m below the latter's present level, though originally the floor of A was lower. When excavated, the passage was completely roofed and its entrance contained a large pile of limpet shells which raised the floor level to that of passage A and extended some distance down B. The passage itself gradually falls and follows a course which curves gently to the right, until it reaches passage C outside house 7 where it turns a right angle towards the entrance to 7 and also gives access to the cell. Towards the end of passage B is a step down, the remains of what seems once to have been a gateway, and a further step down. The top of the passage was discovered during systematic trenching and was filled with sand. Amongst the limpet shells were found bone points with slightly ground heads (SB 122, 123), and in the sand or in the wall were found three beads (SB 925, 925, 928). All lay within the first 1.8 m of the passage. Further up the passage, three bone slices were recovered from the floor level (SB 733, 734, 735), a point was found in the wall (SB 130), another in the sand fill (SB 131) and at other places in the passage were found two mandible blunts (SB 637, 638), an antler pendant (SB 1098), a stone spatula and a polishing stone. At a high level within the sand fill were found 4 points (SB 124, unidentified, 125, 126), a bone pendant (SB 1097), part of a large point (SB 402) and some pottery. Lower down was a bead (SB 925), three points (SB 127, 128, 129) and a large point (SB 403) (Childe & Paterson 1929, 247; Childe 1931b 44-45).

Building 8

This building is distinctive at Skara Brae for several reasons. It is pear-shaped and is the only one which is freestanding and has no midden cover. It had an entrance porch added at the South end and a vent at its North end. It has a central hearth and wide areas recessed into the wall. There is a single cell, but no boxes in the floor or dresser. At the North end of the building, however, there is a square area defined by additional cross-walling and upright slabs. The paving of this area was covered with tight-packed 'volcanic stone'. It was originally suggested that this was a pottery kiln, some yellow clay nearby being the raw material. The stones were then believed to have been used as pot-boilers, but study of the contents of the building suggests its use as a kiln for the heat-pretreatment of chert to improve its knapping qualities. The hole in the North wall would have been a flue and perhaps the porch which was added was an attempt to reduce the through draft. By the hearth was found ash which contained burnt shell, bone and cetacean bone which may have been added to fires for its fat content. The floor was covered with at least 325 flakes, cores and scrapers of chert.

In the East recess were found an awl and a large point (unidentified, SB 408), a mandible blunt (SB 132), 2 points (unidentified, SB 206), a pot containing oyster shells and 57 flakes and scrapers. Further along the South wall were two other blunts (SB 649, unidentified). On the West side was found a mandible blunt (SB 648) and in the rest of the deposits were a further two (SB 650, 651) and a blunt-tipped awl (SB 471). A broken scapula shovel (unidentified) was found and several pieces of bead manufacturing debris in tooth (unidentified, SB 1065, 1066) and bone (unidentified). Cattle astragali were also common finds. Seven were found by the partition at the North of the building and three more in an adjacent cupboard. Whether they were polishers or not is unclear but four astragalus polishers were found by the collapsed West wall (SB 863, 864, 865, 866). In the cell was found a pottery vessel and some animal bones.

Such a concentration of particular object classes requires comment. It is reasonable to interpret the building as a heat pretreatment workshop for lithic materials and a knapping area in which the blunts and awls were used, but two other concentrations have been noted here, those of astragalus polishers and bead-making debris. It is difficult to view the polishers as used with anything other than hide or leather and the groups represented suggest that not only is building 8 a workshop for lithic tools, but also for hide preparation and bead-making (Childe 1930, 173-78; 1931b, 49-53).

The significance of these distributions is important to assess. Clarke's excavations at Links of Noltland and Skara Brae have shown that the debris from tool manufacture - most recognisable as that from bead making - is found in some of the rich midden deposits infilling the structures, although at Links of Noltland there were spreads of midden with neither beads, nor bead making debris. The paucity of objects from the excavations by Childe and earlier workers at Skara Brae, is however, attributable to their excavation techniques, recovery techniques and the selection of which objects were kept for museum collections. Childe and the earlier excavators noted that complete sequences of manufacture were identifiable at this site for the beads at least. It seems likely, therefore, that what has survived to the present day in museums are those objects considered 'complete' and 'finished' with a few items of debris kept for interest. It has been possible to use these objects to infer techniques and sequences of manufacture and to suggest at what stage in a butchering process they became available.

One would expect that contrasts might be drawn between the middens above Passage B and the sort of layers found within the houses. In the middens above the passage are mixed collections of shell, pottery fragments, stone and bone implements forming no clear pattern. Within most of the houses, forming what is sometimes described as an 'occupation deposit', there are distinct concentrations of tools and containers, which tend to be of better quality than those found distributed through the midden. Childe's argument for this feature in House 7, in particular, was that it had been an ordinary working house, suddenly overwhelmed by a sandstorm, and that all the objects lay in situ in their daily position. That the House was overwhelmed by sand is not disputed, but it has been shown that Childe's argument about a scatter of beads down the passage is not evidence of sudden abandonment. When one considers that the deliberately infilled floor areas of Houses 9 and 10 also had objects in the floor deposits, it is reasonable to suggest that there are other factors guiding the abandonment of buildings and the disposal of objects.

When Houses 9 and 10 were slighted and filled in to provide a more secure foundation for later building, a choice was made to leave objects in the floor area, or, perhaps, even to place them there deliberately. The writer has seen abandoned crofts in North Scotland

and the Northern Isles, where a family has moved to a new home, intentionally leaving behind many of the things of the old house. It may be there was some similar attitude in evidence at Skara Brae which would see what might be called the 'burial' of the old houses with their 'grave goods' in place. Given Neolithic burial practices in Orkney, this would not be an exceptional attitude on the part of the people of Skara Brae. Their own view might well see nothing 'special' in such practice, but it suggests that we may be able to appreciate more of the daily ritual of everyday life than has been realised in the past. In studying houses and 'occupation' deposits, it is important to ask why objects are there, rather than assume that they should automatically be there. Cleanliness is not the exclusive right of the 20th century, but it should also be realised that there are different cultural perceptions of what cleanliness is.

Having argued that there seems to be some disposal 'ritual' represented in the distributions at Skara Brae, it is necessary to establish what interpretation can be put on the distributions seen there. There is a higher proportion of complete bone objects from the house floors than from the midden deposits and this supports the view that the latter are made up of discarded soil, ash, broken objects etc. Within the structures, therefore, one would expect object distributions to tell us what was going on in the houses (were Childe's disaster hypothesis correct) or, more subtly, what the inhabitants of Skara Brae saw as an appropriate way of abandoning the site (if the approach suggested here is correct). It may be that there is a significant overlap between the two.

The objects of bone, stone and pottery recovered from within the structures at Skara Brae were placed there or abandoned. That there are differential distributions suggests that they reflect variations in the way the building and space within them was perceived and used by their inhabitants. The large quantity of chert and probable hide-working tools in Building 8 suggests that this was indeed a workshop. The objects from House 2 show a differential distribution with mattocks and beads to the right and piercing tools to the left. Traditionally, the furniture in front of which these objects were found has been interpreted as bed areas, with the larger right-hand bed as male, and the smaller left-hand bed as female. Whether the distribution of bone tools is evidence of a sexual division of labour - men working the soil and wearing beads; women working with skins etc. - is uncertain, but this would be a reasonable interpretation of such a differential distribution.

That beads, pendants, other ornaments and paints were found in Cell 3 of House 1, and running from the Cell in House 7, suggests the use of Cells as storage areas and the restriction of access to these items. Although most of the raw materials for bead making were easy to come by, pendants and tusk beads were not. It has already been emphasised that the production of beads is time-consuming and whilst all people could have made them, the production of thousands would have taken considerable time. Had beads been found in every cell, or in all houses in such quantities, one could have argued for equal access to such personal ornamentation. Their accumulation in caches does, however, suggest restricted access in the hands of individuals or a single family, and that they were being worn (and bodies painted?) on special occasions.

The complexities of House 7 have already been discussed. It does stand out as both exceptional and typical of Skara Brae and this is supported in its location, structural organisation, the burials and the distribution of finds within it. The use of beads at and below its threshold, and the presence of the cache of ornaments and paint, hints at a deliberate use of these items in a ritual or symbolic way. As noted above, everything in this House suggests transition and transformation; moving from one place or world to another. It is likely, therefore, that this is a place of ceremony and ritual nand that the objects recovered from it have to do with moving from one status in society to another. Given all the places in which an unbroken and unused mattock might appear at Skara Brae, this is exactly where one would expect it, and, indeed, exactly where SB 789 (Fig 6.11) was found.

CONCLUSION

The Neolithic settlement at Skara Brae comprises a stone-built village with passageways and working areas which, in its later phase, was semi-subterranean and enclosed within a large mound of midden. On excavation, objects made from skeletal and other materials were found in varying concentrations throughout the midden and on what the excavators considered to be abandoned house floors. Within a number of the earlier houses, which had been deliberately infilled to make way for later building, were placed items of some quality. Other distributions within the site included a massive cache of ornaments, and objects relating to the working of flint, chert and hides. These distributions represent a level of complexity in deposit which is only beginning to be understood. Many of the sequences of manufacture for the tools found at Skara Brae are well understood because not only are there the finished tools, but for some artefact categories there are also examples of the stages of manufacture.

There is very little sign of overlap between materials at Skara Brae and it is really only in the area of pigment containers that objects were made of bone and other materials, in this case stone. Within the range of bone tools, there are a number of tightly defined object categories for which quite detailed instructions about manufacture could be given. Most make use of a specific bone and are roughed out using a fracture technique and finished using pumice as an abrasive grinder.

Whilst the natural fracture properties of long bones were made use of in butchering and the preliminary stages of object manufacture, the main guiding principle in element selection was form. Most object shapes make full use of the morphology of bones and the range of sizes and thicknesses of tools and tool tips shows a good appreciation of the variation in properties across species caused by the differences in thickness and shape of the bones.

Most of the techniques of manufacture seen at Skara Brae were also used at Risga, but it is interesting to note how within a settled farming community, the range of tools needed is substantially different. The bones of sheep were not, certainly, available to most Mesolithic communities, but the main differences between the tool forms at Risga and Skara Brae are in the quantity of forms at the latter site and their reflection of the contrasting activities going on there - e.g. potting and agriculture. There was also a substantial effort put into objects for personal ornamentation. Skara Brae was a settled community whose inhabitants practised animal husbandry, agriculture, fishing and shellfishing. Contemporary with the site are a number of burial places and ceremonial sites which suggest that formalised ceremonial or religion was important to these people. In such circumstances, one would expect that the annual cycle of the farming year and the fertility of animals, crops and people would be important. At Skara Brae, the people seem to have found a series of structural and artefactual solutions to the problems of their lives which remain virtually unchanged for about five centuries at the very least. Such a strong conservatism in material culture suggests that effective solutions had been found and, given that economy, material culture and social organisation are closely interrelated, this would suggest little social change. The most dramatic disturbance at Skara Brae is in the rebuilding of the village which forms Clarke's Period 2, but as has been shown, this is on the site of the earlier village, uses buildings which are only slightly modified versions of the earlier ones and maintains a closely similar range of artefact types. Whilst small scale changes were no doubt taking place at Skara Brae over this time, there is no evidence of anything substantial.

Technologically, the material from Skara Brae can stand as an example of the range of manufacturing techniques available in Late Neolithic Britain. Childe emphasised that the resources used at the site were local in origin and, with the exception of sea-borne wood and pumice, and the initial introduction of domesticated livestock and crops, later writers agree. The range of observations made and conclusions drawn from Skara Brae are of direct relevance within Orkney and probably also the Western Isles. As a range of techniques, fracture, grinding, perforation etc. are known from most Neolithic sites in Britain where bone tools survive, but beyond the Scottish islands, few would be expected to show the same range of tools. Scapula shovels, beads and antler picks are, however, more widely known. Thus, Skara Brae's importance as a general model is in the issues it raises about the use of space, of objects within that space, and the deposition and discard of those objects. Just as the tombs and burial mounds of Neolithic Britain show broad similarities of approach, but with considerable variation in local traditions, so the general conclusions for Skara Brae are important for Neolithic studies whilst many of the more detailed conclusion are of more local interest.

CHAPTER 7

MIDHOWE, ROUSAY, ORKNEY

INTRODUCTION

In examining the manufacture and use of objects of bone, antler, tooth and horn from Iron Age sites, several possible sources were examined. The best preserved material is certainly from broch and wheelhouse sites in Caithness, Orkney and the Western Isles. Some of the sites seem to have been in use for many hundreds of years, but the intention was isolate sites which were, in Orcadian terms, 'pre-Pictish'. Few of the excavations in the last century, or early this century, had enough detail recorded about the site, stratigraphy and finds to provide anything other than a simple finds list and excavation report which lie side by side. The published site of Midhowe (Callander & Grant 1934), did, however, show itself as having detail both about the site and the finds recovered. Given that the other possible site of Gurness had yet to be published when this study was begun, and that dealing with the latter was a major undertaking in itself (Hedges 1987), Midhowe has fitted what was wanted for this study very well. In order to expand the information available about Iron Age sites, the assemblage from the unpublished wheelhouse site at Sollas was also examined and is detailed subsequently.

Included in this study of Midhowe are the objects published by Callander & Grant (1934), as well as others which are held and associated with it, giving a total number of 108 artefacts and worked pieces from the site and 149 items recorded in detail. The collection from the excavation was given to the National Museum of Antiquities of Scotland (now the National Museums of Scotland) in Edinburgh in 1947 as part of the Grant bequest, along with other finds found at that time in Trumland House and believed to be from Midhowe. Further items were donated in 1949.

SITE LOCATION AND DESCRIPTION

The broch of Midhowe (NGR HY 3716 3061) is situated on a raised promontory by the edge of the sea on the South-West coast of the island of Rousay in the Orkney archipelago. It overlooks the island of Eynhallow with the Orkney mainland, and the parish of Evie in particular, beyond it (Figs 5.1, 6.1, 7.1). This part of Rousay has a coastal fringe sloping down from the higher land and it is at the edge of this now rich arable land that the broch stands. Bounded on the South-West by a low cliff and to the South-East and North-West by the distinctive type of inlet known in Orkney as a 'geo', its North-East approach was defined by a large ditch and massive stone rampart which enclosed the circular broch tower and its extramural settlement.

The site is known as 'Midhowe' because it is the central of three mounds, the others being North Howe, also a broch site (Hedges 1987, 116-17), and South Howe (or Brough, Westside), an eroding site which is probably also a broch and at which a long-handled comb has been found (Lamb 1982, 22 cat nos 73-75; RCAHMS 1946 II, 193 cat no 553). Neither of the other two mounds has been excavated and their contemporaneity with Midhowe must be questioned.

The excavation of Midhowe is recorded by Callander & Grant (1934) and has recently been summarised and re-assessed by Hedges (1987, 110-16). Before excavation, the site was a grassy mound with some stones showing through the surface. The report of the excavation does not record the sequence in which the site was tackled, but summarises it in the form of a tour through and around the site, detailing, area by area, its structural elements and history and the location of finds. The report concludes with a list of the finds made, classified by material and functional or formal categories; a discussion of the crafts represented by these finds and the parallels which can be drawn for them; a summary of the main phases of the site concluding with four reports on the human and animal skeletal remains.

Excavation revealed a site with a complex of buildings which was redesigned on a number of occasions (Fig 7.2). The phasing developed by Callander & Grant (1934, passim, but especially 512-13) is given here. In the <u>first period</u>, a hollow-based broch tower was built with guard cells, passages and upper chambers. Its entrance faced almost due West and the whole promontory, on which the broch was built, was enclosed by an inner ditch, massive stone rampart and external stone-lined ditch to the East. During the second period rooms were built outside the wall of the broch, greatly increasing the enclosed space on the site, but necessitating the infilling of part of the inner ditch. It is not clear how extensive these rooms were, since even those which did survive were badly affected by erosion and it is unclear how much of the site had been lost.

The third period involved the shoring up of parts of the broch tower which had collapsed or were in danger of collapse and the subdivision of the extra-mural settlement. The internal arrangements of the broch were also reorganised and it was divided into two halves by a central line of tall upright slabs in line with the entrance passage. The North and South halves of the broch interior (compartments C and D) were divided into a number of radial cells around the interior walls and small roughly rectangular compartments. Each half of the interior had its own hearth, and the discovery of hearths stratified above others (Callander & Grant 1934, 461, 465) suggests that the 'periods' can be related to major structural alterations, rather than directly to lengths of occupation, and do not encompass most of the minor alterations within the history of the site. The rest of the features and structures by the broch tower entrance, the site entrance and in the ditches are difficult to relate to this sequence, but were seen by the excavators as secondary or tertiary. Hedges (1987 III, 16) views both the internal arrangements and the extra-mural settlement as contemporary with the tower, the rampart and ditches. This would simplify the phasing of the site bringing some of the works attributed by Callander & Grant to the second and third periods into the first period.

EXCAVATION HISTORY

The broch of Midhowe was excavated between 1930 and 1933 by Walter G Grant of Trumland House, Rousay, and J G Callander, then Director of the National Museum of Antiquities of Scotland. It was promptly written up, the report read to the Society of Antiquaries of

Scotland on 12 December 1933 and published in the Society's Proceedings for 1933-34 (Callander & Grant 1934). Grant lived on Orkney for most of his life and became interested in archaeology as a result of various activities in the 1920's - local excavations (such as that at Skara Brae) and survey by the Royal Commission on the Ancient and Historical Monuments of Scotland in advance of the Inventory of Monuments (RCAHMS 1946).

Reynolds & Ritchie (1985) have usefully summarised Grant's involvement in archaeology and excavation, and it is enough to say that through his own funds he enabled the study, excavation, and, in most cases, publication of several major monuments on the island of Rousay. Some were consolidated during excavation and subsequently became monuments in state care. Both he and Callander were present during the excavations, the physical work of which was undertaken by the gardener at Trumland House, James K Yorston who 'wheeled out from fifteen hundred to two thousand tons of fallen stones and debris' over 'five consecutive summers and a few winter months' suggesting that some preliminary work may also have been undertaken in 1929 (contra Reynolds & Ritchie 1985, 66, 71-72 and Hedges 1987, III: 110, 149). In 1932 and 1933 Grant was involved in excavating several sites in Rousay each year.

Midhowe was the first site in Rousay with which Callander was involved, and he and Grant clearly made a productive team both in terms of excavation work and in terms of the speed at which many of the sites were published. The finds from the excavation were bequeathed to the National Museum of Antiquities of Scotland (now the National Museums of Scotland) in 1947, at Grant's death.

RANGE OF MATERIALS USED

The principal material used at the site of Midhowe was stone. The Rousay flags, a form of Old Red Sandstone, immediately underlie the site and outcrop only a few metres from it at the water's edge. Its main use was in the fine dry stone wall construction of the broch tower, its outbuildings and the massive rampart and stone-lined ditch. Despite the instability which caused parts of the structure to slump on the South side and need buttressing on the North side, the tower itself was a piece of very skilled construction. The curvature achieved in the alcove in compartment C (Callander & Grant 1934, 458, Fig 8) represents work of high quality and aesthetic ability. The use of large thin slabs should also be noted in the creation of the main internal divisions as well as in its ?decorative use by the alcove (Callander & Grant 1934, 459, Fig 9).

Stone slabs were also used in the construction of tanks, hearths, thresholds, steps and other furniture. Hollowed stones provided socket stones for doors, as well as saddle querns and mortars. There were rotary querns and a range of perforated stones which are usually interpreted as spindle whorls, loom weights and other weights. A range of polishers and whetstones were produced, as well as hammerstones and numbers of thin circular pot lids, one group of seven being found together in a cubicle (Callander & Grant, 1934, 466). In addition there were pieces of jet, haematite, steatite and flint (Callander & Grant, 1934, 496-500).

Virtually all the pottery and fragments represented plain, hand-made vessels ranging from small slightly bulbous pots to more elongated urn-like vessels, and in height from about 92 mm to 298 mm. Complete vessels were found, as well as a remarkable collection of sherd material weighing 17 kg which lay together in a stone cubicle at the foot of the flight of nine steps to the South of the tower (Callander & Grant, 1934, 483). Additionally there were a few fragments of Samian pottery and Roman plain ware. The remains of a clay mould were found and to the East of the flight of three steps to the South of the tower were five or six clay crucibles, fragments of others nearby and pieces of thin sheet bronze (Callander & Grant 1934, 483-84). This presumably represents the equipment for bronze working.

Sheet bronze was also present in the form of fragments of a bronze dish initially interpreted as part of a Roman patera. There were cast bronze implements of local origin in the form of projecting ring-headed pins and penannular brooches and fragments of other bronze jewellery. Though no iron implements survived, Chamber G contained a smelting hearth which was covered with masses of iron slag and was probably used for iron smelting (Callander & Grant 1934, 475).

The crafts represented by the non-skeletal materials are therefore, grain and food-processing, spinning and weaving, potting, iron smelting and bronze working, the latter principally for jewellery and decorative items. Whilst the evidence for iron working and bronze smelting is tied to particular locations and specific events in the history of the site, it is not unreasonable to assume that these were crafts continued during the whole length of occupation of the site.

ANIMAL RESOURCES

The report on the faunal remains from Midhowe broch by Platt, and the additional reports by Ritchie and Calman on the cattle skull, cetacean bone and bird bone (in Callander & Grant 1934, 514-16), provide a good source of information about the species which were exploited and deposited at the site. It cannot be emphasised too strongly, however, that the bones recovered from excavation must not be taken as giving a one-to-one correlation with the range of species used or even killed. The use of animal products such as milk will not be recognisable from a simple species list. The latter cannot tell us about the types of animal husbandry practised. Equally, bones found during the excavation of a site can only be those deposited within the site, in a midden or wherever. We are still far from understanding the mechanics of midden formation and it is reasonable to assume that on a broch site at least, cattle were not squeezed through the complex of narrow passages, to be slaughtered in the centre of the tower. Killing and primary butchering are very likely to have taken place elsewhere and so it is necessary to question what practices were being followed which made bones available for incorporation in archaeological deposits.

Such a detailed approach cannot, unfortunately, be undertaken on the site of Midhowe because of the style of presentation of the faunal material - the identification of species and their listing, irrespective of relative proportions and parts of animals represented. For the 1930's this was, however, a standard approach, if not in the forefront.

Platt identified domesticated animals - horse, cattle (Bos frontosus), and sheep. Pig, roe deer and red deer may have been wild or partially domesticated. In addition there were the bones of wolf or dog, wild cat, fox and Orkney vole. Sea mammals were represented by the bones of cetaceans (species unidentified) and seal, certainly the grey seal. A range of birds was present - goose, duck, chicken, gannet, shag, heron and ?oystercatcher. One part of a fish jaw was recognised but considering that there was no fine sieving of the archaeological deposits, such small representation should not be surprising.

This is the sort of range one would expect on a coastally located site of the Iron Age: domesticated land mammals, a number of wild or semi-wild species including pig, red deer and roe deer, a few sea mammals, shore and water birds and fish. These represent the exploitation of nearby land, coastal and marine resources, though it is impossible to assess the extent to which each species contributed to the dietary or other resources of the broch. Certainly the cattle were butchered (Ritchie in Callander & Grant 1934, 515-16), but the existence of wild cat, fox, Orkney vole and chicken suggests that animals which made use of the site after its human abandonment may also have been included in the analysis.

UTILISED MATERIALS

Land mammals, sea mammals and birds all had bones utilised for tool manufacture. Some of the items identified by Callander & Grant (1934, 485-96) are not considered here to be genuine implements e.g. the 'spatulate bone objects' which are naturally eroded fragments of bone. These have been excluded from the category of 'utilised' material but in addition to the implements themselves, there is a background of butchered and broken bone, most of which is probably debris from food preparation, rather than material selected for tool manufacture.

RED DEER

Apart from one unusual socket (M 35 Fig 7.6) made from a metatarsal, the only bone of the red deer used was the antler (or 'deer-horn' as it is sometimes referred to) and then primarily the beam, the tines being chopped off and discarded. Since it is the beam which was mostly utilised, it is difficult to assess the extent to which shed antler was used as opposed to antler taken from carcasses. Of the 18 pieces of worked, cut or chopped antler which retained part of the burr and can therefore be confirmed as shed or unshed, 15 were shed and only 3 unshed, including a chopped piece of the pedicle (M 71) and the upper skull of a stag from which one antler had been sawn off and the other chopped off. It is difficult to be sure what age the animals were.

SHEEP

As would be expected, most of the bones of sheep which were used are long bones, all of them for tools making use of the slim diaphyses. The majority are metapodials and principally metatarsals, but the tibia and ulna, as well as segments of the scapula, were also used. Most were from mature animals.

CATTLE

A wider range of the bones of cattle was exploited than those of sheep to produce a small number of objects. The head of the femur had been sawn off and used (M 55-57 Fig 7.9) and one tooth had been modified (M 11 Fig 7.3). One tool was from part of the scapula (M 60 Fig 7.9) and one is probably from the innominate bone (M 12 Fig 7.3), both attributed to cattle rather than red deer, although this identification cannot be certain. Where identifiable, these were from mature animals.

PIG

Apart from pig fibulae, only the teeth of pigs were found, the majority those of boar. Of these only one boar's tusk had been modified. Many of the rest were split, but it was impossible to tell whether this had happened as a result of modern handling, during excavation or was part of the original treatment of the pieces.

CETACEAN

It was not possible to identify the species of cetacean used, but the vast bulk of the bone came from parts of the limb bones. One phalanx is present (M 36), one vertebra and a vertebral epiphysis (M 69 Fig 7.11, M 105) and part of what seems to be the pelvis. The large pegged plate (M 23 Fig 7.4) and perhaps one or more of the combs may be from a rib bone. The identification of all the long-handled combs as being of cetacean bone (Callander & Grant 1934, 485) is incorrect as some of these are of antler.

BIRD

Three parts of the limbs of adult birds were used. Two are certainly from the ulna of large birds, one possibly that of a gannet (M 2 Fig 7.3) and the other suggested as being that of a wild goose or a fish eagle (M 61, Fig 7.10; Calman in Callander & Grant 1934, 516).

Other fragments of bone were utilised but cannot be attributed to species or bone element, although the bulk of them are long bones and judging by their thickness and likely circumference would seem to be those of cattle and sheep.

TECHNIQUES OF MANUFACTURE

PRELIMINARY TECHNIQUES

As has been previously noted, the bone, antler, tooth and horn material which was saved and accessed by museums from almost all but recent excavations, frequently represents only recognised worked pieces, complete bones and those parts thought unusual. For this reason, there is quite good evidence for the preliminary stages of the treatment of antler and cetacean bone, since these materials were considered special and unusual, but a poorer representation of the equivalent debris from the bodies of land mammals. Thus, far more detail can be given about the treatment of antler than the legs of sheep. Nevertheless, the range of techniques recognised, and the implements implied by them, do give a general idea of the preliminary stages of tool manufacture.

Butchery and the initial stages of food processing release bones for tool manufacture. The particular joints chosen and the range of products which are being taken from the carcass determine what approach and sequence is followed. For Midhowe, no general statements about butchering strategy can be given save that Ritchie (in Callander & Grant 1934, 515-16) noted that an ox skull had been split through the centre of the forehead to kill the animal and that the vertebral axis with the skull showed marks of hacking with a metal tool. The chopping and hacking marks on the antler and cetacean bone debris (M 71-100, M 103-108 Fig 7.10, Pls 7.4, 7.9) make it clear that long-bladed metal tools, most likely of iron, were being used. The presence of whetstones suggests their use for sharpening bladed tools but none of the latter was found on the site. Callander & Grant themselves realised that this was the case when they comment (1934, 511):

> 'That good strong cutting metal tools were in use at Midhowe is evident because one of the antlers found showed a cut 5/8 inch deep on the slant.'

having argued that processes of decay probably account for their lack of discovery on site and that iron is a more likely material for such an implement than bronze.

The use of large bladed tools is attested by the chop marks seen on some of the antler beams and tines (M 91 Fig 7.10, Pls 7.4, 7.9), and used for the rough shaping of cetacean bone blocks. To suggest this two sources of evidence are being used, debris and pieces which are considered to be unfinished implements. Most of the antlers recovered from the site have had tines removed to free the larger segments of beam for tool manufacture. The techniques used involved a mixture of chopping, sawing and splitting. Tines were removed by making an initial series of chopping strokes around the base of the tine, or sawing part of the way through it, to cut into the compact tissue. A blow was then struck to snap through the rest of the piece. These are alternative techniques as is well-illustrated by red deer skull (M 76) on which one of the antlers was removed by sawing through the compact tissue from four directions and then breaking through the cancellous tissue, and the other was chopped through with a series of strokes. Such techniques were also used in the preparation of tool rough outs as is shown by the shaped blocks of cetacean bone with marks of sawing and chopping. The use of a blade in a splitting manner (M 91 Fig 7.10, Pls 7.4, 7.9) and in the removal of large slices and chunks is also seen on some of the blocks and on the unfinished cetacean bone comb (M 50 Fig 7.8, Pl 7.7).

Despite the existence of bladed tools, percussion fracture of bone with blunt implements (e.g. hammerstones) is also demonstrated on a number of tools and on one piece of bone in particular which shows evidence of at least two impacts (M 102, Fig 7.11, Pl 7.10).

The major preliminary techniques which are associated with both butchering and the creation of blanks or tool rough outs are therefore chopping, sawing and splitting with bladed tools and impact fracture with a blunt implement.

SECONDARY TECHNIQUES

The secondary techniques of tool manufacture are the ones which transform a rough out or blank into a finished object and these will be dealt with in a sequence which reflects increasingly fine tuning in the finishing of an object. Some of the traces from manufacture have, of course, been removed by wear from use, but it is clear that it is once again bladed tools which performed the bulk of the work, though it is presumably smaller knife blades which were used.

Scraping - the movement of a blade across the bone surface at right angles to it - was observed in only a few instances. On the surface of the bird bone tube (M 61 Fig 7.10) and on a sheep tibia point (M 6 Fig 7.3), this is most likely the result of periosteum stripping rather than as a manufacturing technique. On objects such as one of the sheep metapodial spatulae (M 16 Fig 7.3) it seems to have been used simply to shave away a rough or slightly protruding part of the tool.

Trimming accounts for a great majority of the more detailed shaping. This generally involves running a blade across the surface of the bone being worked at an acute angle, and results in the removal of longish slivers of bone or antler. It is particularly suited to the production of rounded surfaces by the gradual removal of thin slivers which leave a faceted surface behind. Occasionally chatter marks are created when the blade slips (Pl 7.3).

Grinding was only noted on two groups of implements; the scapula segment tools (M 58-60 Fig 7.9) where it was used to flatten some of the surfaces, and on the heads of some of the sheep metapodial spatulae (e.g. M 18 Fig 7.4). In the latter case heads are formed by the distal articulation of the bone which, when fresh, often carries fragments of muscle attachments difficult to remove by any other method. The bone also has sharp condylar surfaces which are frequently ground to a flattish or rounded surface so as to be held in the hand more comfortably. No pumice was identified during the excavation, so grinding may simply have been against a piece of sandstone or other rock.

All the pins, virtually all the points and spatulae and many of the other tools have very smooth surfaces. Some of this is the natural result of handling during tool use and is caused by human body fluids and fine dusts being rubbed into the surface. In some cases it may also be the result of tool use against soft organic materials. Certainly with the pins, and probably with some of the long-handled combs and other tools which were hand-held for long periods, the surface was deliberately polished. It is not possible to say exactly what these surfaces were polished with, but after fine trimming or grinding, a smooth enough surface would have been obtained which could have been rubbed with leather and the hands to develop a high polish. Such a gloss as this could have been enhanced by impregnation with natural fats. In all cases polishing would have been the final act of manufacture.

A number of other techniques were used on particular classes of objects and the most obvious of these is fine sawing for the production of long-handled combs. The antler composite comb (M 53 Fig 7.9) is of a form which dates to a period generally later than the rest of the material at Midhowe, but shows a very skilful use of the saw and vice in the manufacture, firstly of small antler segments which are mounted in the comb, and secondly in the fine sawing of the teeth themselves (Ambrosiani 1981, 103-27; Galloway & Newcomer 1981; MacGregor, A 1985, 68-71, 82-95). The teeth on the long-handled combs were also sawn, but the evidence from the partially worked blank (M 50 Fig 7.8, Pl 7.7) shows that the teeth were made by sawing grooves at a very acute angle to the surface of the bone on both sides and then linking the grooves up to create individual teeth. The other unfinished comb (M 49 Fig 7.18, Pl 7.7) shows teeth made by this method, with some also sawn from the distal end of the comb. The saw used must have had a very thin blade. (Cf. Callander & Grant 1934, 508-09 where this was also recorded, but the grooving on M 50 was believed to have been cut rather than sawn, and the teeth on M 49 were thought only to have been sawn.) It may be that once a notch for teeth was well formed, the saw could be used at right angles to the comb's handle.

Several of the objects have hollows, holes or perforations and these were made by <u>hollowing</u>, <u>gouging</u> and <u>drilling</u>. The hollowed implements are primarily sockets of varying purposes and sizes and have been shaped by carving and cutting with bladed tools. One of the cross pieces has a rectangular notch cut in from both sides and the central cancellous tissue removed (M 40 Fig 7.7). The other has had a circular hole made in it (M 38 Fig 7.6). The fragment of cetacean vertebra cup (M 69 Fig 7.11) shows the skill of the bone worker and the more effective nature of the tools available within an iron-using community. By comparison with those found at Skara Brae, the Iron Age cetacean vessels are made from much larger vertebrae and are more finely crafted, leaving a thin, regular wall and base cut out using bladed tools. The hollow in the antler handles (e.g. M 32 Fig 7.5) was simply made by the removal of the cancellous tissue.

Only one object has been made using a gouge and that is the socket for a rectangular blade made from part of an antler (M 34 Fig 7.6). This has a circular perforation, for inserting a haft, which was developed by driving a gouge at right angles into the substance of the antler. Only a metal gouge would be capable of this effect and leave such traces.

Of the tools which have been perforated, the pegged plates (M 23-30, Figs 7.4, 7.5) have holes where antler pegs would fit to attach them to an underlying organic handle, probably made of wood. Some of these holes could have been made simply by turning the point of a sharp knife in a circle on the antler. This would usually leave a distinctive angled hour-glass perforation. On a few of the plates, and certainly on a number of other tools from the site, the results of the use of a straight-sided drill bit are visible. The tooth pin-head (M 11 Fig 7.3) has a straight perforation 3 mm in diameter. The whorls (e.g. M 54 Fig 7.9) have perforations between 8 and 10 mm in diameter. This suggests that not only were drills available, but that the drill bits were of metal.

OBJECT CATEGORIES

The purpose of this section is to list the range of finds made at the broch of Midhowe and discuss their classification, variation and significance in terms of that site. Recent reports (MacGregor, A 1974; Hedges 1987) have reviewed the finds from Orkney brochs and complete lists of parallels should be sought in their work. References are made here to other sites and finds only when they are felt to elucidate individual objects or classes, or to improve the understanding of the site at Midhowe.

POINTED TOOLS

The terms 'point', 'point/pin' and 'pin' cover the same range of pointed implements referred to by Callander & Grant (1934) by their terms 'awl', 'borer', 'pointed tool' and 'pin'. The correspondence is not exact, but their term 'awl' is only used for those items classed here as points, and their 'pins' are here classified as points/pins or pins. They used 'borer' to cover all three groups and gave it as an equivalent to their other terms. In this discussion points are seen as perforating implements, whereas pins are thought to be more associated with dress and/or decoration. All make use of the longitudinal axes of bones to provide a strong resistant segment of bone.

POINTS (M 1-4, Fig 7.3)

Four bone tools simply made from split segments of long bone (of land mammals or bird) or from naturally pointed bones which have had the tips sharpened. Such split segments and naturally pointed bones (e.g. the ulnae of sheep) are frequently misidentified as having been deliberately sharpened even if their pointed nature is completely fortuitous (cf. M 101, 122)

POINTS/PINS (M 5-7, Fig 7.3)

Three elongated pieces of bone, two being pig fibulae and the other one a long segment of compact bone, all of which have been trimmed or scraped for at least a third of their length to produce a sub-oval or circular-sectioned piercing tool.

PINS (M 8-10 Fig 7.3, Pl 7.1)

Three elongated segments of compact bone with a circular cross-section which have been smoothed and highly polished along their whole length (Pl 7.1). All have their tips broken off.

PINHEAD (M 11, Fig 7.3)

A broken pinhead made from a cattle premolar. The apex and crown of the tooth have been removed and there is a single perforation through the flat surface of the tooth into the pulp cavity. It was probably placed on the top of a simple iron spike pin similar to that from the broch of Ayre (Graeme 1914, 38) or on one of bone like those from Gurness (Hedges 1987 II, 203, cat no 122). Another pinhead of the same material is known from the broch of Burrian, North Ronaldsay and these are thought by A MacGregor (1974, 71) to be an Orcadian type. Callander & Grant (1934, 463, 490) wrongly believed that it might have been made from 'morse ivory' i.e. walrus tusk and that the large central hole was artificial rather than natural. The choice of such a raw material would have been for aesthetic reasons.

BLUNT (M 12-15, Fig 7.3)

Bones of various origins - one probably a cattle innominate, one a sheep tibia, and two segments from the diaphysis of a thick long bone - which have been shaped to a thick, rounded or blunted tip.

These may have been used as strong piercing tools, hence Callander & Grant's phrase (1934, 488) 'stout bone borer'. In producing blunt-nosed tools, pieces of bone from a number of sources were chosen, but in each case they have come from thick-walled pieces of bone which would have been resistant to compressive forces.

SPATULAE (M 16-22, Figs 7.3, 7.4, Pl 7.2)

Seven implements made on sheep metapodia, from which the proximal articulation and one side of the diaphysis has been struck and in which the resulting break has been turned into a flattened, polished spatula (Pl 7.2) either in line with, or at right angles to, the anterior surface of the bone. Described by Callander & Grant (1934, 487) as 'rounded chisel-ended implements ... the distal (sic) ends being sliced away on one side' and considered by them to be distinctive Iron Age tools whose purpose had not been explained (ibid. 509). These are described by Hedges (1987 II, 205-06) as 'rubbing and polishing implements', but were possibly also used in weaving as small beaters. All these tools have made use of thinned areas of diaphysis shaft, and in selecting this bone element the straightness of the metapodials will have been an important influence.

PEGGED PLATE, LARGE (M 23, Fig 7.4)

A large bone plate made from cetacean bone, perhaps a rib, roughly rectangular in shape and with the remains of three perforations at each end. The perforations are probably peg holes and, like the other pegged plates discussed below, this can be interpreted as one side of a handle plate. The implement concerned must have been a sturdy one and it is tempting to think of a large, heavy bladed tool such as cleaver or saw which had been made with a substantial tang. Judging by the size of the surviving plate, an average-sized hand would just grip the whole handle securely. Plates of comparable size were found at Gurness (Hedges 1987 II, 195, cat no 5, 15, 19).

PEGGED PLATES, SMALL (M 24-30, Figs 7.3, 7.4, 7.5, Pl 7.4)

Five complete plates were recovered (M 24, 25, 26, 27, 29 Figs 7.4, 7.5), along with one unperforated plate (M 28 Fig 7.4, Pl 7.4) and a single peg (M 30 Fig 7.5), all of antler. M 25 was made from one side of a split tine, retaining its curvature and having two large circular perforations at its distal end. The other complete plates, M 24 & 70, are from the side of a longish segment of beam, trimmed to give a concave area on both surfaces and retaining two peg holes each. M 24 retains one of its original antler pegs and has its surface decorated with rough, oblique, parallel cut marks. The two shorter plates (M 27 & 29) were made from smaller segments of beam or tine which were shaped to have a plano-convex section and one side edge slightly convex, the other being slightly concave. They have peg holes which run down the centre of the plate, the shorter one (M 27) having only two peg holes, the larger one (M 29) having three. M 28 is an unfinished plate, having a roughly rectangular shape, sawn ends, trimmed surface, and flattened, smoothed cancellous tissue underneath. All that was left was to drill out the holes and mount the plate. It is likely that they were attached to the outside of wooden handles which would themselves have had the tang of the object to be mounted inserted into them, rather than being attached directly to the haft themselves. They would have been both decorative and functional. Antler pegs, such as that seen on M 24 and found unmounted (M 30) would have been inserted into holes drilled into the plate and underlying handle, and then trimmed off and polished so that they were flush with the rest of the plate. Similar plates are known from the broch of Ayre, Orkney (Graeme 1914, 41-42) and Burrian, North Ronaldsay (MacGregor, A 1974, 78, cat no 129-131) and in addition, individual pegs and unfinished plates were also found at Gurness (Hedges 1987 II, 194-97, cat no 1-43).

In selecting antler and cetacean bone for handle plates, Iron Age people chose materials which were resilient to pressure from the tang, had a slightly rough surface which probably improved the grip and which could be more easily drilled and pegged than bone.

HANDLES (M 31-33 Figs 7.5, 7.6, Pls 7.3, 7.4)

These can be defined as the socket into which the tang itself was inserted. Antler is commonly used as its shape already suits a handle, since the compact surface provides a suitable grip, and the cancellous tissue can easily be hollowed to take and retain the tang of the implement to be mounted. Antler as a whole would act as an excellent shock absorber for chopping and cutting tools, and the combination of antler compact and cancellous tissue would be far more resilient than the brittleness of bone. There are two antler socketed handles from Midhowe. One (M 32 Fig 7.5, Pl 7.4) is made from a segment of split beam, one side being of compact antler, the other of cancellous tissue. The tang would have been inserted at the very junction of the two. One side has split off showing where the handle broke, presumably during use. The other (M 33 Fig 7.6) is made from a complete segment of beam which retains the remnants of a tine base. The blade was inserted into the cancellous tissue itself and held fast by pegs driven through two pin holes just below the socket mouth. The depth of the hollows made to receive the tang are 54 mm and 91 mm respectively, although the latter may be a little longer than was originally intended since some cancellous tissue has eroded. This length is a reasonable indication of the size of the tang, provided allowance is made for additional collars and binding at the mouth of the socket. This in turn will be related to the weight and length of the blade mounted. Few such handles have survived with their blades intact, and this probably reflects a level of breakage of the handle, rather than in situ corrosion which should have left products on the handle. One surviving handle from Gurness (Hedges 1974 II, 213 cat no 252) carries a blade roughly equal in length to it and this may suggest the type of implement which would have been mounted in those from Midhowe.

SOCKET (M 34, Fig 7.6)

This is a different type of handle, made from an antler tine by sawing into the broad end at right angles to it for a depth of 39 mm. The tang of a blade would then have been inserted directly into it and held on with, perhaps, a collar (e.g. ?M 63) and some binding. M 34 is a much more unusual piece. Made from the base of an antler, the bulk of the beam and tine have been sawn off and a circular hole made through it by gouging into the antler at right angles to it. Cut into the cancellous tissue is a rectangular socket to take a large blade, 21 mm broad. This must have been mounted as a socket for an adze or digging hoe, the perforation being to take the haft. There are no close parallels for this socket. Again, the resilient properties of antler, and the ability of cancellous tissue to grip a blade were being used to produce this socket.

?SOCKET (M 35, Fig 7.6)
This is also an unparalleled implement. It is probably made from a red deer metatarsal which has had the condyles sawn off and a perforation drilled slightly off-centre beside that part. On one side of the bone are six faint linear hollows which radiate slightly. Such marks have been suggested as resulting from a twine binding, tightly tied and then stressed (pers comm W Britnell). That the piece was mounted at right angles on a haft is very likely and, given the possible binding marks, it would seem reasonable to suggest that this was used as another socket.

SOCKETED OBJECTS (M 36-37)
This is a catch-all category for perforated pieces which must have formed parts of composite tools but whose purpose is not clear. It covers a cetacean bone block (M 36) which seems to have acted as a chopping block and socket and a broken piece of cetacean bone with a central, squared hole (M 37).

CROSS PIECES? (M 38-40 Figs 7.6, 7.7)
All three are made from segments of antler beam which have had a perforation cut or hollowed into them. Two were described by Callander & Grant (1934, 493) as 'hammer-heads' and the other as 'possibly a whistle' (ibid. 496). It is very unlikely that these are indeed hammer-heads since there is no evidence of the type of surface crushing one would expect on such implements, and M 40 is certainly not a whistle. They are likely to have been cross-pieces for daggers or blades or part of some other type of composite mounting. It is, presumably, the cancellous tissue in the antler which has made it the raw material choice for those objects.

COMBS, LONG-HANDLED (M 41-51 Figs 7.7, 7.8, 7.9;
Pls 7.5, 7.6, 7.6, 7.8)
Eleven combs were recovered from the site. They are a very distinctive piece of Iron Age material culture, being found throughout Britain. Frequently regarded as 'weaving combs' (e.g.

Callander & Grant 1934, 485, 508-09), Hedges (in Hodder & Hedges 1977, 17-19) finds this unconvincing and later asserts (1987 III, 17) that they are for combing and ornamenting the hair. The original report classifies them all as being of cetacean bone (Callander & Grant 1934, 485) but only six are made of this, the other five being of antler. In objects which have had most of the natural surface of the bone removed, the distinction between antler and cetacean bone can be very difficult to recognise, but M 44 (Fig 7.8, Pl 7.5) still retains some of the worn, rubicose antler surface. A study of these and other combs suggests that two very broad classes can be identified - those with a rectangular section made from cetacean bone and those with a curved section made from antler. This is really a function of the source material, since antler combs will be shaped according to where on the beam the segment was cut off and how thick the compact tissue was. Some of the cetacean combs are from bones so large that such considerations have no effect (e.g. M 48 & 50 Fig 7.7, 7.8, Pl 7.7) and are of a sort which can be paralleled at both broch and non-broch Iron Age sites in the Northern Isles (e.g. Howmae Brae, North Ronaldsay, Traill 1884). Equally, the gradual waisting seen on some combs (e.g. M 51 Fig 7.9) is probably a direct result of the use of a particular segment of antler in which the teeth and the butt were made from the flattened, broader areas by a tine base or at the crown, and the shaft of the comb is from a more circular-sectioned part of the beam. The hollow base or fish-tail end (e.g. M 45 Fig 7.8, Pl 7.5) of some combs may also be seen as appropriate to the use of antler. Thus, combs such as M 42 (Fig 7.7) which is of cetacean bone and shows both these features may be viewed as skeuomorphic.

Combs were made by creating a blank in antler or cetacean bone and carving the rough shape in it. The teeth were then sawn either by making grooves on both sides which were gradually linked up, or by sawing at right angles to the teeth (Pls 7.7, 7.8). On the finished combs, the teeth themselves are generally rounded and worn and show very slight polished notches running round the teeth (Pl 7.6), a feature characteristic of all combs, whether long-handled, double sided or composite. Combs M 41, 42, 44, 45, 46, 48, 49 and 50 (Figs 7.7, 7.8, Pls 7.5, 7.7) survive well enough to be able to quantify accurately the number and size of the teeth. The average is of 9.75 teeth, which are 32 mm long and 8 mm thick at their base, generally sub-oval but becoming more circular towards the tip. Antler combs tend to have thinner teeth, because the compact tissue is less thick than in cetacean bone, and, as a result, they form a more acute angle. M 48 (Fig 7.7) has a completely flat base and M 41, 42, 43, 45, 50, and 51 (Figs 7.7, 7.8, 7.9, Pls 7.5, 7.7) all have hollow bases, fish-tails or the broken remains of them. M 46 (Fig 7.8) has traces of a perforation at the butt, and M 47 (Fig 7.7) is the only comb with any additional decoration, there being a sawn saltire on the comb body, just below teeth. Hodder's analysis of the Scottish combs (in Hodder & Hedges 1977, 25-26) notes some of these features and distinguishes the flat-based stumpy type of comb (e.g. M 48 Fig 7.7) as a separate group (ScotD), but since his classes are defined on the basis of shape alone with no reference to raw material, little significance can be given to such results. The advance shown here is in the recognition that there are some forms which are more appropriate to antler than to cetacean bone and whilst one distinctive cetacean group can be identified, the rest of the combs made from that material show features which are reminiscent of antler and, indeed, overaccentuate the natural shape of an antler comb. Thus the form of long-handled combs can partly be attributed to the natural properties, structure and shape of the raw materials of which they are made, but in several instances, the form of cetacean bone combs must be seen as deliberately avoiding the 'natural' shape. It is hard to see the level of difference as being functional and questions about aesthetics and decoration must be raised to explain this phenomenon.

Both antler and cetacean bone have a structure which makes them less brittle than bone, and easier to saw into for the manufacture of combs. The same properties make them effective implements. The wear on these combs suggests they were used to help beat up resistant parts of a thread being woven and possibly also in the combing of hair on hides and wool on fleeces. Though teeth have broken on the original combs in ancient times, they would have been more effective than bone ones made in the same shape.

COMB, SINGLE-SIDED (M 52 Fig 7.9)

A small one piece comb made from cetacean bone with a decorated, grooved and perforated back and 9 short teeth. A MacGregor lists similar items from two brochs in Caithness and two in Orkney (1974, 80). This is likely to have been a personal comb.

COMB, COMPOSITE, DOUBLE-SIDED (M 53 Fig 7.9)

Part of an antler composite comb, of which only one segment survives, the teeth having also broken off. The side-plates are decorated with ring and dot decoration and are fixed to the tooth-plates with iron rivets. The teeth were closely spaced, there being about 8 teeth per centimetre. Such combs were absent from Gurness, but present at Burrian, North Ronaldsay (MacGregor A, 1974, 80-81). It is probably the latest item of bonework from the site and is 'diagnostically Pictish' (Hedges, 1987 III, 43). This and the single-sided comb, both make use of antler's properties in a way similar to that described for the long-handled combs.

WHORLS (M 54-57 Fig 7.9)

Whorls of bone and of stone were recovered from the excavations. Of the four genuine bone whorls, three are made from the epiphyseal ball on the proximal end of a cattle femur which has been sawn or chopped off and then perforated. One such is unfinished, but some past misidentifications have resulted from the recognition of a natural channel which sometimes runs through the centre of this part of the femur. The fourth whorl (M 54 Fig 7.9) was made from a flattened segment of cetacean bone, which is worthy of note for another reason. The whole piece has been gnawed around its circumference by a rodent. Bone and stone whorls are usually seen as having been used as spinning whorls (cf. Callander & Grant, 1934, 509) and it is the weight and ease of shaping of the whorl that matters.

SCAPULA SEGMENT TOOLS (M 58-60 Fig 7.9)

Three tools made from an oval segment taken from a sheep scapula and including the scapula spine as central. The narrow ends are curved and rounded, or bevelled, and these may have been used as potting tools for smoothing the clay or in leather working. The scapula was selected because of its natural flat blade which could easily be modified to produce such an implement.

TUBE (M 61 Fig 7.10)
A tube formed by the removal of the articular ends of the ulna of a large bird, identified as perhaps a wild goose or fish eagle (Callander & Grant 1934, 489), but equally likely to be from some other species. Another bird bone tube, from Covesea Cave, Moray (Benton 1931, 198, 187 Fig 9.10) was a holder for a long bronze pin. It is reasonable to assume that this piece was a pin sheath or something similar, making use of the long air-filled cavity of the bone.

RING (M 62-64 Fig 7.10)
This term covers two forms of object: circular-sectioned rings of cetacean bone and a hollowed broad segment of antler. The former (M 62 & 64) have been hollowed out of a piece of bone and then smoothed and polished. The latter, probably the 'bead' referred to in Callander & Grant (1934, 481), is a sawn segment of antler with the cancellous tissue removed, rather like the 'collar' identified at Burrian, North Ronaldsay by A MacGregor (1974, 78, cat no 133). These must be part of composite tools or mountings for dress or equipment. The latter may have been used with handles such as M 31. Their appearance would be as important as their natural properties.

?MIRROR HANDLE (M 65)
A Y-shaped piece of cetacean bone with a rounded, knobbed proximal end. It is part of a composite object, but is now slightly broken. On comparison with other items from sites of comparable periods it is reminiscent of a bone version of a bronze mirror handle (cf. that from Balmaclellan, Kirkcudbright (NMS FA 1), just as the bone handle from Bac Mhic Connain, North Uist seems a translation of the bronze one from Lochlee Crannog, Ayrshire (MacGregor, M 1976, cat no 273, 271, 272)). The search for a suitable flat piece of bone would have lead to that of cetaceans as a first choice.

MATTOCK (M 66 Fig 7.10)
Made from the beam of an antler, this implement is unfortunately

broken and it is impossible to tell what sort of proximal end it had or whether this had been removed. The distal part has a round-ended blade edge, forming a shallow angle through the beam. This was shaped with quite a large iron blade which has left traces of chopping marks at an angle to the surface being created. In Scotland, similar implements are really only known from Mesolithic contexts (see Risga above) but the features on this tool suggest that it is part of a digging implement. If it is such an implement, then the choice of antler will have been carefully made for its properties.

PICKS (M 67-68)
Callander & Grant (1934, 495) mention 9 antler picks which have had the bez tine removed and the brow tine hollowed. Examination of the antler material from Midhowe suggests that only two of the antlers have been deliberately shaped and used in this manner (M 67, 68). Both are shed antlers which retain the burr, brow tine and beam, but have had the other tines chopped off. The tips of the brow tine show flattening, wearing and flaking which is consistent with their use as implements used in digging or loosening soil or stones. They are not deliberately hollowed. The rest of the antlers found at Midhowe exhibit features which can be attributed to natural rubbing while still borne by the stag, or as the result of handling during the manufacture of other tools.

CETACEAN VERTEBRA CUP (M 69 Fig 7.11)
This is a fragment of a cup made from the vertebra of a creature of the size of a pilot whale or slightly larger. It is probably from an immature animal in which the vertebral epiphyses had not fused. The spine was removed and then the vertebra was hollowed by chopping and cutting out the cancellous tissue. The base is flat and the rim rounded, the wall of the vessel having been skilfully cut to only 11 mm in thickness. Cups like this could never have held liquids and it would seem reasonable to suggest that they acted as dry measures. Such a skilful piece of work was made possible with the development of iron bladed tools. The sharp lines of the cup and its smooth surfaces could only have been made with such implements. Whilst

vertebra cups are known from earlier sites, they appear poor in quality and scale when compared to those of the Iron Age.

PERFORATED BOAR'S TUSK (M 70)

A single segment from the triangularly-sectioned tusk which has a broken perforation at one end.

ANTLER-WORKING DEBRIS: BEAM/SKULL/PEDICLE/BURR (M 71-82)
: TINES and CROWN (M 83-100 Fig 7.10, Pls 7.4, 7.9)

The bulk of the antler material from Midhowe consists of the debris from antler-working. As has been indicated above most of the antlers used for tool manufacture were shed, but those which were still attached to the stag's skull were sawn or chopped off before use as is the case with M 76. A piece of bone identified by Callander & Grant (1934, 490) as the

> 'proximal end of an ox femur, roughly dressed to a bobbin-like shape'

(M 71) is really the pedicle from a stag's skull which has been chopped off at both ends, and discarded as debris. The strategy followed in the use of antler seems to have been to remove the tines and the burr in order to release segments of beam which were then split to make use of the compact antler for combs, plates etc. Long tines were sometimes used for making socketed handles or pegged plates. As a result, most of the non-artefactual antler is made up of parts of beams and tines which show cut, chop, split and saw marks. None appears to be a blank or rough-out for any tool, but they are best seen as debris which give evidence of the preliminary stages of manufacture as discussed above. A few of the antlers now survive in poor condition, and as a result of their eroded surfaces, it is difficult to be sure whether they have been used at all. Though now fragmentary, one complete antler only (M 127), shows signs of having been gnawed.

Generally the burr and brow tine were removed from the antler as a single unit and discarded, the crown and other tines being chopped and sawn off, leaving lengths of beam which could then be used further (e.g. M 82). There were two segments recovered during excavation which had been cut from tines (M 91, 122), and a tine tip (M 90) which was probably the debris from the production of such segments. In terms of the range of objects represented at Midhowe, this debris seems most likely associated with the manufacture of socketed handles.

WORKED BONE: LAND MAMMAL (M 101-102 Fig 7.11, Pl 7.10)

Fragments of bone split during butchering or marrow extraction and which come to a point or some other shape can be misidentified as deliberately shaped tools. This is the case with M 101 which is the pointed part of the split shaft of a sheep tibia and not a 'bone borer' as thought by Callander & Grant (1934, 488). Towards the articular end of a bone, some fractures leave a distinctively curved, spiral-fractured surface which can easily take on a natural polish through handling and exposure to wind and sand. Callander & Grant (1934, 488) viewed M 102 (Fig 7.11, Pl 7.10) as having had 'its blunt point made smooth by rubbing' but this is not the case, although all the features of this particular piece are the result of fracture impacts and splitting. In both cases, pieces of debris have features which, without an understanding of bone fracture, could be taken to be deliberately manufactured objects.

: CETACEAN (M 103-108)

Six pieces of worked cetacean bone were found. Apart from one epiphyseal surface of a vertebra (M 105) the rest are pieces of limb or paddle bones which had been split and sawn into roughly rectangular or cuboid shapes. Some cetacean bone contained enough oil and fat that it could have been chopped up and used as fuel, but it is likely that the pieces found at Midhowe were being prepared as blanks for tool manufacture or are debris from working.

NATURALLY POLISHED PIECES OF BONE (M 109-121)

These are a number of small pieces of long bone split during butchery or marrow extraction which had been left exposed to the elements. Erosion by a combination of wind and sand (and possibly water) have smoothed the surfaces so that they are rounded and have a high polish, but they are not the 'polishing implements' or 'rubbing tools' identified by Callander & Grant (1934, 471, 481; cf. Hedges 1987, III, 18).

UNWORKED MATERIAL (M 122-129)

A number of bones and pieces of antler which are unworked must be mentioned here since they appear within the published report as tools or as having been worked. One sheep ulna (M 122) and a bird bone (M 123) are naturally pointed bones which show no sign of sharpening or wear at their pointed ends and so must be considered as unworked (contra Callander & Grant 1934, 487). Although slightly polished, the caudal vertebra of a small mammal (M 124) cannot be described as in any way worked and one of the cattle femur heads (M 125) is simply an unfused femur epiphysis with a natural blood channel through it. A cattle horn core, two shed antlers and some boars' tusks (M 126, 127, 128, 129) show no signs of deliberate working.

DISTRIBUTION AND INTERPRETATION

Hedges (1987, III 115) has commented about the finds from Midhowe that:

> 'Re-analysis of the excavation report has brought to light an unexpected degree of stratification.'

That this is true is thanks to the detail included in the report written, and promptly published, by Callander & Grant (1934). Hedges further comments that one of the problems in studying artefactual assemblages from brochs has been:

> 'ambivalence towards multiperiodicity which caused collections to be unusefully and uncritically regarded as 'from' a particular broch site' (1987 III, 15).

He goes on to argue that the internal structures of a broch tower and its surrounding buildings may be regarded as contemporary with the tower and that this enables many of the finds from Midhowe to be phased. The effect of Hedges' thesis is to pull at least some of the internal divisions of the broch tower and some of the extra-mural settlement into the original design concept of the broch complex. There is still a multiperiod aspect to the site, whereby some of the internal structures are later than others: the building of some of the extramural settlement must postdate the redesign of the walls and ditches, and part of the internal division within the extramural settlement is the result of addition, blocking of passageways etc. This would seem to suggest that the changes wrought on the site after its initial construction are, in fact, more at the level of detail and reorganisation, than the sort of major structural change envisaged by Callander & Grant. There is almost an internal contradiction in Hedges' argument since if the 'secondary' constructions inside and outside the broch tower are contemporary with its construction, then the basis for most of the multiperiodicity and significant stratigraphy has been removed. That this is the case can be seen from Hedges' summary of the finds from the site (1987, 115-16) where, of the artefacts which can be attributed to a period, only one object (the composite comb M 53) and two groups of objects (some of the mortars and at least one saddle quern) can be said to be other than of the broch period. The stratigraphic information is, therefore, at a level of detail which does not enlighten us as to long term development or changes in broch use and artefact manufacture, but which enables us to focus upon particular distributions. This is in contrast to the range of finds made at Gurness itself and at Burrian, North Ronaldsay. Apart from one composite comb, therefore, the history of the site at Midhowe can be divided into periods only on the grounds of phases of building or reconstruction and not on changes in artefact origin or morphology. This confirms that discussion of all the finds made from skeletal materials together is in fact a valid approach for this site.

It is possible to be certain of the original location of only 32 of the bone objects from the excavations at Midhowe (M 11, 12, 17, 18, 20, 21, 23, 25, 27, 31, 36, 38, 39, 40, 41, 43, 44, 45, 46, 47, 48, 49, 53, 54, 58, 61, 62, 63, 65, 69, 106, 107). For a few of the other objects (the remaining long-handled combs and spatulae for example) it is possible to give locations for all the objects, but not say which object came from where. Certain categories, such as points and pins, have none of the members of the class individually identified in the excavation report, although their general distribution is noted. Analysis of the distributions can, therefore, follow two approaches - that of the location of objects of particular categories and that of identifiable individual objects.

General distributions can only be considered significant if a class of object contains a reasonable number of members. For the Midhowe bonework, only the pointed objects (taken as an amalgamated group), spatulae and long-handled combs can be considered. Pointed tools were frequently found in groups. The long-handled combs were more often found by walls or upright slabs than in open spaces, but the spatulae seem to have been quite well spread. The details given within the published report about the distributions and associations of other material suggest that there are general concentrations notable e.g. within the broch tower: whorls in the East of compartment D; rotary querns in the East of compartment C; pot lids in the North-East of compartment D and in the South-West of compartment C; and to the South of the whole site pottery in the tank at the foot of the steps. It is impossible to be certain that the distribution of objects on the site can be taken as representative of activity areas and such study begs the question of why objects are to be found within the building at all as has been discussed for Skara Brae. Nevertheless, these patterns may represent activity areas related to spinning, storage and cooking, food processing and pottery production rather in the way that 'G' was interpreted as an iron smelting area. If this is so, then the long-handled combs may have been associated with looms leaning against walls and upright slabs. There seems to be a general spread of tools throughout the rest of the buildings and rooms, but the finds from the two ditches cannot be interpreted as evidence of in situ working and the fact that the distribution continues there must make one even more wary of interpreting the infill material from the broch tower itself.

As to the distribution and stratigraphy of identifiable finds of bone, several phrases are used by to describe their position. Within the broch tower at floor level in the lobby area leading into compartment C were found an antler handle (M 31), a bone point, the cetacean bone pegged plate (M 23), the bird bone tube (M 61), a spatula (M 21), a long-handled comb (M 41), half a rotary quern, two socket stones and five pot-lids. At the East end of the cubicle on the North side of compartment C, two long-handled combs were found, one at floor level (M 43) the other 5 feet higher up (M 49, an unfinished comb) (Callander & Grant 1934, 462). Also at floor level, at various points within compartment D, were three long-handled combs (M 45, 46, 47), a whetstone, a bone ring (M 62), 7 pot lids, a rotary quern and four whorls. At floor level by the East end of the drain by the South wall of compartment D were found a whorl, a ring-headed pin and cetacean paddle bones (M 106 & 107), 18 inches above which were pieces of a bronze patera. The floor of compartment C was covered with a peaty layer up to 5 inches deep which was considered to have been the decayed remains of a carpet of heather and grass. Within this layer were found a large number of objects - a long-handled comb (M 48), a bronze pin, the pinhead (M 11), an antler plate (M 25), a blunt tool (M 12), a whetstone, two spatulae (M 18 & 20), three bone points, two antler picks and two pieces of Samian pottery. The only recorded stratigraphic relationship was between a pot lid and some rotary querns which were below a saddle quern and further rotary querns (Callander & Grant 1934, 462-63).

Objects were found in the infill of the ditches. At the lower level of the inner ditch were a saddle quern, 2 boar's tusks, half a whorl of pottery, a spatula (M 16, 19 or 22) a scapula implement (M 58), the piece of cetacean vertebra cup (M 69), a saddle quern and a pot lid. Two points and a pin were found higher up. In the bottom level of the outer ditch were 2 pot lids, a saddle quern, 2 socket stones, burnt animal bones, pot boilers, hammerstones and a bone point (Callander & Grant 1934, 471-72).

At floor level in 'F' was a bone point. Before the buttressing was inserted on the North side of the tower there were deposited a penannular bronze fibula, a long-handled comb (M 42 or 50) and a hollowed stone. Several objects are described as having come from relatively high in the stratigraphy. A cross-piece (M 39) was found high up in the debris in the entrance to the more southerly of the entrance cells and at a higher level on the path between the inner ditch and the broch tower were the composite comb (M 53), a bone pin and the point of another, two bone points, a small rounded stone, part of a saddle quern and three hammerstones.

Most of the rest of the objects of bone were recovered from thin deposits which showed no real stratigraphy. Such stratigraphic information as has been recorded does not allow us to draw distinctions between different classes of objects or between any groups within a class, with the exception of the composite comb which, as would be expected, comes from a late context. There seems to be no repeated pattern in the groups of objects which are found together on the site, whether in terms of the bone objects alone, or across the full range of materials used, other than the general distributions alluded to above. It seems likely that the excavated deposits represent a sequence of working areas and debris which may have collapsed from upper storeys. A depth of five feet is unlikely to form without abandonment or deliberate infilling. One further concentration which should be mentioned is within the more southerly of the entrance cells in which pieces of antler were found on the floor near the door and stuck into crevices in the wall. This concentration and location may simply represent a place for storing antler, but would seem more likely to have been decoration, in the sense of a trophy room, or perhaps religious or ritual. The cell is not an ordinary broch entrance cell which gives access to a bar hole to enable the door to the broch to be shut. There is a hole, but it leads out of the cell further down the passage than the door would have been and there is no hole in the wall on the opposite side of the passage for a bar to slip into in order to secure a door (Callander & Grant 1934, 450).

CONCLUSION

The broch and site at Midhowe presents a picture of a defendable farmstead occupied within a restricted length of time during the Iron Age when Roman pottery was available in Orkney. Bronze and iron working were undertaken at the site and probably also potting, as well as animal butchering and crop processing. The range of items believed to be associated with textile production suggests that spinning and weaving were being undertaken. Given that only some of the brochs in Orkney have extramural settlements, the site can be seen as a prosperous one which was well linked into the local social hierarchy though not occupied for as long a period as some sites. Roman pottery, bronze pins, penannular brooches and sheet metalwork are not common finds and would testify to the site's influential connections.

In terms of the use of skeletal materials, bone was only used for a few items of jewellery - the pins and pinhead. The handle plates, handle sockets and cross pieces in antler and cetacean bone were both functional and decorative. By far the bulk of the implements are working tools related to fleece preparation, spinning and weaving (the combs, whorls and perhaps the spatulae). The points and blunts are probably associated with the preparation of hides and in straw working. Picks and a single mattock blade are evidence of ground preparation for agriculture or the removal of roots from the soil. It is possible that the scapula implements are potting tools and the cetacean vertebra cup represents the storage of dry goods.

It is difficult to assess the extent to which different materials were used for similar objects since two important materials - iron and wood - do not survive from the site. It is possible that iron was used for the production of piercing tools, but on contemporary sites at which iron pins have survived, they are, as with those of bronze, pin shafts for jewellery. Only one bone container was found: the cetacean vertebra cup. Whilst there is some overlap of use with the pottery from the site, the latter, though porous, would have been able to hold liquids. There is certainly a variety in the range of materials from which whorls were made - stone, bone and pottery.

In terms of attitudes to materials, use was made of land and sea mammals, and to a small extent, birds. Most of the bones used were those of domesticated animals, but a large number of implements were made from antler (both shed and unshed) and cetacean bone. Artefacts made from antler and cetacean bone were very rarely also made with other bones. This would seem to be recognition of the similarity in resilience of antler and cetacean bone as opposed to the more brittle nature of e.g. cattle and sheep long bones. Any difference between the use of antler and cetacean bone themselves is related to questions of scale of the finished implement, objects of the same class made of cetacean bone being larger than those of antler. As at Skara Brae, some implements are simply modified bones, other use antler and cetacean bone as bulk materials. More evidence of the latter is seen at Midhowe than at the earlier sites and this is the effect of having heavy bladed metal implements available.

Quite a large number of object classes are represented at Midhowe. Some, such as the long-handled combs, are clearly defined, others, for example the range of points and pins, is rather diverse. In terms of the sequence from animal butchery to finished object, some tools have quite strict formulae for their production, and others are quite relaxed. This is an approach paralleled at Sollas and other Iron Age sites which have been examined, but which contrasts with the much tighter sequences at Skara Brae and the even freer approach seen at Risga. The phenomenon is probably attributable to the relationship between form and physical properties. Given a particular set of requirements for an object, there are only a certain number of species and bone sources which can be exploited. Far more exist for the production of simple pointed implements than for the more complex handle plates. Whilst both make use of the natural properties of the original raw materials when developing the manufacturing techniques and in producing the final product itself, handle plates have a more restricted number of sources available when selecting for greater resilience and the shape and size of the plate itself. Again it is the structure, form and properties of the available raw materials which have been exploited to develop a wide range of tools.

The objects excavated at Midhowe can stand as a good example of Iron Age broch material from the Northern and Western Isles, and areas of Caithness and Sutherland. The techniques of manufacture themselves are exemplary of those from virtually any Iron Age site in Britain, through the use of iron bladed tools and a number of other, simple techniques. What is local to the broch area is the use of cetacean bone in such abundance. On more inland sites, antler would have to have be used more frequently than it would at Midhowe if an equivalent for cetacean bone were being sought.

CHAPTER 8

CNOC SLIGEACH, SOLLAS, NORTH UIST

INTRODUCTION

The Western Isles are rich in the type of Iron Age site known as the 'wheelhouse'. This is a circular stone built structure, the interior wall of which has radial cells all round which themselves focus on a central circular area containing the hearth. Most are not single, isolated structures, but are usually linked to other buildings of various shapes and sizes. A few sites are known from the Northern Isles and the North coast of Scotland, of which those at Jarlshof are probably the most famous (Hamilton 1956, 58-80). The relationship between brochs, wheelhouses and their occupants has long been an area of interest (Lethbridge 1952; MacKie 1965) and it is clear that in terms of technology, there is a great similarity amongst these which also shows as a substantial overlap in categories of objects made.

A large number of sites was investigated early this century by Beveridge (1911) who left useful records, but did not always make clear the extent to which the sites he examined were fully excavated. During the mid-1950's a large number of archaeological sites on the machair areas of the Western Isles were threatened by military developments and test ranges. Sadly, few of these sites have been published, with the exception of remains at A Cheardach Mhor and A Cheardach Bheag (Young & Richardson 1960; Fairhurst 1971) and when the opportunity was given to study the material from the sites at Sollas whilst Finlay (1984) was working on the large faunal assemblage, this site was chosen. This was seen as providing an assemblage from a site within an Iron Age tradition linked to, but following on from, that of the brochs. 175 items were examined, of which 65 were artefacts and 91 were pieces of worked bone or antler, the balance being damaged but unworked. The material falls within a wide range of categories. Working debris is present and some stratigraphic and distributional information about the site available.

SITE LOCATION AND DESCRIPTION

The site is known variously as Cnoc Sligeach ('shelly mound'), Middlequarter, Machair Leathann ('broad plain') and Sollas and comprised a ruined wheelhouse (Sollas A Fig 8.3) and a nearby substantial midden into which had been dug the more complete wheelhouse (Sollas B Fig 8.4). It is situated at NGR NF 801 752 in what is now a hollow within the large coastal machair system of North-West North Uist (Figs 5.1, 8.1, 8.2). The shell sands of this area make rich soil and along the coastal fringe are a large number of settlement sites of all periods, well preserved within the sand dunes. One of the nearest, about 3.5 km to the North-East, is The Udal, a site with evidence of almost continuous settlement from Neolithic times to this century and including several wheelhouses (Crawford 1967-70, 1980, 1981-83, pers comm). When first seen by Beveridge (1911, 121-29), the site, Cnoc Sligeach, was a grass-covered dune, about 2.6 m high and covering an area 100 by 68 m, at one end of which were the eroding deposits of a midden. The site easily filled with wind-blown sand and had been reburied by the time the survey for the Royal Commission Inventory was undertaken (RCAHMS 1928, 89).

Sollas B was cut into the South-West edge of a preexisting mound of midden of about 37 m^2 in extent, which was interleaved with sand lenses. The site comprises a circular building with 13 radial cells around an open central area, which has a hearth and a water tank slightly off centre. Only some of the cell walls ran up to the outer wall and a few of them also had a line of stones defining the edge of the central area. Leading from cell 1 is a short passage which opens out into an oval chamber with its own external entrance. The main entrance to the wheelhouse itself is through cell 3, outside which is a bar-hole and threshold from which runs a funnel-shaped passage or courtyard. This passage was made narrower later in the history of the site. At the top of the walls were a number of cupboard spaces. Two floor levels were recognised in the wheelhouse, separated by a thin lens of sand. Within the central area and cells 129 pits had been dug into the floor, some containing unusual deposits of animal bone e.g. parts of carcasses, whole animals and the cremated remains of a sheep in an urn. An archaeomagnetic date of AD 200 was obtained for the hearth (in litt RJC Atkinson). Beveridge (1911, 123) was wrong in his description of 14 cells. This was probably a mistake caused by the way he had explored the site on two separate occasions resulting in one of the cells being counted twice.

Sollas A lay clear of midden, about 75 m to the West of B and was considerably robbed. It seems to have been a wheelhouse of which only traces of part of the central area, associated cells, storage places and entrances survive. Atkinson identifies 6 periods of construction (A-F) mainly on the basis of changes to the location and form of the entrance passage, but he attributes other deposits and finds simply to an 'earlier' phase (A-C) and a 'later' one (D-F) with some items post-dating the robbing or destruction of the site. It is possible that the midden into which Sollas B was dug had been generated by the occupants of Sollas A and that the latter site was robbed of stone in the building of the former (in litt RJC Atkinson).

EXCAVATION HISTORY

The site was first recorded by Dr Erskine Beveridge (1911, 121-29) in one of a number of volumes which detail those archaeological sites and monuments in which he had been interested and had excavated. Simply because of the shape of the mound and traces of midden, it was realised that it was an underground dwelling. In 1906 cattle succeeded in uncovering four of the cells and these were explored by Beveridge. Although the four cells soon filled again with sand, he later excavated the remaining ones, the central area and the adjoining structures. During this work he must have unknowingly re-excavated one of the previously discovered cells (hence the omission of cell 11 in this discussion). Cell 2 was found to have a storage area which contained some pottery. Cell 6 had three large storage areas and had been paved. Within cell 6 were found limpet shells and pottery. Beveridge cleared out the central area and found the hearth. Annexe A was found to have 13 small niches in it and to be cut into a midden which contained limpet shells, bones and pottery. Beveridge also made preliminary explorations into Sollas A which he was able to confirm as a subterranean structure, but which he found very ruined.

When Atkinson excavated in 1957 he was a lecturer in the University of Edinburgh and undertook the work on behalf of the Ministry of Works in advance of the proposed construction of a guided missiles range on the West coast of the Uists. He left Edinburgh in 1958. He re-excavated Sollas B, examining the floor deposits and pit fills for the first time. He cut trenches into the surrounding midden to sample it and undertook auguring elsewhere within the midden mound. Sollas A and part of the area around it was also excavated in detail. It is the material recovered from Atkinson's excavations which is discussed here. Objects from Sollas B were recorded according to the pit, cell and layer within it in which they were found, or the particular quadrant of the central area. Finds from Sollas A were measured in and noted by layer. After excavation the site was backfilled.

RANGE OF MATERIALS USED

Stone was available from nearby sources and was used for the buildings at Sollas, as well as the hearth and a number of socket stones. Beveridge (1911, 27-28) records the discovery of a some hammerstones and a quern fragment, though the latter may be the upper stone of a rotary quern noted by Atkinson. From Atkinson's excavations there also came two stone spindle whorls.

Both sets of excavations recovered iron slag but no iron objects. Beveridge purchased a bronze pin said to have been found in one of the western chambers and Atkinson found evidence of the production of such items in the form of a fragment of a clay mould for a bronze ring-headed pin and a small crucible which had been used.

Fragments of pottery and the remains of generally plain, almost complete, hand-made vessels were recovered, representing tall urn-like forms similar to those found at Midhowe. There were no loom weights or other such items.

In the range of non-skeletal materials used and the processes in which they were involved, the finds from Sollas provide a close parallel with Midhowe. Stone was important as a building material and in crop processing. There is evidence of iron production and the manufacture of decorative metalwork in bronze, but only items in the latter material survive. There are various containers made from locally produced pottery and evidence for spinning in the form of spindle whorls.

ANIMAL RESOURCES

Finlay (1984, 58-77) examined the faunal material from the excavations at Sollas and other sites in the area. The pit deposits within Sollas B must be set aside for the moment. The animal remains from wheelhouse A, the midden around B and within B were, in order of importance, sheep, cattle and pig, with red deer and cetaceans represented primarily in the form of worked material, and a few horse, dog, seal, bird and fish bones. The sheep were a slim-limbed breed comparable with the modern Shetland, and the cattle were close to the West Highland 'black' cattle. Finlay (1984, 61) suggests that the sheep were kept as breeding stock and for dairy produce and wool. Sexual dimorphism was recognised in the cattle. Only a few pigs are likely to have been kept and the red deer would have been wild. It was possible to suggest the strategy of butchering for both sheep and cattle (Finlay 1984, 72-76).

The deposits within the pits of Sollas B are not of exotic species, but seem to be the remains of joints of meat, parts of animal carcasses or whole carcasses and in one case the remains of a cremated sheep. The majority of the cattle and sheep represented in the pits are adult or under 18 months (Finlay 1984, 70) and the pattern of deposition seems exceptionally varied, there being no consistency in which species or parts of an animal were buried or the extent to which they were burnt or mixed. Atkinson viewed these as being ritual deposits and inferred that the building was the house of a priest or medicine man. Subsequent excavation on a number of other sites (Fairhurst 1971, 80-81; pers comm Ian Armit) suggests that similar deposits of bone within the floors or by the hearth are regularly found in wheelhouses and that Sollas B is not exceptional, though unusual in the quantity of deposits.

Again the parallels with Midhowe are clear and show the exploitation of domestic species as well as the occasional use of the wild creatures of land, shore and sea. Shellfish were also exploited, but the paucity of evidence for fish probably results from the fact that the deposits were not sieved.

UTILISED MATERIALS

Only the bones of land and sea mammals were exploited. Most of the 'worked' material from the site was examined and can be identified as butchering debris, although there is a large amount of antler- and particularly cetacean bone-working debris. At times these form localised deposits which are discussed below. No bird bone objects were found.

RED DEER

Although no bones of red deer were identified within the utilised skeletal materials, it is possible that some of the items included under cattle were actually made from red deer bone. Antler was certainly used and is represented by a range of tools as well as the debris from tool manufacture. Only two of the pieces of antler studied retain the base and both of these are shed. Given such a small number it is unwise to speculate on the relative importance of shed and unshed antler, but the small amount, or even absence, of deer bone from the site implies a reliance on antlers which had been collected.

SHEEP

Most of the identifiable objects are made from the leg bones of sheep, though many of them retain little of the articular ends and attribution to this species is often on the basis of the thickness of the bone. Of identifiable bones, all are adult sheep metapodials apart from one os malleolare (the remnant fibula). The rest are tools made from long segments of compact bone, most of which are also likely to be metapodials. There is a group of points made from rib bones and, given the thinness of the compact layer, these are also likely to have been from those of sheep.

CATTLE

There are no objects which retain the articular ends of cattle bones and so the attribution to cattle is purely based on the thickness of bones and the identification may be equally applicable to some bones of red deer. Apart from part of one scapula, the rest of the objects are made from segments of compact bone.

CETACEAN

Apart from two large cetacean vertebrae, one of which was made into a vessel and the other apparently a vessel in process of manufacture, the cetacean bone used was entirely paddle bone which could not be further attributed to element or species as most of it had been sawn or cut into segments (Pls 8.5, 8.6, 8.7, 8.8, 8.9).

At Sollas there is a heavy reliance on antler and cetacean bone. Apart from these materials which have their own distinctive properties, the species and elements utilised mirror those more generally exploited for food etc., but detailed analysis is hindered because of the removal of diagnostic features. It would seem that the resilience of antler and cetacean bone was being specially selected.

TECHNIQUES OF MANUFACTURE

PRELIMINARY TECHNIQUES

The large quantity of antler- and cetacean bone-working debris identified from the site gives a good indication of the range of preliminary techniques used to produce segments and to make object rough outs. Generally, the base and beam of antlers were <u>chopped</u> into with a number of strokes by a bladed tool and then <u>split</u> across. Sometimes they were chopped around the beam before splitting. Most of the tines and crowns were <u>sawn</u> into on one side only, or all round, so that the compact material was cut completely through, and the cancellous tissue was then simply broken through. For a few of the tines and beams, however, this process is reversed, tines being chopped and split and the beam sawn before splitting. The more regular pattern seems to suggest that the practice was to chop into the thicker beam, but saw off the thinner tines.

Only a few pieces of cetacean bone show signs of chopping (Pl 8.9). Most are segments of the compact area of paddle bones which had been split into long segments by hacking with a large blade, and striking the bone down to split it into pieces rather the way firewood can be split with an axe. A number of chips or flakes from this process were recovered (SS 139-46, 150-51, Pl 8.8). The long segments were then sawn transversely into smaller rectangles (Pl 8.7). Since few objects were found which were made from such pieces of cetacean bone, it is possible that they were being split and sawn for fuel, though this seems a great deal of effort for such a result.

As on the other sites discussed here, animal long bones were split by percussion fracture before being further modified. Most of the points from the site were made from long, thin splinters of bone split from long bones. A few objects show traces of scraping with a metal blade, but since most are the points made from rib bones (SS 3-4, 10, Fig 8.5), this is likely to have been simply the scraping away of periosteum, prior to removal from the carcass.

The main preliminary techniques of manufacture are those which were a natural extension of the butchering process - chopping, splitting, fracturing and scraping, with the addition of sawing.

SECONDARY TECHNIQUES

Once the segments or sections of skeletal material had been prepared, the finer shaping was undertaken. The principal techniques used were chopping and trimming, the former removing small chips from the piece being worked and the latter removing longer, thinner shavings. Most of the antler was worked by this method, presumably after soaking. Broad notches and recesses on a number of antler and cetacean bone objects have been chopped out (e.g. SS 38, 57, 59 Figs 8.7, 8.8).

The fine shaping on the pointed and blunted tools was achieved by trimming (Pl 8.1). Very occasionally the tips of the points were ground or polished, techniques used in the final shaping of the spatulae and spatulate tools (SS 26-29 Fig 8.5, 8.6, Pl 8.2). No pumice was found on the site although there was probably still some available in Iron Age times which had floated across the North Atlantic from Iceland. Otherwise the objects could easily have been shaped by grinding on any of the locally available stones. A few pieces had also been polished and, as suggested in the other case studies, this was probably produced by rubbing with leather and a fine powder abrasive.

Two types of perforation are evident. The antler plates (SS 30-34 Figs 8.6, 8.7) have had their perforations drilled straight through with a metal drill bit, one group being only 2-3 mm in diameter, the others being 4-6 mm. The perforated points (SS 12-14 Fig 8.5) and the sheep metacarpal (SS 39 Fig 8.7) had the holes made by turning the point of a knife on the surface of the bone to produce a sub-oval perforation with a very angled edge. The antler socket (SS 38 Fig 8.7) has a large perforation 27 x 17 mm drilled straight through the beam.

The three antler socketed handles (SS 35-37 Fig 8.7), had the cancellous tissue hollowed out to take the tangs of the bladed tools which were inserted. SS 36 and 37 have circular hollows, but SS 35 has a short circular hollow at one end and a rectangular one at the other end. Some of the cancellous tissue would have been hollowed out before the insertion of a tang and the rest crushed and shaped when the tang itself was inserted.

One of the antler socketed handles has also been grooved or notched at one end (SS 37) and light notching was used on the edge of a small sliver of bone which may have been used as a saw (SS 62 Fig 8.8).

OBJECT CATEGORIES

POINTED TOOLS

All the implements which have sharper, blunt tips have been made in line with the longitudinal orientation of the bone structure, thereby making use of its natural strength in compression in this axis.

POINTS (SS 1-10 Fig 8.5)

Five of the points (SS 2, 4, 7, 8, 9) are made from thin splinters struck from compact bone which have been trimmed and then ground to quite stubby tips. Generally they have a convex section which reflects the origin of the bone used. SS 6 is also from compact bone but its shaft was shouldered before tapering to the circular-sectioned tip. SS 1 is a point made from the shaft of a mature sheep metatarsal, split so as to retain part of the proximal articulation. The other points are made from segments of ribs which have been split in half, through the cancellous tissue, and then trimmed and ground to produce a much less acute tip than the rest of the points from the site. A similar piece was excavated at A Cheardach Mhor (Young & Richardson 1960, 155 Fig 13.34). All have polished areas from use extending about 20-30 mm from the tips and are most likely piercing tools.

LARGE POINT (SS 11 Fig 8.5)

One large and very stout point is made from a segment of scapula, possibly that of cattle, which includes part of the spine. The scapula was split and the point formed by longitudinal grinding.

PERFORATED POINTS (SS 12-15 Fig 8.5)

All four perforated points are pierced at the widest part of the object. In two cases (SS 14, 15) this part is a deliberately made, angular expansion, towards the proximal end of a segment of compact bone, which has an elongated kite shape. Parallels for these were found at wheelhouse sites at Foshigarry, A Cheardach Mhor and Kilpheder (Beveridge & Callander 1931, 334, 366 Fig 19.17-24; Young & Richardson 1960, 147 Fig 7.6-7; Lethbridge 1952 187, 183 Fig 4.5). With SS 12 it is the natural articular end which forms the widest point and in SS 13, a carved section of the compact bone provides a, now broken, rounded head. All were pierced from both sides with the tip of a knife, though the broken perforation of SS 13 has rounded edges. Points similar to SS 12 were found at the broch of Burrian, North Ronaldsay (MacGregor, A 1974, 71, 75 Fig 8.98, 8.100).

POINTS/PINS (SS 16-18 Fig 8.5, Pl 8.1)
There are three points/pins which have been made from trimmed and polished, circular-sectioned splinters of compact bone. One (SS 16) has a chisel-shaped head and is slightly waisted near the tip, apparently as a result of the knife slipping during manufacture. The others have gently tapering sides. These are pieces which have been well-finished all over and as such are different from the points. They may be simple decorative pins but may also be piercing tools.

PEGS (SS 19-21 Fig 8.5)
These are three short pieces of antler which have trimmed edges and bluntish tips. SS 20 has a highly polished tip with a slight waisting just above it. The other two are not polished and may be pegs used in securing handle plates, though they are larger than the example from Midhowe and much larger than the pieces surviving in the plates from Sollas.

BLUNTS (SS 22-25 Figs 8.5, 8.6)
There are two groups of blunt implements. SS 22 and 23 are made from trimmed lengths of compact antler, the former of which has quite straight sides and a flat tip, the latter having convex sides and a rounded tip. SS 24 and 25 are made from split segments of long bone, the latter having a more gouge-like tip. It is unclear how these tools were used, but they may have been small grinders.

SPATULA (SS 26 Fig 8.5)
SS 26 is a broken miniature spatula made from a ground piece of compact bone and reminiscent of cosmetic, toilet and medical equipment from Roman sites.

SPATULATE ?POTTING TOOLS (SS 27-29 Fig 8.6, Pl 8.2)
These three implements have one end ground and polished to a flattened, chisel shape. SS 27 and 29 are made from bone with the

spatulate end being curved and the other end forming a blunt. Their whole surface is smooth. SS 29 curves near the blunt end. SS 28 is made from an antler tine which has had a straight-ended spatula formed on the tine tip. At the thicker end, a notch has been cut at a slight angle to the shaft. All would make effective potting tools. Fairhurst (1971, 100, 101 Fig 10.7) found a tool similar to SS 27 and 29 at A Cheardach Bheag. Such tools make use of the thickness of compact bone which can be ground to a flat surface and a rounded edge.

PEGGED PLATES (SS 30-34; Figs 8.6, 8.7)
Five roughly rectangular, pegged antler plates were found at the site. None seems to have been from a composite comb, but in form they are close to that found at Midhowe. Apart from SS 32, which retains the natural, but worn, convex rubicose surface, all have flattened upper surfaces. SS 30 is the only one to have peg holes in the four corners and a trimmed surface which might be taken for decoration. One of its holes retains a peg. SS 31, 32, 33 and 34 have 3, 4, 2 and 4 holes respectively, all lying more or less in line, SS 32 and 34 having two groups of two holes closely spaced. All the pegs have survived in SS 31 which has two of the holes closer together. The two holes in SS 33 are slightly eccentric, larger than the others and more oval than circular. All the holes were drilled. It is likely that these plates were attached to wooden socketed handles as side plates for tanged iron implements such as knives and daggers. Antler forms a good grip for such a use and makes a very durable handle plate, able to resist the pressures under which it is put.

HANDLES (SS 35-37 Fig 8.7)
All three socketed handles are of antler, a material well suited to the stress to which a handle is subjected. SS 35 has a very smooth surface and is sub-rectangular in section. It was made to take a rectangularly-sectioned tang and the other end is also socketed. It is likely that this took some sort of decorative pommel, perhaps even a peg such as SS 53. This would have given it an appearance similar to SS 37 which is made from a tine and has had the proximal end grooved by sawing round it to give a slightly phallic look.

SS 36 was also made from a tine but is broken and it and SS 37 have quite short, round-sectioned sockets.

SOCKET (SS 38 Fig 8.7)
Made from a section of antler beam near the junction of a tine, this implement was probably the sleeve mounting for a stone or metal blade. One end of the piece shows smoothed compact and cancellous tissue but the other has had the cancellous tissue hollowed out and, later, part of this socket has split away, presumably as a result of damage caused by pressure on the mounted blade. Near the middle of the piece is an oval perforation right through the beam which is at the centre of two rectangular notches cut into the surfaces of the socket. The use of antler sleeves has already been discussed in the section dealing with Skara Brae, but it is worth re-emphasising that this is an excellent material to act as such an intermediate, shock-absorbing material.

PERFORATED BONE (SS 39 Fig 8.7)
This is a sheep metacarpal which has been simply perforated mid-shaft on both sides with the tip of a knife to provide a hole which runs right through the bone. Subsequently one end of the piece was gnawed. Such bones are quite common from sites in the Northern and Western Isles and have been described as bobbins for thread and twine, or snoribens (snorri-bones) - children's toys which are made to whirl round by inserting twine through the hole and making the bone spin one way, and then another by pulling on the twisted twine. Parallels are known from several sites including the wheelhouse at Bac Mhic Connain (Beveridge & Callander 1932, 66, 65 Fig 12), the broch of Gurness (Hedges 1987: II 209, 108 Fig 2,34, cat no 188-90) and Jarlshof (Hamilton 1956 79, 71 Fig 37.6). For such an implement, it is the straightness and symmetry of the metapodial, and the fact that it is hollow, which are the most important features in choosing the raw material.

TURNED OBJECTS (SS 40-52 Figs 8.7, 8.8, Pls 8.3, 8.4)
There are a large number of 'turned objects' from Sollas. Apart from SS 49 (Fig 8.8, Pl 8.4) and 51 (which may be a fragment of SS 49) they are of antler. All show traces of having been fitted into a

socket and turned in a circle and hence their traditional interpretation as 'quern handles' (Lethbridge 1952, 187). A MacGregor (1974, 76), in discussing ones from Burrian, North Ronaldsay is sceptical and additionally mentions their possible use in bow drills. Semenov (1964, 189-91) suggests that similar items were used as thong stretchers, which he had studied, but they are marked in the middle of the bone or antler rather than at the end as is the case with these ones. Few are complete, but it is clear that they are not broken pieces from objects twice the length. Certainly the marks left on the pieces are what one would expect from a rotary quern handle simply inserted directly into a hollow socket and this may well be how some of the larger pieces were used although only one reused rotary quern was found. A similar type of wear pattern would result from their being used as the central spindle or pivot in a rotary quern. It is difficult to view pieces as small as SS 42 (Fig 8.7, Pl 8.3) which is made from an antler tine tip and fitted a hole 13 mm in diameter as being used to turn a quern or set between two stones so perhaps some were inserted into the bases of wooden doors, for example, to act as pivots to enable them to open. There is certainly no room to hold SS 46 (Fig 8.7) and the whole object looks as if it must have been completely inserted into something. That made from cetacean bone (SS 49 Fig 8.8, Pl 8.4)is very large indeed and would have fitted a hole over 40 mm in diameter. SS 47 appears to be in the process of manufacture. Others have been found at the wheelhouse sites of Foshigarry (Beveridge & Callander 1931, 332-33, 330 Fig 13), A Cheardach Mhor (Young & Richardson 1960, 147 Fig 7.13-14; 155 Fig 13.44) and A Cheardach Bheag (Fairhurst 1971, 102, 101 Fig 10.11). Additionally they are known from a souterrain at Galson (Edwards 1924, 201, 200 Fig 9.2) and a number of broch sites including Gurness (Hedges 1987: II, 207-08, 108 Fig 2.34, cat nos 177-82). Since both antler and cetacean bone were used to produce these implements, it seems likely that their stability and resilience were being deliberately selected in preference to the greater brittleness of bone. Shafts of antler and cetacean bone make strong solid handles or pivots in a way that the more compact and hollow long bones do not.

GAMING PIECE/PEG (SS 53 Fig 8.8)

This is a small ball-headed peg which was made from two pieces of antler. The carefully trimmed head has been made from the tip of a tine and inserted into its base is a small pin of antler. It may be a playing piece which was used with a board or in the sand, or perhaps the pommel from a knife handle or other composite implement.

CETACEAN VERTEBRA VESSELS (SS 54-55)

SS 54 is a wall fragment from a large cetacean vertebra vessel. SS 55 is just such a large vertebra which has been used as a cutting block on one side but had attempts to hollow out the cancellous tissue on the other side, with the presumed intention of creating a vessel. The broken vessel has had the spiny processes removed and the cancellous tissue chopped out, leaving a smooth cancellous surface to the interior of the vessel which follows the curves of the vertebra's exterior and is about 9 mm thick. Such vessels have already been discussed from the site at Midhowe and could only have held dry goods.

CETACEAN BONE ?BLANKS (SS 56-59 Fig 8.8, Pl 8.5)

These four objects are all sub-rectangular pieces of cetacean bone which have been shaped, but not into any finished object. SS 56 has a bluntish nose at one end, SS 58 is peg-shaped and SS 57 and 59 have a V-shaped and U-shaped notch respectively cut into the cancellous surface. These would seem to be blanks for objects but there were no finished objects found at the site which would have needed blanks such as these.

POLISHER (SS 60 Fig 8.8, Pl 8.6)

This is a fragment of an antler beam or tine which was broken during excavation or post-excavation but seems to have had a flattened, very heavily polished area which was artificially created.

MISCELLANEOUS OBJECTS (SS 61-65 Figs 8.8, 8.9, 8.10, Pl 8.6)

SS 61 (Fig 8.9, Pl 8.6) is a length of cetacean bone with a rectangular section which had one sawn end, two sawn notches part way down the shaft as if about to be sawn further and split, with traces of a third notch, and an angular, straight blade-like tip which has a very high polish on one side only. It is difficult to be certain whether this is simply a piece of cetacean bone being sawn into segments, but the high polish suggests that this has been used as a peg struck into sand where differential wear has been caused by it being under tension, or whether it might be a beamer or hide cleaning tool.

SS 62 (Fig 8.8) is a thin segment of compact bone which has had one surface notched to form groups of angular teeth which are now very worn down. It may be that this is some form of tally stick or a musical instrument, but if the teeth were notched into a freshly struck bone flake, this would have made an effective saw for animal soft tissue and vegetable products, though it would have blunted quickly.

SS 63 (Fig 8.8) is an elongated segment from a rib which was split in half and had the cancellous tissue ground flat. It has one rounded end and a slight concave notch by its other end. It may have been used in netting or weaving.

SS 64 (Fig 8.9) is a very small rectangular tablet of bone which has been ground all over and whose use is unknown.

SS 65 (Fig 8.10, Pl 8.6) seems to be a stake made from the paddle bone of a whale which has been sawn and trimmed flat at its top, deeply trimmed at one side to make a concave area on the shaft and split to form a point.

WORKED BONE (SS 66-70)

Most of the 'worked bone' is not discussed here since it was kept with the general faunal material and items showing butchery marks and practice. SS 68, however, is the tibia of an immature, perhaps neonatal, ?sheep which has been trimmed all over its surface and has removed most of the natural features of the bone. The rest of the pieces are split bones which have fortuitously pointed parts.

ANTLER-WORKING DEBRIS : BEAM/SKULL/PEDICLE/BURR (SS 71-105)
: TINES AND CROWN (SS 106-124)

There was a large amount of antler-working debris from Sollas available for study since Finlay was able to lay aside all the pieces for viewing. As has been already noted, all the utilised antler which had diagnostic features was from shed antler. Both tines and segments of beam were used to make tools at the site, primarily the turned objects, pegged plates and socketed handles, but also a number of the pegs, blunts and spatulate tools, all of which required a resilient material. Most of the debris, therefore, relates to the releasing of segments of beam and tines for tool production and so there are quite a number of small pieces of beam which have been chopped off, junctions between the beam and tine, and tines of various length. Other than this there are no clear patterns recognisable in the debris, perhaps for the very reason that both the beam and tines were being used.

WORKED CETACEAN BONE/CETACEAN BONE-WORKING DEBRIS (SS 125-156 Pls 8.5, 8.7, 8.8, 8.9)

There was a substantial amount of worked cetacean bone recovered from the midden around Sollas B and a smaller amount found within it. All of it comes from the paddle bones of a large cetacean which had been split open and had the thick compact surface split into long segments and then sawn and split to form rectangles from 27-201 mm in length. These may have been blanks for other implements, although the cetacean implements from the site were made from completely different bones and in a different way (apart for SS 61), or they may have been sawn up to use the fats within the bone as fuel in fires. Along with the rectangular sawn segments are small chips or flakes of cetacean bone which had been chopped off whilst splitting the bones.

UNWORKED MATERIAL (SS 157-175)

For completeness, a list of unworked material which has been examined is included. This ranges from naturally pointed bones which might be mistaken for having been sharpened or used, through pieces of bone which have simply been split, to a number of scapulae which have polished areas and breaks which were originally thought to have been as the result of usage as shovels but which are the result of trampling and erosion.

DISTRIBUTION AND INTERPRETATION

The distribution of material from the site at Sollas can be examined in three main ways. Firstly there is the general distribution of the range of objects i.e. are there more of one class of material from Sollas A than Sollas B; secondly there is the variation through time at Sollas A and in the midden around B; and thirdly there is the distribution within Sollas A and, more importantly, Sollas B which has a well-structured internal space.

In examining the occurrence of the classes of material recognised in the three contexts of Sollas A, the midden around Sollas B and Sollas B itself, it is only the socketed handles, the turned objects and the antler-working debris which have a distribution which extends to all three general contexts. This is a very basic group of material which has as its linking element the use of antler represented both as debris and as objects. As to the rest of the material from the site, although Sollas B had a more diverse range of objects, both Sollas A and B contained similar types in more or less the same proportions apart from the pointed objects. Wheelhouse A has the majority of the perforated points although the angularly-shouldered one from B (SS 15) has an almost exact parallel from the later deposits in A (SS 14). Wheelhouse B has almost a monopoly on the other types of points - small, large and pin-like - with only two simple points coming from the midden around B. The distribution of worked cetacean bone and ?blanks is particularly distinctive since it comes almost exclusively from the midden around Sollas B and primarily one area of it, although there are four pieces from wheelhouse B itself.

There are more objects and object classes from the later phase at Sollas A (Periods D-F) than there are from the earlier one (Period A-C) and it may simply be quantity which accounts for the greater similarity between finds from the later phase of A and those from wheelhouse B. Nevertheless, when individual groups and their distribution are examined, the later ones from A do bear a closer resemblance to those from B than those from the earlier deposits at A.

There are very few implements from the midden around Sollas B and the only real concentration which is notable if that of worked cetacean bone in the upper layers of trench EE, a cutting put down E of the entrance.

Given the ruined state of Sollas A, it is difficult to recognise any patterns in the distributions of objects. The only groupings which are worth noting are the discovery of the two early perforated points (SS 12, 13) close together, the later group comprising a socketed handle and two turned objects (SS 35, 41, 42) and the fact that the later pegged plates (SS 30, 31) and the two pegs (SS 19, 20) were found in the central area.

The distribution of objects at wheelhouse B is more interesting, partly because there are more objects to examine, and partly because the building itself was preserved well enough that objects could be attributed to particular cells or locations within the central area. Given the extent of the central area by comparison with that of the cells there is a surprisingly small number of objects from it and it is unlikely that Beveridge's excavations account for this, since he worked in the cells as well as the central area. There is a concentration of objects (SS 17, 33, 34, 49) and worked material (SS 69, 95, 117, 155) in cell 13 (including two pegged plates which were found in the same layer) and an equivalent one in cell 5 (SS 7, 48, 62; 66, 94, 116), which lies opposite cell 13, both being roughly at right angles to the mid-point between the two entrances and both also containing a turned object, a pointed tool, worked bone and antler. The two cells at right angles to cells 5 and 13 are nos 2 and 9 and the only material found in them was worked cetacean bone (SS 153; 154). There is a concentration of bone points in cell 1 (SS 3, 4, 5) which also gave access to the oval enclosure, and within the South-West quadrant of the central area were the broken cetacean vertebra vessel and the one in process of manufacture (SS 54, 55). Only cell 3 had neither objects made from skeletal materials nor debris and this is probably because it was the main entrance way into the building.

It is not clear exactly how the cells in a wheelhouse were used but it is likely that they acted as sleeping areas, storage areas and working places in addition to the central part of the building. Given this it is interesting to see evidence of simple binary concentrations which seem to coincide with axes of symmetry within the wheelhouse. It is difficult to be sure of the significance of such distributions. Particular object categories are otherwise spread generally throughout the cells and central area, apart from the points in cell 1 and the whale vertebrae in the South-West quadrant noted above.

On a site where pits had been dug into the floor of a building and had animal remains etc. inserted into them, one has to think carefully about the attitudes of its inhabitants to the disposal of refuse, debris and concepts of cleanliness. Debris from manufacture was most often found in the middens and would be expected to be dumped there as refuse. The objects in Wheelhouse A are difficult to associate with the phases of building, because of the demolition of the wheelhouse. In wheelhouse B, however, there were deliberate deposits made within the building at an early stage in its history (the pits), as well as items being found in the cells. At face value, the former are storage pits and burial places, the latter objects left where they were being used, or lost among the straw or heather in the building. What seems to be shown here are variations in the everyday ritual of the wheelhouse users.

CONCLUSION

Many of the conclusions drawn about the assemblage from Midhowe also apply to that from Sollas. The wheelhouses at Sollas seem to form a sequence within themselves (Wheelhouse A - midden around B - Wheelhouse B) and give the impression of a settlement site which may have additionally had important ritual aspects. A range of activities took place at the site - metalworking, animal husbandry, and probably crop processing, but there is no sign of material associated with spinning. The various perforated points may have been related to weaving, netting, or the working of finished textiles or hides.

As at Midhowe, much use was made of heavy-bladed metal tools for the preliminary shaping of objects from skeletal materials, although none survived. Antler and cetacean bone again appear as materials used in similar ways and for objects which require more resilience than bone would give. Only the bones of land and sea mammals were used on the site and it is possible that all the bone tools are made from domesticated species apart from those made from cetacean bone. The latter came from large animals, although the quantity of cetacean bone recovered from the site is only a tiny proportion of what would have been contained within a living individual. No evidence for the use of unshed antler was found, although a small number of deer bones was found in the site deposits.

The range of object categories from the site is in general comparable to that at Midhowe although in their details (e.g. the design of the points) they are distinct. The major difference is the absence of combs and the presence of the 'turned objects' which, as discussed above, are difficult to interpret as a single group because of the variation in size.

Considerable differences can be seen between the sites at Midhowe and Sollas on the one hand, and those at Risga and Skara Brae on the other, in the attitude to what can be done with hard skeletal materials. The role of antler, and to an even greater degree, cetacean bone, on the Iron Age sites is much more important than bone. On all sites, the original shape of bones strongly affects the shape and use of the final objects. At Risga both bone and antler were used as bulk material to make small objects. At Skara Brae, very tight morphological groups of artefacts were consistently made from specific bones, with only the largest long bones and the sources for beads being used as bulk materials. At the Iron Age sites, however, antler and cetacean bone were used as bulk raw material to be shaped with iron bladed tools into a wide range of forms. The iron tools were far more effective and versatile than any stone ones that had come before, and are the reason why antler and cetacean bone could be used in these ways. Whilst the Iron Age approach to bone also utilised its original form, changes were made to the natural shapes, with epiphyses being chopped off and with techniques such as sawing, cutting and chopping.

In terms of the Iron Age occupation of Scotland, the broch and wheelhouse settlements of the Northern and Western Isles provide us with some of the richest evidence we have for the types of buildings people lived in, the way that space was organised, the range of materials and objects they used and the activities they performed. That there is such quality of evidence, derives from the materials used in building (stone) and the conditions of preservation which supported the survival of metal and organic remains which would have decayed under less favourable conditions. The finds made at Midhowe and Sollas are good 'typical' examples of the range of objects and materials found at broch and wheelhouse settlements and can be seen as of general importance for those northern and western coastal sites.

Comparisons can be made between the material culture of these sites and other contemporary settlements in Scotland from which we can identify some artefact groups represented across the country - long-handled combs, points, spatulae, handles etc. The techniques of manufacture recognised at at Midhowe and Sollas are the same as those at these other sites. There will have been differences in the availability of raw materials such as cetacean bone, which is likely always to have been only a coastal resource. Red deer bone, antler and the bones of most of the domesticated species seem to have been available across the country. Thus the two Iron Age sites studied here have both general and more local applicability.

CHAPTER 9
CONCLUSION

The intention of this thesis was to examine the technology and utilisation of hard skeletal tissues in prehistoric Scotland. Given the potential sources of information it was felt necessary to use objects which had well-preserved marks of manufacture and traces of wear and which came from sites of importance for these periods. The availability of information regarding the two-dimensional distribution of the finds and any stratigraphy present on the site was considered an advantage. As a result the four sites examined here were chosen - Risga, Skara Brae, Midhowe broch, and the wheelhouse sites at Sollas. Each had well-preserved material in some quantity and was a site of importance for its own period. It was considered that generalisations made about technology and utilisation on these sites might form the foundation for general statements about the use of materials within the periods during which they were occupied and provide a basis for future work on isolated finds, ones deposited in burials and those from less secure contexts. The more detailed observations from the individual sites also raise questions of significance on a more local scale.

As a preliminary to studying the objects themselves, it was found necessary to establish details of the structure and properties of bone, antler, tooth and horn which might affect the way they reacted during working and so a biomechanical and materials science approach was taken in order to understand why the tissues developed as they did and what features might be advantageous for a craftworker. Comparison was made with other studies and some experiment undertaken in order to gain a first-hand feeling for the materials and the way they react.

Hard skeletal tissue is brittle and can be fractured, as well as cut and abraded by a range of techniques. Bone in particular has a very complex, multilevel structure, with a number of overt structural orientations which mostly run along the long axis of the bone, but some of which are concentric to the bone and osteones within it. These orientations determine the particular breakage pattern seen in brittle fracture and flaking techniques of modification. Whether a long bone is split simply to make marrow available, or to provide further raw materials for object manufacture, its shape and structure, and the angle and strength of the blow struck, directly affect the size and type of breakage which takes place. It is possible to identify broad approaches to the butchering of animals, and the fracturing of their bones, by recording repeated points of breakage. The effectiveness of cutting, sawing, chopping scraping and abrading techniques are also determined by the properties of the bone being worked and of the tools being used to work it. These are techniques which remove specific parts of a bone, rather than inducing a dynamic fracture. In all techniques, and for most objects, however, there is a recognition of this natural 'grain' in the bone and its resistance to stress in the longitudinal axis is exploited.

Solid compact bone formed an important raw material for tool manufacture. Antler and cetacean bone have the same components as bone, but because of differences in structure, they are more resilient than it and seem to have been used for a range of objects which had to resist shock and stress. They also have a natural grain which was exploited. What made most teeth an attractive source for objects was the combination in colour and texture of enamel, dentine and cementum, as well as the polish which dentine can take, rather than their combined brittle nature. For some implements no raw material preference was seen (e.g. the bevel-ended tools at Risga in bone, antler and stone) whereas others were made from sources chosen for their natural properties (e.g. combs of antler and cetacean bone, handles and sleeves of antler etc.).

The skeletal finds from each site were studied in detail, records being taken of each one. If the rest of the faunal assemblage survived, it was examined to see whether marks of butchering or splitting survived. The site history and the role of other materials was assessed. In studying the skeletal assemblage, general statements were made about the species and parts utilised by comparison with the range of species represented on site in other ways, in order to establish the processes of selection.

The range of species available to the Mesolithic settlers on Risga was, understandably, more restricted than that for the later communities with their domesticated animals. Since bone working is a subtractive process, modification of a bone to form a tool cannot produce a final object larger than the original bone, unless composite objects are being made. Equally, the shape of particular bones makes them suitable as sources of raw material for some implements more than others. Thus, in making a tool of a given shape and size, there will be a selection of possible sources which will sometimes be restricted to a single bone (e.g. scapula for shovels), and sometimes available from a much wider range (e.g. simple points from most long bones). At such sites as Skara Brae, there is a very strong correlation between animal and bone origin and the final tool form. At Risga, and to a greater degree at the Iron Age sites, there is more freedom in the way the sources are used. This relates in part to the techniques and tools of manufacture, and partly to the cultural and social context in which objects were being made and used.

The range of techniques of manufacture was identified and ordered into the sequences in which they were used. The objects themselves were placed into categories on the basis of raw material, morphology and to a certain extent function. These groups were then examined to see the extent of internal variation. Distributions of particular finds and concentrations within each site were identified and their significance discussed. Each site study is supported by a summary catalogue of the objects examined.

Detailed study was undertaken of techniques of manufacture, and an attempt made to distinguish the wear patterns left by utilisation. This was essential to interpreting the history of individual objects and enabled sequences of raw material acquisition, manufacture, use, breakage and disposal to be established. Experimental work helped set parameters for this and showed the distinctions between fracture and other techniques of manufacture. The former tends to be less predictable in its results than chopping, but was, nonetheless, an important preliminary shaping technique during the periods discussed. Variations and similarities in techniques of manufacture were noted within object classes. For most groups, it was possible to identify to what extent object form resulted from the shape of the original bone, and from the manufacturing techniques employed.

The nature of the objects found on an archaeological site will be determined by the activities taking place at that site and the practices of the people inhabiting it in relation to to tool use, activity areas, cleanliness and disposal of debris. It is untenable that these are universal constants and they are likely to have varied considerably through time and in different places. As a result, simple comparisons between Risga and Skara Brae, or Skara Brae and Midhowe, would be facile and could not compare like with like. What is suggested here is that to begin to understand one element of material culture on an archaeological site, one must appreciate what that site is about and how much different materials and activities interrelate. Though such an understanding is of importance only for that single site, it provides analogies for, and poses questions about, the interpretation of contemporary sites and those of other periods. For example, some comparison can be made between Midhowe and Sollas, being sites roughly contemporary with each other, and deriving form broadly the same cultural tradition. The techniques of manufacture on these two sites are certainly very close, as are some of the object categories, but there are enough dissimilarities in the skeletal assemblage, and particularly in the use of space created in the broch and wheelhouse, to show that there are significant differences between the sites and the way their inhabitants lived.

With a change in the scale of study, comes a change in the wider significance of the information. The discussion of bone and antler as raw materials is universally applicable. The techniques of manufacture, identified in the sites of each period, are broadly transferable to most other contemporary or near-contemporary sites. The level of detailed examination of raw materials and of objects made on a particular site, has much more local significance to areas with access to a similar range of resources and at which equivalent activities took place. It is in this interrelationship of material use, actions and tasks performed, use of space, attitude to resources and the organisation of activities, roles and society, that one can define a particular culture and its nearness or distance to those seen in other places and times. Bone, antler, tooth and horn are one small element in such a matrix.

The details of the utilisation of materials on each site have been discussed in chapters dealing with the individual sites, but it is worth emphasising some of the more general, technical conclusions which can be drawn. No evidence was found for the use of horn, either in the form of finished objects or suitably cut horn cores. Horn was, however, being used during the period as demonstrated by a horn ladle found with a beaker at Broomend of Crichie, Aberdeenshire and its use for dagger hilts such as that from Ashgrove, Methilhill, Fife (Clarke et al. 1985, 223; Henshall 1964, 170, 176-77). The animals whose skeletons are utilised for tool manufacture are generally those which would also be kept or hunted for meat and other animal products. The likely exceptions are large cetaceans which were probably washed up on the beaches rather than hunted, sea birds, some of which may have had bones removed from dead individuals washed up on the sea shore and antler, which seems to have been collected in large proportions when shed in the spring. Objects are made from the skeletal element which most resembles the artefact to be made, taking into account the differing properties of antler, cancellous bone and compact bone. Impact fracture is one of the most important preliminary techniques of manufacture irrespective of the range of blades, knives etc. available and the materials of which they are made. Blanks, rough outs or preforms are usually produced before final shaping and trimming takes place. The use of bladed tools of metal greatly increased the facility with which skeletal materials can be worked since large chopping and slicing strokes are possible which rapidly shape pieces of bone and antler in ways that are impossible with lithic tools and grinding.

Some object categories are very tightly defined, there being a strict 'recipe' for the production of objects within them and at Skara Brae virtually all the objects fit into clearly defined categories. At the other sites there is a core of objects which are easy to categorise but a much larger number than at Skara Brae of pieces which are unique or less rigidly defined. The only real areas of overlap between materials are at Skara Brae where bone, tooth and stone are used to make beads and small vertebrae and stone dishes are used for holding colouring material; and at Midhowe and Sollas where decorative bone and bronze pins were produced and probably also ones of iron. Cetacean vertebra vessels were also used at these three sites in addition to pottery. There may have been some further overlap with composite objects such as flint-barbed points of which the organic components have not survived, but this is impossible to assess.

The information about the skeletal materials from each site must be seen as only one component in the range of materials exploited and in the types of objects made. An attempt has been made to link the artefacts studied here with the rest of the materials by studying them in terms of the sequence from raw material acquisition to manufacture and discard, and examining the relationship between tools of manufacture and tools made.

The interpretation of patterns of manufacture, utilisation and of objects deposited within archaeological layers should take note of the active role of material culture which both structures and is structured by social practice. Objects are not simply the result of actions but integral to them. In this thesis have been combined a number of approaches; a developing understanding of the role of material culture, the detailed analysis of objects and debris in terms of choices within a range of technology and utilisation and the study of distributions. Together the approaches allow the development of explanations which begin to address questions about the choices made in past societies and the range of values they had.