MIDDENING IN THE OUTER HEBRIDES: AN ETHNOARCHAEOLOGICAL INVESTIGATION

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Abstract

This thesis comprises two complementary parts: an investigation, using interviews and published accounts, of how and why nutrients are recycled in a 'traditional' farming economy; and an ethnoarchaeological analysis of samples from an abandoned farmstead to identify potential traces of recycling. The Uists and Benbecula in the Outer Hebrides were selected for fieldwork because local conditions favoured intensive recycling in the recent past, farmers with experience of such practices are still available for interview, and surviving farmers can identify functional areas on abandoned farmsteads.

Interviews and published sources emphasise the importance of recycling in maintaining the fertility of cultivated blacklands and peatlands and in enhancing the fertility, stability and water-retentiveness of cultivated machair. The use of nutrients reflects their intrinsic properties, their availability and the characteristics of different land types. For example, dung is preferentially applied to blackland and staple grain crops, seaweed to machair and fodder crops. Dung and seaweed are complementary in availability: dung from overwintering livestock is subject to the same constraints as arable farming, while seaweed is most abundant in stormy winters, a slack time for farmers.

Samples from different functional areas within an abandoned farmstead were analysed for biological, physical and chemical composition. Functional areas can be distinguished using the variables measured. This results from, and allows the tracing of, the recycling of resources within the farmstead, from the barn and kiln to the byre, thence to the midden and finally to the vegetable plot.

In conclusion, archaeological implications are briefly explored for the Outer Hebrides. Intensive recycling may have been less necessary and the accumulation of dung less difficult in prehistory, if climate was warmer, soils more fertile, population density lower and society less inegalitarian. Iron age 'midden' sites with deep organic dumps may be evidence that recycling was indeed less intensive.

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CHAPTER ONE

INTRODUCTION

1.1 Occupation of Marginal Areas

Archaeological and historical evidence is available to support the long term occupation by agricultural communities of remote and marginal areas in the Highlands and Islands of Scotland, despite the climatic and physical limitations imposed on agricultural productivity and the consequent effects on the social and economic development of the resident communities.

The available evidence would suggest the inception of farming at approximately 3,000 to 3,500 B.C. in Scotland, during the climatic optimum of the present interglacial and after a long period of environmental improvement which included the growth of forest and the associated development of fertile soils (Barber, 1985). The new agricultural communities slowly absorbed the existing hunter-gatherer populations and practised cultivation based on the production of barley with some wheat (Boyd, 1988; Greig, 1991; Fairweather and Ralston, 1993). Towards the end of the Neolithic period, however, average temperatures began to fall and the level of rainfall increased, which initiated a steady deterioration in climatic conditions from the beginning of the Bronze Age, at *ca.* 2,000 B.C. (Bennett *et al.* 1990).

The cold, wet conditions that prevailed were directly detrimental to agriculture due to the shorter average growing season and the reduced altitude at which cultivation is viable, whilst the increase in precipitation caused acidification and podzolisation of the soils and accelerated the growth of peat. As a result, once suitable arable land was lost and the regeneration of woodland ceased (Barber, 1985). The problem of land limitation was compounded in some areas, in particular the Outer Hebrides, by the encroachment of sand along the west coast, due to the destabilisation of existing sand systems, together with fluctuations in sea level (Ritchie, 1979; Ritchie and Whittington, 1994). The environmental changes were paralleled by a significant shift in the pattern of subsistence, whereby cultivation was dominated by the production of the more durable and tolerant barley and wheat was rare or absent (Boyd, 1988; Greig, 1991). Barley has remained dominant in the Highlands and Islands throughout the subsequent periods of settlement, despite several attempts to reintroduce wheat, which reflects the same restrictions on cultivation, due to similar climatic conditions and the continued marginality of these areas.

Despite the environmental factors challenging the feasibility of agriculture, however, the evidence for cultivation since the beginning of the climatic deterioration reflects the success of strategic agricultural adaptations. The viability of agriculture depended on the evolution of strategies that were able to lessen the risks imposed on crop production by the unyielding environment and which involved the most efficient use of the available resources.

> *"the basic essential was the way in which the arable, producing grain, was integrated with the pasture, producing grass to feed stock, in relation to the general milieu, and to the size of the population."*
>
> (Fenton, 1976 p.1)

1.2 Agricultural Viability and Efficient Energy Flow

Traditional agricultural techniques commonly persisted in the marginal areas of the Highlands and Islands of Scotland throughout the documented stages of agricultural improvement and the influential episodes of enforced land re-organisation. Historically, critics often viewed the traditional systems as primitive and underdeveloped because of the simplicity of the agricultural techniques and equipment used, yet the viability of these systems was frequently judged on the basis of successful lowland agricultural practices without full consideration of the environmental constraints imposed by the marginality of the area. Consequently, the continued use of traditional methods was usually equated with ignorance of the latest agricultural innovations and any notion of positive selection, based on the most suitable choice, was rarely considered (Fenton, 1976; Dodgshon, 1992). The traditional agricultural systems were, however, the long evolved response to environmental circumstances and represented a balance between the productivity limits of the available resources and the requirements of the local population (Fenton, 1987).

Efficient resource management is an essential part of maintaining equilibrium in the traditional agricultural systems of marginal areas, especially in respect of the potential limitations imposed by resource availability, which necessitates the economic re-use of materials and their by-products. By maximising the utilisation of resources, valuable materials are retained within the system and, in turn, labour investment is minimised. This phenomenon is demonstrated by the use of plant derived materials as fertiliser for land rejuvenation, where the nutrients contained in plant by-products are eventually returned to the depleted arable and grazing land in order to maintain the optimum productivity levels.

In studies of traditional agricultural communities in the Northern Isles in Scotland, Fenton (1978a; 1978b; 1986) identified a diversity of resources used as fertiliser. A range of treatments is associated with the different resources, including the direct application of some material types such as marl, where no preparation is required, to the deliberate decomposition of other materials in the form of managed compost heaps or 'middens'. The production of compost involves the regular mixing of the organic materials to introduce oxygen and encourage fermentation in order to convert nutrients to a form available to plants (Darling, 1945; Fenton, 1981).

The traditional middens found in the Northern Isles can be variously composed of dung, straw, turf, seaweed, ash etc., depending on the availability of local resources and the specific cultivation requirements. Commonly, plant by-products, such as dung and ash, are supplemented with purposefully collected materials, such as earth, turf and seaweed, in order to draw out the supply of domestically produced resources and increase the total quantity of fertiliser.

The midden, therefore, represents an accumulation point, at which the latent energy in valuable resources is converted into more available forms and finally channelled into the production of crops and stock, thereby perpetuating the survival of the system. Due to the continuous process of formation and usage, the midden is a transitory feature, removed from the farmstead and utilized at regular intervals on the arable land.

1.3 Archaeological Midden Sites

Many archaeological sites have been discovered, in the machair deposits of the Outer Hebrides, which have traditionally and indiscriminately been described as 'middens', or 'kitchen middens'. Within this general category, two distinct forms of site have been defined by Barber (unpublished). Deep stratified organic deposits, which possibly incorporate many artefactual and structural remains, are commonly exposed in the coastal section of the eroding machair, as at the Udal in North Uist (Crawford, 1977), whilst seemingly shallow, but extensive, organic deposits may be exposed horizontally, as at Rosinish (Shepherd, 1976), where the deposits contain pottery and evidence of cultivation. These sites can range in date from the Neolithic to the Iron Age, as demonstrated for example by the structures discovered at the Udal, but most are confined to the Iron Age.

The description 'midden' is, however, misleading with regard to the interpretation of the past function of these sites. It is possible that one or a combination of functions may be represented by these predominantly organic deposits. They may be: (1) true farmyard middens, composed purely of byre and other organic waste; (2) domestic refuse heaps or general settlement debris, which could contain both domestic and byre waste; or (3) the remains of man-made cultivation surfaces such as plaggan soils, which result from the annual spread of organic waste and may include any combination of the different refuse types (Barber, unpublished).

Distinguishing the true nature of the archaeological sites may be possible on the basis of the artefactual remains. For example, the *in situ* farmyard midden is less likely to contain settlement debris and structures than the domestic refuse heap, and a cultivation surface would in theory consist of alternating layers of plough marks and contain no structures. Interpretational problems might arise, however, due to possible overlap between the deposit types associated with different functions. If, for example, settlement structures are not discovered, due to the quantity of over-burden, the nature of excavation or the extent of erosion, the distinction between the different waste deposits may be less clear, particularly if some domestic refuse is also contained in the farmyard midden. Similarly, if plough marks are absent or their presence ambiguous, recognition of a cultivation surface may be difficult, especially if settlement debris has been introduced with fertilizer in the form of the farmyard midden or domestic refuse.

The distinction between the two refuse types may only be apparent if selective deposition produces recognisable differences in the distribution of remains. For example, the quantity and range of material is likely to be greater in the refuse deposits in and around a settlement than in the farmyard midden or cultivation soil.

Environmental evidence represents a potentially valuable source of data to supplement the artefactual remains and clarify the distinctions between deposit types. For example, botanical, faunal, molluscan, phytolith and pollen remains have been retrieved from the Iron Age sites of Hornish Point and Baleshare on the Outer Hebrides. Inter- and intra- site differences in environmental evidence have been tentatively interpreted but the lack of modern analogue material from comparable agricultural and settlement deposits, particularly farmyard middens, has hindered the identification of specific deposit types. The absence of relevant, comparative data imposes severe limitations on the understanding of site formation processes and, in turn, the interpretative potential of the archaeological evidence.

There is a need to trace the pathways of materials in the modern context to identify unique signatures associated with the function of different areas in and around the settlement. Traditional agricultural practices are still used in many places on the Outer Hebrides, which provides the opportunity to investigate aspects of the farming strategies evolved in a marginal area.

1.4 Oral History

For this thesis, two parallel methods were employed to investigate the nature of agricultural strategies in marginal areas. Descriptive and analytical information are required to determine the nature of resource management, model the pathways of material by-products in relation to resource utilisation and provide an analogous data base for identification and improved interpretation of archaeological deposits.

As the first part of this research, information regarding traditional agricultural practices in the Outer Hebrides was compiled by reference to historical and contemporary literature and through the collection of ethnographic data gained from contemporary Hebridean residents, particularly farmers, in order to establish the nature of resource management specific to this area in the present day and recent past. Investigation of the resource availability, especially the identification of predominant limiting factors, was necessary in order to evaluate the efficiency and adaptability of particular agricultural strategies. By comparison with other marginal areas, the degree of specificity of the local strategies may be determined and, in turn, evaluated with reference to environmental similarities and differences.

Details were also collected regarding the use and disposal of material resources in relation to specific activities conducted at particular locations within a traditional agricultural farmstead. A record of such inputs and outputs provides the basis on which to model the movement of material types and differences in soil properties around a typical agricultural system.

1.5 Analytical Techniques

To complement the ethnographic information, contribute to the model of material movement and identify taphonomic processes, information was required regarding the biological, physical and chemical composition of deposits which represent known activities. Such information provides a framework of analogous data, with which to compare the archaeological deposits and elucidate the nature of site formation.

The formation and composition of middens and refuse heaps, as focal points for the disposal and redistribution of material by-products, required particular attention in order to evaluate the importance of their role in efficient resource management, as indicated in the ethnographic literature regarding other marginal areas. Precise compositional details of different refuse types were essential in order to differentiate between archaeological refuse deposits and distinguish their associated functions. Furthermore, compositional details of the refuse deposits potentially provide a means of identifying land use strategies through the investigation of the qualitative and quantitative application of fertiliser to farm land.

Material types and soil properties were selected for investigation on the basis of their long term viability, cost-effectiveness and ability to complement one another. A range of analytical techniques was considered including the study of material remains commonly used in palaeo-environmental or economic reconstruction and pedological techniques for sediment analysis.

1.5.1 Macroscopic Evidence

Cultivated plants, such as cereal crops, are brought intentionally to areas of habitation whereas wild plants can be brought onto a site deliberately, as food or fuel, or incidentally as crop contaminants etc. Plant remains may be preserved by a number of different processes such as charring, waterlogging, mineralization or desiccation. Charring is the predominant means of preservation, owing to the common use of fire in domestic situations, and charred remains may result from deliberate contact with fire (e.g. due to fuel combustion and waste disposal) or accidental contact (e.g. due to spillage during crop processing and cooking or due to destruction from uncontrolled fire). Cereal grains may indicate parching or food preparation whereas straw, chaff and weed seeds may represent the by-products from crop processing which can be used for fodder (Hillman, 1981; 1984; Jones 1984). Differential preservation of grain and chaff, however, may influence the proportions of plant components, grain surviving better than chaff or straw (Boardman and Jones, 1990).

The use of peat and turf for fuel may be indicated by the presence of charred wild plants (especially seeds) indicative of the habitats from which they derive, though the accidental combustion of material used for construction, bedding, rope etc. would be difficult to distinguish. Furthermore, the preservation of seeds during combustion of these traditional fuels may be poor (McLaughlin, 1990). Nevertheless, differences between 'functional areas' in and around settlements may be reflected in variations in the quantity and type of plant remains.

Animal bones may provide information regarding the strategies of animal husbandry, based on the age and sex of the species represented. The body parts present, the evidence for butchery, burning, gnawing and degree of fragmentation may provide details regarding the use and consumption of animals and the disposal of associated by-products. Variations in the quantity and type of faunal remains may, therefore, enable functional areas to be distinguished. For example a large quantity of cut, burnt and gnawed bone may represent food waste in association with domestic refuse. The reuse/reworking of deposits, post depositional activity and preservation bias impose some limitations on the interpretative potential of faunal analysis.

Molluscs are good indicators of environmental conditions due to the specific habitat preferences of many species. The abundance and distribution of land snails is largely dependent on factors such as climate, pedology, vegetation cover and exposure, which facilitates reconstruction of the past climatic and vegetation changes and, on a smaller scale, the nature of the local environment. The recognition and interpretation of distinct micro-environments is therefore possible on the basis of the species composition. Marine molluscs may provide useful information regarding the disposal of food remains or indirect evidence of the use of seaweed or driftwood. Mollusc preservation is limited to neutral and alkaline conditions due to the calcium based composition of the shell. Despite these limitations, however, molluscs represent valuable indicators for distinguishing functional areas.

Coleoptera (the beetles) represent the largest order of insects. Remains of beetle exoskeletons survive in conditions where decay has been inhibited, especially in waterlogged deposits. Beetle remains can provide valuable information for use in environmental reconstruction, both regional and local, due to the adaptation of many species to narrow habitat niches. Analysis of modern analogue faunas has also been conducted, which examines the faunas associated with floor and roof materials in traditional buildings on the Outer Hebrides (Smith, 1988).

1.5.2 Microscopic Evidence

Pollen analysis is one of the most important techniques for the reconstruction of the regional and local environments (Moore *et al.*, 1991). Pollen is generally produced in abundance and, despite the differential rate of production between species, differential deposition and differential preservation, it still provides useful information. In the farmyard, pollen may be used to identify distinctive (especially imported) plant materials and, in turn, may help to distinguish different functional areas, for example areas of hay or peat storage.

Phytoliths are formed within many plants by the intra- and extra-cellular deposition of silica. The internal shapes of the cells are replicated, either fully or partially depending on the stage of silification, to produce a range of phytolith morphotypes. Phytoliths are produced in quantity by many families of higher plants and display great resilience to high temperatures and long term durability in a wide range of soil conditions. Phytoliths, unlike seeds and pollen, are not species specific but the analysis of phytolith suites has provided a means of distinguishing a wide range of taxa and material types (e.g. Pearsall, 1982; Piperno, 1988; Powers *et al.*, 1989). Functional areas may potentially be differentiated on the basis of phytolith abundance, indicating a concentration of plant matter (Gould *et al.*, 1979).

The rate and mechanism of silica deposition within the plant cells directly affect the quantity and type of phytoliths produced and are influenced by many environmental factors including the availability of silica in the soil and the degree to which it dissolves (Sangster and Hodson, 1986; Piperno, 1988). This introduces a potential bias into the use of phytolith abundance and morphotype frequency. The considerable advantage of durability in a wide range of conditions, however, outweighs the problems of species non-specificity and the variable degree of silicification.

Diatoms are unicellular microscopic algae which occur in abundance in a wide range of aquatic habitats, including marine, brackish and freshwater environments, and in some terrestrial habitats. The silica valves surrounding each organism survive decay but are difficult to identify (Battarbee, 1986). Diatoms are good indicators of water condition and may provide information regarding the extent of a waterbody, and the levels of salinity, acidity etc. (Battarbee, 1986). Diatoms may potentially be used to distinguish materials from distinctive habitats, such as seaweed, which may in turn provide the basis on which to differentiate between functional areas.

1.5.3 Physical Soil Properties

Particle size analysis provides primary information on the physical properties of the soil and provides the basis for assigning each soil to a textural class. It is particularly useful in the examination of deposits that appear relatively homogenous after other characteristics have been obscured. Distinct textural characteristics may be associated with different depositional environments and, therefore, analysis of particle distribution may indicate the sedimentary/pedological origin of deposits which may, consequently, enable a specific activity to be inferred.

Micromorphology involves the microscopic study of soils in thin section in order to analyse the nature and organisation of individual particles *in situ* within a deposit. This facilitates the examination of small structural features and soil components which may reflect the operative processes that contributed to the formation of the deposit, i.e.. sedimentary, pedological and anthropogenic processes (e.g. Courty *et al.*, 1989). The interpretative potential is based on the recognition of general pedogenic processes (natural) from specific non-pedogenic processes (anthropogenic), with further potential for identification of particular activities associated with anthropogenic disturbance through the use of experimental data and modern analogues. The accumulation of data using thin section analysis, from modern comparative contexts such as those associated with cultivation (e.g. Jongerius, 1970; 1983; Grieve, 1980), trampling (Courty *et al.*, 1989) and traditional activities within abandoned farms (Quine, 1986; Davidson *et al.* 1992), has provided invaluable modern analogue material and increased the potential applicability of micromorphology as an interpretative technique in archaeology .

Certain pedogenic processes can serve to enhance the magnetic susceptibility (response to a magnetic field) of the surface soils, due to the conversion of non-ferrimagnetic iron to a ferrimagnetic form (Thompson and Oldfield, 1986). Such enhancement can occur in almost every soil type and under most climatic conditions. The increase in surface susceptibility may be less apparent if the parent rock is strongly ferrimagnetic, and under conditions of waterlogging or intense leaching the surface enhancement process may also be halted or even reversed (Gale and Hoare, 1991; Thompson and Oldfield, 1986). The magnetic susceptibility of ground surface horizons can be particularly enhanced by fire (especially when the burning occurs in reducing conditions) and possibly by trampling (Allen and Macphail, 1985; 1987). This indicates the potential of magnetic susceptibility for the identification of anthropogenic activities. In conjunction with other soil properties the level of magnetic susceptibility may indicate the derivation of the deposit, distinguish associated activities and, therefore, differentiate between functional areas.

1.5.4 Chemical Soil Properties

Soil pH may reflect the environments from which particular material types are derived, for example acid peat from moorland and alkaline shell sand from beach or dune. On this basis, pH provides the potential for differentiating between functional areas receiving different imported materials. The transience of pH, however, imposes limitations on the reliability of direct interpretations regarding anthropogenic activity. pH is, nevertheless, an important indicator of pedogenic processes and conditions and is particularly valuable for the interpretation of many other material types and soil properties.

The organic content of a deposit is dependent on both the quantity of organic matter deposited and also the rate and nature of decomposition, which in turn are dependent on more general environmental conditions. Total organic content also provides important information for the basic characterisation of soils and the interpretation of other soil properties, such as the levels of nitrogen and phosphorus. On this basis a distinction between natural and anthropogenic deposits may be possible, and potentially, differences between specific activity areas may be reflected (e.g. Griffith, 1981). For example, it may be possible to distinguish the deliberate accumulation of organic rich material, in association with waste disposal, from the deliberate depletion of organic matter and addition of inorganic materials in association with floor construction.

Nitrogen is the second most important component of soil organic matter (after carbon) and represents an important macro-nutrient necessary for plant growth. The relative proportions of nitrogen and carbon have been used to describe the organic matter status of ancient deposits, and locate site boundaries (Cook and Heizer, 1965). The success of these investigations was based on the overall enhancement and detectability of nitrogen resulting from the accumulation of very high quantities of nitrogenous materials in association with anthropogenic activities. In most cases, however, the mobility of nitrogen imposes severe constraints on the applicability of the analysis.

Phosphorus is obtained from the native organic and inorganic compounds present in the soil, and through the addition of plant, animal and human waste. The soluble sources of phosphorus added to the soil, such as manure, become less available through chemical fixation, and eventually become highly insoluble (Brady, 1984). The amount of phosphorus retained within the soil is dependent on soil pH, moisture content, temperature and the concentration of minerals, particularly iron, aluminium and calcium, the availability of which, in turn, is influenced by pH. Despite the potential limitations, measures of phosphorus still provide a valuable means with which to distinguish the areas of organic matter, accumulated in association with anthropogenic activity. The level of soil phosphorus can be enhanced through food storage, processing and waste disposal, and the accumulation of manure. Phosphorus analysis has been used to locate and define settlements (e.g. Provan, 1971; Hammond, 1983; Cavanagh *et al.*, 1988) and less commonly for the examination of intra-site variability (Conway, 1983).

The calcium, magnesium and potassium present in most soils is derived from the parent material. Calcium also occurs in many waste products and has been used successfully as a direct indicator of anthropogenic activity and for site delimitation purposes (Ottaway and Ottaway, 1982; Konrad *et al.*, 1983). Calcium is also useful in the interpretation of phosphorus concentrations due to its importance in fixing phosphorus as insoluble tricalcium phosphates etc. The information obtained by calcium analysis, however, parallels much of information obtained from the analysis of phosphorus and overall the interpretative potential is little improved through combined application. Furthermore, the reliability of calcium distribution decreases with time due to the losses caused by high mobility. Due to the large proportions of magnesium in wood ash and bone, this element has been investigated as a potential means of differentiating anthropogenic activities but few investigations have produced consistently successful results, which may reflect the problem of high mobility and loss. Due to the solubility of both calcium and magnesium in soils with low pH, these elements may prove of limited use. High concentrations of potassium may indicate food waste and burning (Tarrant, 1956; Scotter, 1963), yet the use of potassium analysis for the purpose of site delimitation is uncommon and the success of such analyses is inconsistent (Lutz, 1951; Griffith, 1980). The infrequent analysis of potassium distribution may reflect the similarity to phosphorus analysis in terms of the interpretative potential of the available information and problems caused by the high mobility of potassium in the soil.

The analysis of trace element concentrations (e.g. iron, aluminium, manganese) can potentially provide additional information for the interpretation of other soil properties and may help distinguish between natural and anthropogenic processes. Many trace elements are contained within animal and plant materials, and the differences in concentration may enable identification of different deposit types (Lambert *et al.*, 1979; Rheingold *et al.*, 1983; Ottaway and Matthews, 1988). Most trace elements are very soluble under acid soil conditions whereas fixation in alkaline soils may cause deficiencies of some elements, particularly iron. The high level of mobility also lessens the reliability of these elements as long term indicators of past processes.

Stable carbon isotope analysis (Simpson, 1985) has demonstrated great potential for the identification of different organic materials, such as shell sand, marine materials (probably seaweed), peat ash and manure. On this basis, the various contributions of different material types to the composition of plaggan soils and farm middens in Orkney have been identified (Simpson, 1985; Davidson *et al.* 1986). Further investigation is required, however, to assess the reliability of this costly technique. Potential limitations include the uncertain effects of organic matter decomposition, the processes of which may affect isotope fractionation. The combination of materials of mixed origin may also cause the effects of individual materials, such as marine inputs, to be obscured. If different material types can be characterized reliably, however, the technique may provide a valuable means of distinguishing different activity areas.

1.6 Thesis Structure

In chapter two, details obtained from documentary sources regarding traditional agriculture in the Highlands and Islands of Scotland, with specific reference to the Outer Hebrides, are presented. The interview and excavation methods used during fieldwork are described in chapter three, and the methods used for the laboratory and statistical analysis of samples are described in chapter four. In chapter five the results of interviews with farmers from the Outer Hebrides are presented, with particular reference to the nature of contemporary and traditional agricultural practices and the strategies of resource management. The results of the laboratory and statistical analyses are presented in chapter six and, on the basis of these results, activity areas are characterized and the disposal routes of material resources identified. In chapter seven the ethnographic and analytical results are brought together to clarify strategies of resource management and to model the disposal routes of material resources. Factors determining the strategies of resource management are considered with reference to earlier agrarian communities.

CHAPTER TWO

AGRICULTURAL HISTORY AND ETHNOGRAPHY

In this chapter, first the geomorphological and environmental background of the Outer Hebrides are presented. Secondly, using historical and ethnographic documentary sources, the traditional system of land organisation and the agricultural regimes in the Highlands and Islands of Scotland, are discussed. Thirdly, with specific reference to the Outer Hebrides, the methods of tillage, crop processing and animal husbandry are described.

2.1 The Outer Hebrides- environmental setting

2.1.1 Situation

The Outer Hebrides are situated 60-80 km off the north west coast of mainland Scotland, separated by The Minch in the north and the Sea of the Hebrides in the south. The archipelago stretches 213 km from The Butt of Lewis to Barra Head, and consists of 119 named islands of which only 16 are now permanently inhabited (Boyd, 1979). The island chain, once known as "The Long Island" (Carmichael, 1884), divides geographically into two main groups, the Sound of Harris separating Lewis and Harris (total *ca.* 214,000 ha) from the southern islands (total *ca.* 76,000 ha), namely North Uist, Benbecula, South Uist and Barra. The Outer Hebrides form a breakwater against the Atlantic from Cape Wrath in the north to Ardnamuchan in the south and provide some shelter to the mainland and Inner Hebrides, situated to the east (figure 2.1).

The land is mountainous in Harris, gently undulating in Lewis and generally low lying in North Uist, South Uist and Benbecula, with the exception of Eaval (347 m) on the south east of North Uist and a ridge of mountains along the east side of South Uist, the highest, Beinn Mhor, rising to 620 m. The majority of the land is, however, below 100 m O.D. Numerous lochs occur in the low-lying land of North Uist, Benbecula and South Uist.

2.1.2 Geology

The Outer Hebrides are formed from an eroded platform of Precambrian Lewisian gneiss over 3000 million years old. Subsequent episodes of significance to present day Hebridean geology, were the major emplacements of granite in Harris and south Lewis - the Scourian (older than 2200 million years old) and the Laxfordian (less than 2200 million years old). The only sedimentary rock is Triassic sandstone, occurring around the shores of Broad Bay, Lewis. The whole of the Uists are made of Lewisian gneiss, with a thrust plane running north-east, south-west, associated with the mountainous band on the eastern seaboard. On the west coast the sea bed is shallow, due to a submerged platform forming an extensive area of continental shelf. Differential erosion of the gneiss, coupled with a complex fault patterning has contributed to the irregular surface of the hard rock (Boyd, 1990; Gribble, 1991).

The present day landscape results from glacial activity in the Quaternary era, during which the hard, acid Lewisian gneiss was eroded, leaving a gently undulating platform, trenched and hollowed along ancient fault lines. Glacial drifts of gravels and sands were deposited on to the ice-sculpted platform. Between 9000 and 5000 years ago the Lewisian platform subsided, due to differential rates of sea level rise and isostatic uplift, which resulted in the formation of numerous salt water lochs due to marine inundations. In the Uists, the glacial deposits are now eroded in places or overlain by peat, particularly in the upland regions in the east, and divided by oligotrophic freshwater lochs. On the western seaboard, the glacial deposits and peat are overlain by highly calcareous windblown sand, forming dunes systems and sandy plains with eutrophic lochs (Boyd, 1990).

2.1.3 Soil

The southern Outer Hebrides can be divided into three broad zones of soil types which, moving from west to east, comprise the dune system and low-lying machair plain, the blackland and the moorland zone (figure 2.2).

The machair comprises grassland formed on gently sloping shell sand deposits. The nature and evolution of machair formation is discussed in detail by Ritchie (1976; 1979). Large quantities of shell sand were swept landwards, aided by rising sea level, to form an extensive pre-machair sand dune system. High energy waves and strong Atlantic winds caused the deflation of beach dunes and swept sand inland. Where the sand stabilised, the characteristic calcophile grassland established to form long stretches of sandy machair plain. Radiocarbon dates for offshore peats underlying the machair suggests that machair formation commenced before 5700 BP (Ritchie, 1979).

The machair forms an almost continuous fertile strip along the exposed Atlantic seaboard, up to one kilometre wide in places. With the associated dune systems, the machair covers approximately 120 square kilometres along the west coast of North Uist, Benbecula and South Uist. The calcareous soils have high pH values, 6.5 to 7.5 in top soils and 7.5 to 8.0 in subsoils. The dune-machair soils range from calcareous regosols and brown calcareous soils to poorly drained calcareous gleys and peaty calcareous gleys, depending on the drainage conditions and levels of the water table (Glentworth, 1979; Hudson, 1991). Water percolating from the freely draining sands has contributed to the formation of lochs and fens in the slack behind the machair. Areas of machair are prone to seasonal flooding.

The soil system of the inland zone is based on shallow acidic glacial deposits and predominantly acid rock, which frequently lies near the surface or protrudes as rocky outcrops (Hudson, 1991). Blackland is formed where the peat and shell sand combine with glacial drift, to provide some of areas of good agricultural land. Drainage is good on areas of coarse-textured drift, and brown forest soils or cultivated humus-iron podzols may occur. In areas where drainage and permeability are slow, soils include non-calcareous, humic and peaty gleys (Hudson, 1991). Peaty gleys and podzols occur on areas adjacent to the cultivated blackland, where the peat has been removed for fuel. The acid reaction of these soils is lessened and, therefore, the cultivation potential improved, by the addition of calcareous shell sand.

Further east lie large open tracts of gently sloping blanket peat rising and giving way to hills or mountains. The character of the moorland is determined by the extent of waterlogging which, in turn, is dependent on rainfall, temperature and topography. The extreme eastern coast is steep and rocky, in places plunging to depths of 50 m or more into the Minch.

2.1.4 Climate

The western seaboard of Ireland and Scotland lies on the climatic frontier between two weather systems: the moist oceanic air to the west and the dry continental air to the east. The result of the interaction between these opposing air masses is a storm-belt, particularly energetic over the Hebridean shelf (Boyd, 1990). The climate of the Outer Hebrides is characteristically cool, cloudy, windy and wet although oceanic air and North Atlantic drift result in relatively mild winters. The annual and diurnal temperature ranges are extremely small, (the annual range of only 8.8°C is one of the smallest in Britain), with cool summers and generally frost free winters. The warmest months are July and August (12.9°C), despite the sunnier months of May and June, and the coldest months are January and February (4.1°C). It is rare for maximum daily temperatures to fall below 0°C (Angus, 1991).

South and south-west winds prevail on the Outer Hebrides due to the frequency of north-bound depressions crossing the islands (Angus, 1991). High wind speeds are common, at Stornaway the average is 14.4 knots (7.4 m/s) and 50 days of gale force winds are recorded each year (Angus, 1991). The mean annual rainfall on low ground is 1020-1270 mm (Manley, 1979), which compares favourably with agriculturally productive areas elsewhere in Britain. The distribution of rainfall throughout the year is unusual, with over 200 raindays commonly occurring each year. The driest months are May and June, which together account for only 10% of the annual rainfall. It is this factor, combined with lower summer temperatures and high relative humidity, that produces such a wet climate compared to areas with comparable rainfall on the mainland. Owing to Atlantic Ocean sea spray being carried inland by prevailing winds, the rain on the Outer Hebrides has a chemical composition similar to dilute sea water (Waterson *et al*., 1979).

2.1.5 Vegetation

The vegetation of the Outer Hebrides as a whole reflects strongly the island status, with definite marine influences (Boyd, 1990). The restricted flora on the islands compared to the Scottish mainland, and even to the Inner Hebrides, results from the limited habitat availability, climate, high levels of acidity (owing to the bed rock and peaty soils) and a history of human interference. The more fertile zone of machair on the western coast is species rich (Currie, 1979; Dickinson and Randall, 1979). Marram (*Ammophila arenaria*) dominates the sand dune systems (Robertson, 1984), and eyebright-red fescue dune pasture occurs on more stable areas (Hudson, 1991). On unfenced areas of uncultivated blackland, mat-grass (*Nardus stricta*) or heath-grass (*Danthonia decumbens*) are the dominant species (Hudson, 1991). The peatland areas are dominated by ombrogenous bog, acidic heath and grassland (Goode and Linsey, 1979).

2.1.6 Problems with machair cultivation

Machair, although productive when fertilised, is problematic to cultivate. The alkalinity of the shell sand base means pH is above the optimum for most crops, whilst nitrogen, phosphate, potassium, copper and manganese are deficient. The low organic content means the capacity to hold water is low and, in dry periods, these conditions are exacerbated. Most of the machair is exposed so that not only is wind erosion a problem to the land but the seed and crops suffer from the lack of shelter and can incur damage from sea salt spray (Grant, 1979).

The unstable sand dunes and machairs are particularly prone to wind erosion and sand-drift in the winter months. Occasions are noted in the historical documents of sudden blowouts during storms, causing arable fields and settlements to be desolated by the liberated sand. Such an incident was noted by Walker (1764-1771) on South Uist, where some arable crops were covered by up to a metre of sand within a few days. In the early nineteenth century, the islands of Heiskeir were virtually abandoned for fifteen years due to severe storm damage, which denuded the land of grass and soil (Otter, 1867). Digging up rue (*Galium verum*), used for dyeing cloth, also threatened the stability of sand in many areas and this practice was banned by magistrates in South Uist (MacLean, 1837). Further recommendations to prevent destabilization were to plant marram or to place turf sods, taken from adjacent ground, on the affected area (MacLean, 1837).

2.2 Agricultural Organisation and Farming Regimes in the Highlands and Islands

2.2.1 The Sources

In considering the historical aspects of agriculture in the Outer Hebrides, the physical and climatic characteristics specific to this region need to be recognised, for these will have influenced the nature of the agrarian systems evolved over the many years of occupation. In particular, poor and intractable soils and the short growing season pose serious problems. Land shortage and abundant labour supply also directly influenced the methods that were developed. The resultant agricultural regimes, however, should be considered within the framework of local bye-laws, regulations and customs, some obviously sensible, others latterly restricting but all adopted as a means of maintaining these communal activities within the challenging environment.

The evolution, execution and effectiveness of the Hebridean farming system is elucidated by a detailed study of all the available historical documentary, testamentary and statistical evidence. For the seventeenth, eighteenth and early nineteenth centuries, the bulk of this information is provided by travel writers such as Munro (1549), Martin (1716), Walker (1764-1771), Rev. J.L. Buchanan (1793) and MacDonald (1811); and from the old Statistical Accounts such as those written by Rev. G. Munro (1794) and Rev. R. MacLean (1837).

At the end of the eighteenth century, estate surveys were commissioned by many landowners, with a view to improving land utilisation, and the report by Blackadder (1800), on North Uist, and the estate plans by Bald (1805) clarify land use and the state of agriculture at this time. Later testimonies are descriptive of 'crofting', that is the modified system of land tenure and use imposed on these communities by the landlords in the early nineteenth century, based on the recommendations of the earlier estate surveys. Crofting was intended to improve the agriculture, by ending the traditional system of run-rig in favour of fixed tenure, and by extending the areas cultivated whilst maintaining a high population to process the kelp, which was lucrative to the proprietor. Such descriptions were provided earlier this century in Carmichael's detailed account for The Crofter's Commission, of 'Grazing and Agrestic Customs of the Outer Hebrides' (1884), and in a second report by the Crofter's Commission, twenty years later (1905).

Ethnographic studies made this century are an invaluable source of extra information and provide comprehensive descriptions of agricultural activities, often unobtainable from the historical literature. Studies such as those made by Fenton (1978a; 1978b) for the Northern Isles, and Lewis, in the Outer Hebrides, clarify the workings of these localised farming systems. The former is a detailed compilation of historical and ethnographic data, and highlights the extent of specific differences between these disparate, yet marginal, agrarian communities, each with individual adaptations suited to localised conditions, where the pressures of land availability and growing population were unique for each region.

In the Shetland Isles, conditions were the hardest: with limited arable land producing meagre crops, the situation was only offset by the possibility of raising enough stock on the rough upland pasture to supplement both diet and rent (Shaw, 1980). In the low-lying Orkney Isles, fertile arable land was not limited but pasture was, which led to the development of a strong arable base and less emphasis on the pastoral element of the economy (Shaw, 1980). In most of the Outer Hebrides, however, although the varied terrain resulted in sufficient arable land in most places, with some areas as productive as Orkney, the abundant hill grazing easily provided for a large number of stock, and the system that developed reflected a more balanced mixture of pastoral and arable farming.

2.2.2 The Integration of Arable And Pasture in the Landscape

2.2.2.1 The Arable

The agricultural communities in post-Medieval Scotland were commonly grouped together in multiple-tenancy farms (Fenton, 1980). The size varied, depending on the availability of land and plough power to work it, but was usually only the size of a hamlet or small village, containing on average about a dozen farmers (Smout, 1969; Fenton, 1980; Shaw, 1800). This was the farming township, variously known as the 'toun', kirktoun, wintertoun or clachan.

The township acted as the base for most arable activities. The land within it was used for open-field cultivation, wherever it was possible or appropriate to till and, where not, the land was used as pasture or natural meadow. In the Highland and Island regions the township settlements were usually scattered, following the best available arable land (Smout, 1969), which in most places tended to be near the coastal fringes. In the Outer Hebrides, the majority of settlement was situated along the western side of the islands, owing to the location of the prime arable ground, the machair and blackland (Fenton, 1980; Caird, 1979).

The entire toun was usually leased by the proprietor directly to a group of joint tenants or to a Tacksman, who in turn rented out the land to tenants who actually practised the farming. The Tacksman was often a kinsman of the landowner (in later years, often an outsider), and he was responsible for the collection of rents from the tenants, as produce, labour or money (Lythe and Butt, 1975). An alternative to this arrangement was for the proprietor to manage his own land directly (MacDonald, 1811). The systems of leasing have implications for the reliability of the old Statistical Accounts, as a means of gauging the number of tenants, because the true number working a toun could be concealed by ambiguities in the rental accounts.

2.2.2.2 The Summer Pasture

In winter months, when the inclement weather dictated mostly home-based activities, the animals would graze on the unplanted open fields within the township. Once crops were sown and had started to show through the soil, it was vital to keep the animals off the arable land. Within the township there existed a certain amount of permanent pasture, the droveways and ground too wet or difficult to cultivate; and the semi-permanent pasture of fields under fallow. These were inadequate, however, for the needs of the entire herd, in both quantity and, by this stage, quality. In early summer, therefore, the animals were moved, beyond the designated limits of the township, to the common grazing, the area of rough moorland adjacent to and surrounding the settlement.

The common grazing was co-ordinated with the main settlement as a complementary pastoral base, providing 'unlimited' supplies of grass in the summer months, at a safe distance from the growing crops, and also constituted the main source of turf and peat used for fuel, building and fertilising (Fenton, 1976). With the exception of the 'door land' of the central Highlands (Fenton, 1980), 'tounmal' of the Northern Isles, the occasionally documented 'kailyard' of the Outer Hebrides and small but permanent adjuncts of land allotted to tenants for use as kitchen gardens and general grazing (Shaw, 1980), it appears from the historical records that the township pasture land was held in common, both within and outside the settlement. Together with communal tenure came the need for organisation, and general dates were often assigned for the removal of stock from the township land, thus scheduling the movement of stock to coincide with the need of the arable sector.

In the Highlands and Western Isles, where the hilly and often mountainous terrain also provided important areas of extensive upland grazing, there were situated secondary and more remote bases for summer pastoral activities; these were the 'shielings', in Gaelic *'airidh'*, the temporary huts of which formed a nominal 'summertoun' (Fenton, 1980). The development of a system of transhumance to the shieling bases, by the people and stock, was a natural and sensible adaptation to the resources of the region, and did not detract from the necessary role of the nearer moorland grazings. Together with the arable base, the moorland grazings and shielings were essential components of the rhythmical subsistence economy in these regions where, owing to the nature of the environment, great emphasis was placed upon pastoralism and the importance of the summer grazing base (Fenton, 1980).

Historical records do not directly relate the use of shielings in the Northern Isles although, as Shaw (1980) points out, this does not negate the possibility of such transhumance, and it by no means lessens the importance placed upon pastoral activities. The low-lying Orkney Isles do not have the same upland regions as the Highlands and Western Isles, and the Shetland Isles, although rugged, do not provide grazing areas of either the same extent or distance from the farm base (Shaw, 1980). Instead, it can only be inferred that the different terrains dictated development of regimes more suited to the local geography, with grazing requirements satisfied where possible by the moorland pastures, without 'wholesale' removal to the distant hills.

An interesting feature of the Hebridean transhumance system concerns the grazing practises on the smaller islands, where the amount of upland grazing was limited. The people would instead move their stock to other small uninhabited islands or mainland areas adjacent to their settlements, for the duration of the summer months, in order to take advantage of the grazing land. This was noted to have taken place in Lismore, in the Inner Hebrides, in the seventeenth century (Shaw, 1980), and is also documented for the islands of Heiskeir, off the west coast of North Uist (Beveridge, 1911; MacGregor, 1969), and those of Great Bernera, off Lewis (MacGregor, 1949; Fenton, 1980). Nevertheless, despite the similarity of terrain, there is no record of this same practice on the Northern Isles.

2.2.2.3 The Head Dyke

The 'head dyke' was the crucial line that divided the township land from the common grazing areas. A significant territorial boundary, it was important, where open field farming was in operation, as a means of separating the frequently hungry animals from the struggling crops. In these areas it normally took the form of a broad stone and earthen dyke, and could be in all stages of repair and disrepair (Smout, 1969; Shaw, 1980; Fenton, 1980).

In the spring the head dyke was closed, and most of the animals would be kept outside the boundary during the cereal growing season, except for the milk cows and draught animals, which could be tethered inside buildings, yards, and droveways, or within 'folds' or 'pounds' for convenience. In the autumn, when the crops were harvested, it would be reopened to allow the animals freedom to graze the township lands along with the common grazings and, in this respect, the head dyke acted more as a 'control valve' than a barrier (Fenton, 1980).

In some areas, more time and labour were invested in the building of dykes than in others. For example, a second dyke, the 'march dyke', was sometimes erected between the land of neighbouring farms. This was more common in areas where arable land lay close together, in the flatter, more fertile islands (Shaw, 1980). The whole practice of dyke building was more extensive, and their maintenance more conscientious, on the Northern Isles than on the Outer Hebrides, a feature often noted in the historical documents, and one which most likely reflects a geographical phenomenon than adherence to old custom. Such labour intensive tasks were mainly developed and retained if they had relevance, and the difference most probably relates to the availability of pasture; the distant hills and shieling bases of the Outer Hebrides providing physical distance between the crops and the hungry animals until harvest time, when the cereals were removed from the open fields and the animals could once again return to the township land and the refreshed pastures within, thereby diminishing the necessity for the head dyke.

The geography of the Northern Isles differed from most of the Outer Hebrides, and the lack of extensive upland grazing at sufficient distance from the settlement and crops prevented the development of a safely separated pastoral base. This emphasises the importance of dyke building in the Northern Isles as a means of keeping the animals away from the arable land. This is well demonstrated in Shetland in the seventeenth century, where the very limited amount of arable led to regulations ordering the erection of dykes. Likewise, in Orkney, bye-laws decreed the 25th March as the date by which dykes should be effective (Shaw, 1980), around which time the sowing of crops began.

The neglect of dyke building in the Outer Hebrides was noted by the early agricultural observers, and the lack of any form of enclosure was blamed for the recorded poor state of farming (MacDonald, 1811). The March dyke was evidently important in some areas, however, for Martin describes in detail the custom employed in North Uist to pass on the knowledge of the march dyke location, where such boundaries were in danger of being lost:

> *"They lay a quantity of ashes of burnt wood in the ground, and put big stones above the same; and for conveying the knowledge of this to posterity, they carry some boys from both villages next the boundary, and there whip'em soundly, which they will be sure to remember, and tell it to their children"*
>
> (Martin, 1716 p.114)

Most recommendations for agricultural improvement involved the enclosing of land, for open field farming was broadly considered retrogressive, and so the lack of head dykes in the Outer Hebrides was poorly regarded. The logic behind the Hebridean response to environment, with the substitution of these protective barriers by the adoption of transhumance, was not recognised by the agricultural improvers who recommended the enclosing of land.

2.2.3 Land Organisation

The most important component of the township was the farm land. This was all the land enclosed within the head dyke: arable, pasture and meadow. The system of land use that developed varied depending on the conditions of land tenure, the nature of the terrain and the availability of land.

The traditional system of land tenure and farming was abandoned, in the majority of areas, very early on, yet was still practised in parts of the Hebrides until the late eighteenth to early nineteenth centuries (Walker, 1764-1771; Pennant, 1776). In this system, all the land was held in common by the husbandmen; cultivation and crop sharing were communal, and the rent was paid as one lump sum. Common cultivation preserved a strong collective interest in the land, important in this area in the years prior to the seventeenth century, when raiding by neighbouring clans was possible. The sophistication of agricultural methods came second to the security of the settlement (Shaw, 1980).

More usually, the type of farming that developed in these areas was similar to that practised in Lowland Scotland, although tailored to suit the different environments of the Highlands and Islands. Instead of completely collective arrangements, the arable component of the township land was divided between the tenants, who held their own share as a number of strips and patches, scattered amongst the land of their neighbours. The areas of pasture and meadow were not usually divided, but utilised on a communal basis.

The arable land was generally classified into two types, 'infield', and 'outfield', the former usually farmed continuously and the latter given over to periods of fallow. Areas of land within these categories were apportioned equally between the farmers, and the tenancies of individual shares were rotated according to township regulations. In this way each tenant farmer had a share of the different land types, in equal proportion, and for an equal length of time as his neighbour.

The subdivision of the arable land did not preclude joint tenure and, whether the tenants were working the land collectively or on an individual basis, the nature of joint tenure established the role of the Tacksman as intermediary between the farmers and landowner (Lythe and Butt, 1975).

2.2.4 Run-rig

Run-rig was a method of land organisation that allowed fair allocation of good and poorer soils by physically dividing and dispersing the land between the farmers, and then rotating the tenancies. The strips of land that formed the basis for allocation and working were known as 'rigs'. The cultivation usually took the form of ploughed ridge and furrow, but this was dependant on the terrain and, in some places, spade cultivation would be employed (Slaven, 1975; Fenton, 1976). Ridge cultivation was not unique to Scotland. It was partly the result of ploughing from the centre to the outside, the soil always being turned towards the crown, which created the crested appearance of the ridge on which the crops were grown. This enhanced the growing bed, by minimizing the loss of soil to the neighbour's strip, and also created the furrows, that served as ditches for draining the surface water. Even on land that drained naturally, however, the rig was still the basic working unit, as its width was particularly well suited to the use of hand tools (Fenton, 1976).

The rigs varied in width according to the local organisation of the land, the nature of the terrain and the soil type. Overall they varied from 5.5 - 11 m in width, rose to 1.2 m at the crest, were often curved and generally ran up and down hill, thereby providing a minimal form of drainage (Fenton, 1976; Slaven, 1975). The special feature of the run-rig arrangement was that the tenancy of the rigs was initially re-allocated every one to three years, thus giving each a fair share of all the soil types, especially as the strips were always scattered, each one between those of different joint tenants. In this way, run-rig disallowed any specific or continuous holding of arable soil on an individual basis.

It is from the system of rotating the rigs that the name run-rig is derived. Carmichael (1884) defines the term run-rig as a modification of the gaelic 'Roinn Riuth' meaning 'division run', or parallel divisions. He suggests the word 'run' is used in the sense of common, as in gaelic the system was also called 'Mor Earann' or 'Mor Fhearann' meaning 'great division' and 'great land' respectively (Carmichael, 1884).

His account is some evidence for the longevity of this ancient system throughout many countries, and for its persistence still in the Outer Hebrides at his time of writing:

> *"The system of Run-Rig prevailed of old over the whole British Isles and the continent of Europe. It was common in Ireland, it is extinct in England, and obsolete in Scotland, except to a limited extent in the Western Isles. There the system still lives in three different forms, more or less modified - two of these being gradations of decay"*
>
> (Carmichael, 1884 p.452)

He describes in detail the exact procedure of the land sharing on the run-rig basis, according to custom on the islands of Heiskeir, one of the places where a remnant form of this system still survived, and continued to survive until abandonment in the 1940 s. He relates the stages of the operation, from the initial choice of the area of land to be divided amongst the members of the community, through the role of the constable in dividing this into the appropriate number of strips, to the drawing of lots from a hat (Carmichael, 1884).

Run-rig was discontinued at different times and in different places in the Hebrides, but generally came to an end in the first half of the nineteenth century, particularly with the imposition of crofting. The old style communal land division is often referred to disparagingly by the writers of historical testimonies, especially those written around the time of the Improvements. MacDonald, in his 'General View of the Agriculture of the Hebrides' recommended that: *"run rig and co-partnerships in tillage and paying rents , ought, in every case, to be done away"* (MacDonald, 1811 p. 568), for he saw these arrangements of land tenure as the main obstacles to the improvement of the agricultural state of the Hebrides. MacLean (1837) is equally disapproving of run-rig, which continued in South Uist until 1818 according to his testimony. He describes the system as:

> *"attended with ruinous effect; the people were not so industrious as they have been since* (the Improvements) *nor did they preserve their corn and potatoes from being damaged by cattle"*
>
> (MacLean, 1811 p.190)

2.2.5 Lazy Beds *'feannag'*

2.2.5.1 Occurrence

Lazy beds, or *'feannag'* in Gaelic, were basically the spade dug equivalent to ridge and furrow (cf. run-rig), as they consisted of a series of raised beds with ditches in between (Fenton, 1976). The lazy bed technique was used most commonly where ploughing was not possible, either because the nature of the terrain precluded the use of the plough (as for example on the peaty blackland, or ground too wet or stony), or simply because the technology was not available or had not been obtained (for example in Lewis, as noted by Walker, 1764-1771). Lazy beds were also invaluable on the Hebrides as a means of artificially creating a cultivation bed on land that otherwise had insufficient depth of soil in which to grow anything; notably, the rocky areas around the lochs, where soil is only in patches and even then is very shallow. Equally important, as a technique suited to the Hebrides, is the way in which lazy beds facilitate drainage so effectively, which is vital on the peaty areas of ground where they are often situated.

2.2.5.2 Construction

To construct lazy beds, manure or seaweed was laid out onto the untouched ground in parallel 1 m wide strips, with approximately 1 m between each strip. Turf was pared and flipped over onto the fertiliser from either side, and the newly exposed earth also piled up on top of the line of inverted turves and fertiliser (Fenton, 1976). This operation was repeated for several strips, to form neat patches of prominent ridges, the total size of the area determined by the amount of land available and the requirements of the farmer. John Buchanan (1793) mentions the practice of lazy bedding in his 'Travels in The Western Isles', giving it a different Gaelic name - *'taomadh'*. He also describes the practice of *'taomadh a broin'*, that is when the middle of the ridge was cut out and spread to the sides, which was necessary when the crown of the bed became too sharp and needed flattening. He observed that, when the corn was sown on the ridge, it would be either harrowed or raked in preparation.

The digging of lazy beds was best performed as early in winter as possible, so that the newly dug wet peat could be exposed to the maximum amount of frost, in order to aid its reduction to a mould (MacDonald, 1811). It was claimed by MacDonald (1811) that, if the same were done in summer, the 'moss' thrown from the furrows would immediately turn into hard peat. If the beds were prepared in advance, as recommended by MacDonald, then the seed would have to be planted by dibbling holes and filling them in afterwards with a rake (Buchanan, 1793). This was not always the case, however, and the lazy beds were often dug in spring, when either the seed corn or the seed potatoes were placed onto a layer of dung or seaweed, and then covered with earth from out of the furrows (Buchanan, 1793).

Since their introduction to the islands in the mid-eighteenth century (from Ireland to South Uist in 1743 - Beveridge, 1911), potatoes have been the crop most commonly associated with lazy beds; but before this date, at least in the sixteenth century (Fenton, 1976), they proved to be excellent growing beds for a whole variety of crops. Barley was particularly suited to lazy beds, benefiting from the horticultural conditions which they provided (Fenton, 1976).

The technique was also a good way of breaking up and reclaiming peat or waste land, for the previously compact earth would disaggregate with root action and the furrows aided drainage. Potatoes were especially suited to breaking-up the soil surface and, once the crop had been pulled, it needed only to be raked over in preparation for barley or oats, with no extra manure necessary. Sometimes two lazy beds would be raked together to form a larger cultivation bed for the succeeding crop. This may account for why in some places, such as Lewis, quite large beds can be seen on slopes, permanently in place, and with retaining walls to counter the natural processes of soil creep (Fenton, 1976).

2.2.6 The Infield - Outfield Divide

The arable component of the township land lay entirely within the bounds of the head dyke, and was usually divided into two categories: the 'infield' and 'outfield' (or 'in-bye' and 'tillage' after Darling, 1955). These terms are descriptive of different arable land types, and hence different cultivation intensity, and the two types could lie in intermingled blocks rather than as spatially separated fields (Smout, 1969). There was no definitive pattern, for the nature of the system was dictated by the terrain; some areas had no infield whilst others had no outfield.

The infield was the most intensively cultivated ground, whereas the outfield land rotated between short periods of cultivation and longer periods of fallow. In this way elements of simple shifting cultivation and the basic 'one-field' system of agriculture, where land is utilized continuously in a rotation of arable, pasture and fallow, are combined as a rudimentary 'two-field system' (Slaven, 1975). It is argued that, owing to the intermittent cropping of the outfield, the agriculture practised in this form was in reality a variation of the one-field system (Slaven, 1975). Where ground was poorly drained, common in these regions, the blocks of arable land were frequently scattered and interspersed with a large proportion of pasture, so that the overall organisation was a tripartite division of the townland: infield, outfield and permanent pasture; complemented by a fourth element, the common grazings and shielings (Dodgshon, 1980). It is not possible to see such divisions in all areas of the Hebrides from the historical records, either because the divisions were not made, or possibly because they were never documented.

2.2.6.1 The Infield

The infield was the best available arable land, normally a quarter or less of the total cultivable land, usually farmed continuously in a crude rotation of crops. It commonly lay adjacent to or at least near to the settlement. In the case of the Outer Hebrides this was usually the sandy machair, where the fertile, light and well drained soil allowed plough cultivation, and the blackland, whose peaty and stony nature often dictated spade cultivation in association with the lazy bed technique. Local variations did exist, and sometimes the land would be fallowed for several years after exhaustion by intensive cropping.

The infield was planted with a greater selection of cereal crops than the outfield, though even then the range was limited. It carried the 'drink-crop' of the community, 'bere' a local species of barley (6-row, hulled *Hordeum vulgare*), oats (the small black variety, *Avena strigosa*), and in some places rye (*Secale cereale*). The small black oats were well suited to exposed areas such as the Outer Hebrides, because their light-weight nature meant they were better adapted, than the heavier white oats, to the harsh winds and rain (Campbell, 1965).

In the Outer Hebrides, the machair was most commonly associated with oats, but also supported bere and rye, while the blackland was best suited to bere, oats and later potatoes. The great extent of local variations within the Outer Hebrides can be demonstrated here for, although rye was grown on the Uists, it was not grown on Lewis according to Walker (1764-1771), and was grown on Harris prior to 1772, in great quantities, but stopped because it was apparently prejudicial to the soil (Walker, 1764-1771).

The most basic cropping regime was an alternation between bere one year and oats the next, as recorded for the blackland of South Uist by Walker (1764-1771), and also for Lewis and Harris (Walker, 1764-1771). More usually, the infield was farmed as a three-break system, where the whole area would be divided into three equal parts, one section only receiving manure, but all three sections continually cultivated. The usual cropping schedule, the Outer Hebrides included, was bere in the first year, sown in spring (May) on the newly manured section, and then oats, also sown in spring (but earlier than the bere), with no extra fertiliser for the next two years, but again local variations existed. For example, rye could be included within the three-break system. Later, with the introduction of wheat and peas, a four- or five-break system existed, though this was not overly popular, in the Outer Hebrides (Fenton, 1976). This could possibly be connected to sowing times of wheat: if sown in November or December, it would preclude the use of those infield areas for general grazing by the common herd during winter, and would force them to be enclosed as individual units, contrary to the open-field arrangements of run-rig (Fenton, 1976). This would be incompatible with the Hebridean system where the lack of food for the animals in the winter months was so critical.

To achieve a useful level of soil fertility in order to maintain the continual cropping, the infield was the most regularly and intensively manured land, receiving the majority of the dung from the byre and stable - hence the alternative names 'mucked land'. It was quite usual in coastal areas for the more fertile and low-lying land near the shore to be the most intensively cultivated, as the coast provided seaweed, vital not only as a way of returning moisture to the soil but also as an important additional source of fertiliser to that from the animals, albeit a burden to carry on the backs of either horses or humans (Shaw, 1980). Consequently the nature and success of arable cultivation would have been influenced by the availability of fertiliser types and the logistics of their dispersal, and such factors must have contributed to the many local variations that appear to have existed in infield rotation. The fact that coastal areas were the most intensively cultivated, even on low-lying islands, where the whole area was fertile, confirms the importance of the availability of seaweed (Shaw, 1980).

2.2.6.2 Outfield

The outfield consisted of a number of irregularly strewn and discontinuously cultivated patches of land, further from the settlement, and often higher up the slope. The outfield land was usually of an inferior quality compared to the infield and of greater extent. In the Hebrides it was quite often on the peatlands, where ploughing in rigs was not possible, and instead the lazy bed technique was employed. The unstable machair was, however, also designated as outfield, the fallow periods providing an essential opportunity to rest.

The outfield was worked extensively on a form of rotation, where a number of scattered patches could be under crop or fallowed as pasture at any given time, usually as a seven- or eight-break system. The most common regime was to alternate several years of fallow with only a few years of a less demanding, more tolerant crop, usually oats, but bere was also grown in some places. Even so the average return was often only one to three. The outfield has been likened to shifting cultivation because in some places it was cropped to the point of temporary exhaustion, when the grain returns no longer justified the cost of planting (in both effort and seed grain), and then abandoned (Campbell, 1965; Smout, 1969; Slaven, 1975; Lythe and Butt, 1975).

In areas like the Highlands and Outer Hebrides, where pasture was plentiful, less emphasis was placed on the outfield as a source of grass. Consequently, outfield cropping could be more frequent; but, even so, theoretically no township would crop more than half of the outfield at any one time (Dodgshon, 1980). The areas that had been cropped were left fallow so that grass would regenerate for pasture. Usually, as the cycle moved on, this ground was used as a temporary fold, receiving manure from the grazing animals in the process, and was thus prepared for the next cropping (Fenton, 1976). Due to the emphasis on stock rather than crop cultivation in the Hebrides, however, the use of hill pasture and shielings meant there was less opportunity for regular outfield folding, for the herd would have been absent for three months of the year (Fenton, 1976).

Infield and outfield should not be considered as inseparable from run-rig; they could and did exist apart (Dodgshon, 1980). There has been much discussion on the origins of these systems of land division (Whittington, 1973; Dodgshon, 1975; 1980; Baker and Butlin, 1973) but, as yet, no consensus of agreement. Whittington's (1973) hypothesis links outfield to shifting cultivation, with the development of the infield at a later date. Baker and Butlin (1973) suggest infield-outfield develops out of an infield system. There is little historical evidence available to clarify the matter, and problems exist with both arguments. Dodgshon (1980) suggests a tenurial distinction, with infield as assessed land in the township records, and outfield as non-assessed land, thereby establishing a sequence of development. Infield logically acquired an intensive character, being the initial nucleus of the toun. Explaining outfield is more difficult, but it could have developed from use of the incidentally manured pasture land.

2.3 Farming Practices in the Outer Hebrides

2.3.1 Agricultural Regimes

The exact cropping rotation employed for the infield and outfield on the Outer Hebrides had local variations depending on the soil type and geography, as for everywhere else. In his Report on the Hebrides (1764-1771), Rev. Dr. Walker described the state of agriculture on South Uist, including the details of the cropping regime he observed, although this is obviously generalised for the whole island.

The machair was fertilised with 'sea wrack' (seaweed, see 2.3.2.2) and had one year of bere, followed by two years of rye with no extra fertiliser. It was then fallowed, and at the end of five, six, or seven years cropped again in the same manner. The blackland he claims to have "*afforded crops of Grain immemorially, without respite*" (Walker, 1764-1771 p.77) with crops of bere and oats being taken alternately, the seaweed being put on the bere crop only. This implies the standard infield practice of constant cropping, unlike the machair which, if left to fallow, implies it was being treated as the outfield. The yields are not consistent with this, however, for the machair is the more productive of the two land types: 25 or 26 pecks of barley meal per annum (the unit of land is not specified) from the machair, as opposed to 12 or 14 pecks from the blackland although, as he points out, this land was kept in constant tillage. The yields of oats and rye were both seldom above 4 fold but, of the two, they valued the rye crop more (Walker, 1764-1771). The yield of these crops was very much affected by the annual weather patterns for, after a wet summer, grain would be exported yet, after a dry summer, it would have to be imported.

Walker (1764-1771) gives details of the sowing times of these crops, which he obviously views to be late, considering the Hebrides do not experience much frost or snow and that much of the ground is in general sandy and dry. The rye and oats were not sown until the beginning of April, and the bere in the latter half of May. Reaping began on or about the 15th of August.

Comparing this regime to those observed on Lewis and Harris by the same author and during the same tour, differences are apparent but are too scant to draw firm conclusions. He reports only the cultivation of bere and grey oats in both places, but with no information as to which land type they were cultivated on. Reference to the machair is made when he reports that rye was grown in the past on Harris, but stopped due to the damage incurred to the light sandy soils (see 2.2.6.1). Martin's account in 1716 is different to that of Walker. He records Lewis to be fruitful in barley, oats and rye, as well as flax and hemp; and he describes the west side of Harris to be productive arable, if manured with 'seaware' (seaweed, see 2.3.2.2), yet reports only rye and barley as growing there. In a single reference to the east side of Harris, he describes some parts of the hills as *"naked without earth"* (Martin, 1716 p.31).

For North Uist, Martin (1716) reports a return of 10 - 30 fold yield of barley in a good year, providing the soil was manured with seaware and enough rain fell. If the plot of land had *"lain unmanur'd for some years"* (Martin, 1716 p.52), it would in a good season produce the extraordinary return of fourteen ears of barley from one grain. He reports barley, oats and rye, as the crops grown, and considers the soil able to support wheat.

He describes South Uist as quite similar, the western side being the plain arable land, where the sandy soil yields good returns of barley, oats, and rye, of equal quantities to those from North Uist. The arable lands here were apparently much damaged by the overflowing lochs, which he does not mention this for any of the other places.

Another reference to land utilisation and cropping regimes is a recommendation made by MacLean (1837 p.192) for an area of machair in South Uist. He predicted that if the land were reclaimed with seaware, sown with patches of barley and the cropped areas then put to fallow for a few years, that the whole area would eventually yield abundant grass.

The estate plans drawn up by Reid (1799) for North Uist, show the main arable land as the inner areas of machair and some low lying areas of drift-covered ground. There are also some areas of peatland, cultivated on the east side of the island. In the report associated with this plan, Blackadder describes the machair as *"producing* *the most abundant crops of grain and rich pastures or meadows*" (Blackadder, 1800 p.127 in Caird, 1979). He reports on the organization of land tenure and use:

> "*one half of the arable land is kept in tillage, cropped three years and allowed to turn to grass. The part to be broken up is covered with sea ware, and for two years successively with Bear, then Oats (small grey oats) and the fourth year is allowed to run to grass, the first crop is for the most part good, the other two, owing to the bad culture, are often worth little or nothing.*"
>
> (Blackadder, 1800 p.127 in Caird ,1979).

A similar estate survey was commissioned for South Uist at this time, but only the plans drawn up by Bald (1805) remain. For the whole of South Uist generally the machair is again distinguished as the most cultivated area. In a more detailed plan of Boisdale, South Uist, however, settlement and cultivation are clearly shown on the eastern side away from the machair. These plans are especially useful because they differentiate between ploughed and spade dug land. The areas of machair and the well drained peatland near the coast were ploughed, but only constituted 27% of the estate, whereas the inland acidic peaty areas, despite the labour intensive nature of spade digging, were more widely utilized forming 73% of the estate (Caird, 1979).

Descriptions of agricultural practices from historical sources highlight the localised differences in cropping regimes even within the different islands of the Outer Hebrides. They also highlight how difficult it is to determine any regular and definite patterns of land use, such as infield and outfield. A widespread and recurrent pattern, however, is the use of the sandy machair areas, when fertilised and fallowed, and also the use of the black 'croft' land which, although fertile, was more difficult to cultivate because of its rocky, shallow and patchy soil.

2.3.2 Fertilization

2.3.2.1 The Farmyard Midden

The farm midden was one of the most important elements of the whole Hebridean agricultural system, as the soil would have been unable to support any form of regular cultivation had it not been frequently fertilised.

The animal dung was the most obvious source of fertiliser. Traditionally this accumulated inside the byre over the winter, or was cleared out of the byre and stable to form the midden heap, immediately outside these buildings or somewhere within the farm compound. The time and frequency of mucking out, and the volume of the midden are not recorded in the older historical literature, but in the early photographs taken of farm compounds near the beginning of this century, (in Macaulay, 1984), these characteristic midden heaps can be seen. The midden would be composed of the actual dung of cattle and horses and the bedding on which they were stalled. The bedding material could be formed of almost anything available, including straw (although most was used as fodder) and turves.

The process of composting is essential to the efficient management of certain resources, where the combination of material types will affect the success of organic decay and nutrient release. For example, it is necessary to accumulate cattle dung with absorbent materials, not only to reduce the large proportion of water contained within the manure (over 75%), but to encourage the process of fermentation and nutrient release (Darling, 1945). The accumulation of manure with bedding material *in situ* within the byre, as in deep-litter stalling, is a particularly efficient method of composting. First, minimal losses are incurred through rain fall and run-off, which from unprotected middens may be up to 30% of the value of the manure, and, secondly, the trampling of the cattle contributes to the breakdown of the bedding material (Darling, 1945). Evidence suggestive of cattle stalling dates from the Late Neolithic or Early Bronze Age of continental north-western Europe although in northern Britain and Scotland, the tradition of byre-dwellings dates from the Viking period (Fenton, 1981). In the Northern Isle variations on this method are the accumulation of dung, composted with turf, peat and/or ashes, inside the byre but mounded against a back wall away from the animal's feet, and the formation of outdoor middens constructed of alternate layers of dung with turf, earth, seaweed and/or ashes (Fenton, 1981).

The midden dung would have been moved out to the fields in large wicker baskets called creels, on the backs of horses, or women and men, in preparation for spreading. This dung could be spread immediately, by itself, or mixed with seaweed.

2.3.2.2 Seaweed

Seaweed was the other predominant form of manure for the land, and of vital importance in the Hebrides. Seaweed is rich in nitrogen and potassium and poor in phosphorus, while dung is richer in phosphorus and contains less potassium, an element in short supply on the machair (Fenton, 1978a). The seaweed used was of two main types, 'tangle' or 'ware' (*Liminaria*; *L. digitata*; *L. saccharina*) and 'wrack' (*Fucus vesiculosus*). The tangle was the most commonly used form of seaweed, for it was by far the more easily obtained, washed up on the shores of the west coast after a heavy storm. Where supplies of loose weed were not available, seaweed would be cut. Wrack grew on rocky places, mainly on the east coast (MacLean, 1837), and sometimes on rocks purposely placed to encourage growth. It was cut from the rocks using a small sickle, notched with a file along one edge, like a saw (Beveridge, 1911).

The 'seaware' is often cited in the historical literature as giving the best returns when used on the crops, but it is possible that this result is related to the greater availability of the seaweed (usually) rather than to a qualitative difference. The only instance of dung and seaweed actually being compared with one another appears in MacQueen's (1837) account on North Uist. He reports seaweed to be the chief manure and favourable to the production of barley although not able to enrich the ground as much as dung, which was also used but not in such great quantities. Munro, however, has no doubts about the value of the seaweed:

> *"were it not for the immense quantity of floating sea-ware that is thrown a-shore during the winter-storms, the inhabitants never could manure the ground, so as to raise a crop that signified, of any kind"*
> (Munro, 1798 pp.293-294).

Likewise, Buchanan (1793) speaks favourably of seaweed as a source of fertiliser good for barley and potatoes, on any kind of soil, although oats do not do so well, producing only a small grain. He reports seaware to have the:

> *"effect of making the deepest and coldest moss keep a firm sward, even when applied by men whose judgement in farming is by no means of the first rate"*
> (Buchanan, 1793 p.19).

The seaweed was so well valued that a watchman was appointed for the different villages to report when it had been washed ashore, and then each holding was allotted an area from which to collect their weed (MacKenzie and Campbell, 1957). There were various methods employed to get the weed to the arable land, according to the local circumstances. In some cases a boat was required in the initial stages, although this would later need to be supplemented by the more usual forms of transportation as, for example, at Boreray in North Uist, which Beveridge describes as:

> *"a small procession of women ascending from a geo, and laden with sea-ware in sacks slung across their shoulders, while upon the same island another system was observed, the manure being borne in panniers on horseback"*
>
> (Beveridge, 1911 pp.325-326).

When horses were being used, the tangle was put into baskets on each side and also heaped across the pony's back, protected by a long mat made of marram. At Lieravay on North Uist, the panniers were made of wood, with a device that enabled the quick release of the seaweed from out of the bottom. Later, when carts became more widespread, these were used for moving the tangle to the fields (Beveridge, 1911). Martin reported that the ground in North Uist was manured until the 10th of June, if they had enough of the *'Braggir'*, which he describes as *"the broad leaves growing on the top of the Alga-Marina"* (Martin, 1716 p.54).

2.3.2.3 Alternative Fertilizers

Martin also noted a different local technique for fertilising the land, on the island of Bernera in the south of the Hebrides. In addition to the use of seaware, which they carried in ropes upon their backs over the high rocks, they would:

> *"fasten a cow to a stake, and spread a quantity of sand on the ground, upon which the cow's dung falls, and this they mingle together, and lay it on the arable land"*
>
> (Martin, 1716 p.94)

On Lewis, Martin noted that they also "fattened" the land with soot, but this method apparently contaminated the corn grown on it, so that the people suffered from jaundice (Martin, 1716 p.2). It was, however, common practice to spread old roofing material from the houses onto the land on Lewis (Fenton, 1978b), a dressing which would have consisted mainly of soot impregnated straw, or straw roots. Thatch was constructed from the cereal roots cut off the bottom of sheaves after the crop had been up-rooted at harvest time. With no underlying layer of turf, because the scarcity of wood rendered the roof too feeble to support the extra weight, stubble was thrown directly on to the timber frame and tied down with ropes made of heather (Walker

1764-1771, p.128). The roofing material would have been replaced every year in most cases (Fenton, 1978b).

Another unusual source of manure for the land was cockles, also used as cement and food. This method was practised on Barra, where they had more cockles than the other islands, and noted by Martin (1716); Munro (1798) and MacDonald (1811). At one time, even fish were put on the land, although this was not the normal practice, but followed an unusually large catch of herring.

2.3.2.4 Manuring for Land Reclamation

In later accounts of those people concerned with land and agricultural improvements, the correct fertilisation of the land was an important issue. MacDonald (1811) describes how he went about reclaiming a piece of moorland and the dressings he applied to produce good returns. In the first year, he applied either dung or seaware, and followed this in the second year :

> *"with a top dressing compost, made the summer before of sea-sleech, or mud, dung, drifted sea-weeds, and rubbish of lime"*
>
> (MacDonald, 1811 p797).

In the third winter this was covered with shell sand (10 tonnes to the acre) and the land thereafter proved to be a valuable source of rich hay.

This confirms the value of alkaline substances on such acidic soils for, where patches of sand or lime had accidentally been dumped, there was always a rich cover of clover and daisy, as observed by MacDonald on South Uist (MacDonald, 1811). MacLean (1837) also recommended the use of shell sand as a manure on peat, for the production of oats and bere. He promoted the need for road building to the eastern areas of moorland, where land could be reclaimed, as then sand and seaware could be taken from the shore directly to the peat with greater ease, and peat brought back in return. Overall this would mean more cultivable land (MacLean, 1837 p.193).

It was not only the moorland areas that it was considered necessary to bring into cultivation. MacLean (1837) recommends the use of seaweed as a means of reclaiming some 600 acres of machair land in South Uist that, previous to 1837, had lain waste for over 100 years. He implies this action was possible owing to the proximity of the seaweed (MacLean 1837, p.192). He also accuses the local tenants of being:

> *"backward...... to commence cropping their this waste, under the idea that they should have nothing for their labour"*
>
> (MacLean, 1837 p.192).

Owing to the frequency and intensity of the use of seaweed elsewhere, however, it seems unlikely that the local people had not attempted cultivation of this tract of land if it were at all possible.

2.3.3 Tillage

> *"The Hebrides having been for ages chiefly devoted to grazing, the cultivation of crops requiring regular tillage was not a primary object. Agricultural implements were accordingly simple and imperfect, and the system of ploughing or tilling the ground made no progress for several centuries. Even to this day, the idea continues to prevail in some parts of these regions, that it is unwise to turn the soil at all, because the moisture of the climate, the poorness of the land, and the consequent insecurity and lateness of corn crops, render every mode of management inadvisable, excepting that followed by their ancestors, namely, corn-cropping the rich infields and grazing the natural old pasture with the indigenous live stock of the country"*
>
> (MacDonald, 1811 p.174)

The traditional implements for cultivation were often rudimentary, on first appearance, and were often criticised by the agricultural observers for their simplicity and lack of evolution. As pointed out by Fenton (1976), however, they had actually evolved to best suit the environment in which they were used and other, more complicated and standardised, designs would not necessarily have proven advantageous, let alone able to cope with the difficult and localised terrain of the Hebrides.

2.3.3.1 Plough Cultivation- *'crann-Nan-Gad'* and *'crann ruslaidh'*

Land to be prepared for the seed grain, was tilled from the beginning of March to the middle of May (MacDonald, 1811). Although recommended by MacDonald (1811), no autumn or winter tillage was ever practised, but this is understandable in an open field system, where the animals graze on the arable land over the winter months.

The ordinary horse drawn plough was employed where at all possible, which in the Hebrides was a variation on the mainland Old Scots Plough, a lighter form called in Gaelic the *'crann-nan-gad'*. This was adapted to rocky conditions and shallow soil, the predominant local conditions. The front end of the beam skidded along the ground, making it easier to lift over obstacles such as stones, and the share with its broad cutting feather allowed the implement to carve off shallow slices of earth. It was quite a labour intensive device, needing four or five horses in the traction team, and two people to control it, an indication of the communal nature of such ploughing (Fenton, 1976).

The *crann-nan-gad* was often worked in unison with the *'ristle'*, Gaelic *'crann ruslaidh'*, of Norse origin, suggesting its antiquity (Fenton, 1976). It was very simple in construction consisting of an iron blade, like a plough coulter, that was mounted into a wooden beam. It was worked by only one or two horses, pulling it from the front with one man to guide, while another man walked alongside to control the direction using the handle fixed at the rear. The effect was to slice through the earth, cutting the mat of roots and vegetation that often built up on waste or fallowed land, and which was especially tough on the sandy machair. The narrow channel it produced prepared the way for the *crann-nan-gad.* (Fenton, 1976).

The *crann-nan-gad* was only a recent introduction to Lewis around the time of Walker's tour (Walker, 1764-1771) yet was used frequently in Harris and the Uists. The *ristle* likewise is found all over the Hebrides, except possibly Lewis (Walker, 1764-1771), and therefore coincides with the main oat producing areas of the Hebrides (Fenton, 1977). Both of these ploughs relied on communal activity to use them most efficiently. The teams employed were large, regardless of the implements' slightly small size compared to mainland ploughs, which is why they are often criticised, in the historical documents written around the time of the 'improvements', as being one deterrent to agricultural improvement (MacQueen, 1837).

The shallow cultivation beds, where the seed was sown on the surface and then covered by harrowing, helped to prevent sand drift, as the root mats holding the soil together were not disturbed as much as they would be by deeper ploughing (Grant, 1979). Weed infestation has always been a big problem and, despite the frequent manuring, the crop was usually so full of weeds that the yield was impeded more than by harsh climate alone. Perennials, causing most trouble, are couch grass and silverweed; and the annuals comprise charlock, runch and corn marigold (Grant, 1979). The type of cropping on the machair, often with periods of fallow, and the shallow cultivation do nothing to counter, and if anything encourage, weed growth (Grant 1979).

2.3.3.2 Spade Cultivation- *'cas-chrom'* or *'cas tilgidh'*

In many areas the land abounded with natural obstacles, thus impeding the use of the drawn plough. In such cases the *'cas-chrom'* , meaning *'crooked leg'* or *'crooked spade'*, was an invaluable implement. Essentially a foot plough, this simple looking instrument was effectively adapted to break up earth consisting of solid peat, interspersed with rock and small stones, and to till areas that drained badly, in preparation for almost any crop. Once tilled the usual choices and methods of manuring and cropping applied (Fenton, 1978).

The *cas-chrom* consisted of a stout curved wooden handle, usually of oak or ash, about 1.6 m to 1,8 m long. This was set at an obtuse angle (approximately 120°) into a straight wooden footpiece, some 0.8 m long, and tipped by a rough iron coulter of quadrangular form. A strong wooden foot peg was inserted at the junction of the shaft and head, used for driving the blade into the soil when in use. With strong leverage and a certain knack, the sod was flipped up and over, always to the right. The movement was repeated one step backwards, and so on to complete the furrow (MacDonald, 1811; Beveridge, 1911; Hamilton, 1963).

A different form of *cas-chrom* also existed, the *'cas-direach'* or *'straight leg'* . This had a much slighter bend, and was seemingly obsolete by the time Beveridge (1911) visited the islands. These implements are equivalent to the *'delling spade'*, of the Orkneys and Shetland Isles, as described by Fenton (1978a), each being simple types of footplough.

MacDonald's thorough research into all forms of indigenous Hebridean agricultural implements rated the *cas-chrom* extremely highly, as an effective means of tilling mossy and boggy ground, where no horse could walk, and stony ground inaccessible to ploughs (MacDonald, 1811). After careful comparison of a variety of circumstances and places, he ascertained that:

> *"12 labourers will turn an acre of land in a day with the caschrom, and that so completely, that the operation is nearly equal, in effect of pulverising the soil, to two ordinary Hebridean ploughings."*
>
> (MacDonald, 1811 p.152).

If used in conjunction with the *ristle*, the team could be reduced to ten men per acre. The *cas-chrom* was especially efficient when used in unison, but was equally feasible as an effective means of tilling on an individual basis, playing an important role within single family farming units. Examples show that it was possible to support a family by *cas-chrom* alone:

> *" He can till in one day as much ground as will sow a peck of oats; and if he works tolerably from the end of January till the middle of May, he will cultivate ground enough for supplying himself and a family of six children and his wife, with meal and potatoes all the year round. This is done without any expence, but merely the half crown paid once in 10 or 12 years for his caschrom"*
>
> (MacDonald, 1811 p.153).

Although extremely effective as a means of working this type of poor uneven ground, it was still labour intensive to use and, therefore, not so advantageous on level land, unless to dig the first furrow when reclaiming it from waste. MacDonald (1911) calculates the relative financial merits of the foot plough versus the horse drawn plough and concludes that, where the larger team plough could be employed, it was a better financial option. This assumes that an ordinary plough would be available for use, which was usually the case due to communities sharing such large items of equipment. This was not the case everywhere, however, according to documentary evidence for, on Lewis, Walker reports the scarcity of

> *"any instruments of agriculture, but the Carschrome, which is a crooked spade, and a little Harrow with Wooden Teeth which is drawn by a man"*
>
> (Walker, 1808 p.127).

If the ground were to be tilled by hand, the *cas-chrom* easily proved it's superiority to any common trenching spade that penetrated the ground perpendicularly, due to ease of use and the long length of clod it was possible to lever over. The design and strength of the implement allowed stones of up to 200 lbs to be levered out of the soil. With an improved coulter, these factors make the *cas-chrom* ideal for the cutting of drains, another practice highly recommended by MacDonald (1811), but at that time not common in the Hebrides.

A characteristic, noted repeatedly in the documentation, concerns the higher productivity of land tilled by *cas-chrom* (e.g. Darling, 1945). This factor would offset the labour intensive nature of the implement: for example, although a man working from January to April could only deal with 5 acres of land, the yield would be 5 seeds per seed planted, compared to only 3:1 from ploughed ground (Hamilton, 1963). Martin (1716) refers to this fact for both Lewis and Harris, describing the locals as very industrious in the task of spade digging, some 500 people being employed daily for some months:

> "*This way of labouring is by them call'd Timiy ; and certainly produces a greater increase than digging or plowing otherwise*
> (Martin, 1716 p. 3).

A peculiar, although consistently stated, fact was that when the crop failed, it failed totally. This was reiterated to MacDonald throughout the northern Hebrides, with no satisfactory reason given (MacDonald, 1811).

While especially suited to and latterly most associated with the cultivation of potatoes in lazy beds, the origin of the *cas-chrom* may predate the introduction of the potato to the Hebrides, although precisely when it was introduced is unrecorded. The 'Old Statistical Account' for Sutherland describes the *cas-chrom* as: "*of great antiquity*" (1793, vol vii pp.288-289), and MacDonald describes the implement as, "*probably the very oldest tool known in these districts. It has been in general use from the most ancient times*" (MacDonald, 1811 p.151). As Beveridge (1911) points out, since both these references date to a period when the potato had not been cultivated for more than 70 years in the Hebrides, greater antiquity for the *cas-chrom* itself is implied. Either way, it is an extremely important implement, of great simplicity yet great effectiveness, due to being so well adapted to demanding terrain. All writers and observers seem equally impressed, to the extent that MacDonald had already introduced it to a wine district in Hungary, where the implement was successfully used on the hard rocky ground; and he also recommends it for the West Indian colonies (MacDonald, 1811 p.154).

2.3.3.3 Harrowing

The land was harrowed once, and this immediately succeeded the broadcasting of the seed, so that the harrowing served to implant the grain affording it a little protection (MacDonald, 1811). Harrows were simple in design, made entirely of wood, and usually pulled by hand across the fields. Martin (1716) describes the harrows in use on Lewis:

> *" They have little harrows with wooden teeth in the first and second rows, which break the ground; and in the third row they have rough heath, which smooths it. This light harrow is drawn by a man having a strong rope of horse-hair across his breast"*
>
> (Martin, 1716 p.3).

Buchanan (1793) describes an alternative method, where the implement was drawn by a rope or thong, fastened to the tail of the horse. The primitive harness consisted of ropes, backbands, and traces made of twisted horse hair, cut from both the mane and tail. Sometimes, instead of ropes for the halter and harness, sticks and birch were twisted and knotted together *(Hamilton, 1963).*

Beveridge (1911) noted the occurrence on North Uist of the *'racan'* or *'clod breaker'* (*'racan-buntata'* or *'potata rake"*), a different implement, although seen in regular use on soft ground as a substitute for the harrow. This was a strong, heavy, wooden rake, with a handle 1.2-1.6 m long. The head was sharpened at both ends, and along the middle it was fitted with six or seven thick teeth. According to MacDonald (1811), the teeth continually broke or loosened from the head, a factor he considered detrimental to efficient use.

Beveridge also described two implements, both *ca.* 1 m in length, specially designed for joint use in the planting of potatoes, particularly in connection with lazy beds. The first was a rake, similar to the *racan*, but with a blunt-ended head and only four teeth, and the second was effectively a long handled dibbler, with a pin fixed in the side to function as both treader and stop. In North Uist, the Gaelic for dibbler is *'sliobhag'*, but in Harris and Skye it is known as *'pleadhag'* (Beveridge, 1911).

2.3.4 Harvesting and Crop Processing

2.3.4.1 Harvesting

Throughout the Hebrides, according to the historical documents, the common method of reaping the crop was to up-root. Buchanan (1793) and Martin (1716) both report this method, notably for barley.

Later, the sickle was commonly used for cutting the crops (MacDonald, 1811; Hamilton, 1963), despite MacDonald's strong recommendation that the scythe would be preferable to the sickle, owing to the scarcity of straw and fodder, and due to the lightness of the crop. In his description of the barley harvest, MacDonald (1811) recorded that one labourer, for every five reapers, would follow and tie the crop into sheaves, or *'dorlach'* (*ca.* 30 - 35 lbs each), using bands or strings made of the longest barley culms. These were then placed heads upright, and left until the evening when they were grouped into *'threaves'* (small stacks). If the weather was bad they formed narrow rectangular stacks instead, known as *'dash'*, approximately 3- 3,5 m long, 1,8 m high, and 1.2 m broad. These were designed to aid the drying of the grain, for the corn ears were placed in the centre, where they received air but avoided rain.

The crop was left *'dashed'* for 2 to 3 weeks, and then taken to a dry part of the field where it was stacked cylindrically, with a cone on the top, typical of hay stacks. When all the crops were harvested, the big stacks were finally taken on sledges, carts or horse back to the stack yard of the farm, a process named *'croghadh'* and one attended with great festivity (MacDonald, 1811). Virtually the same operation was applied to the other grain crops, but the different cereal types were stacked and moved separately.

The sickle is recorded by Buchanan (1793) as being used to cut oats and the grass hay. The hay was carried on the backs of horses where they could be employed, and where not, on the backs of women and men.

2.3.4.2 Threshing, Winnowing and Drying

Buchanan (1793) describes one flail as a hand staff and a short supple length of tangle, but there were many variations in the form a flail could take. According to his account, the oats and barley were threshed by the women. When the straw was needed for thatching, and was most useful with as long a cum as possible, alternative methods for threshing were employed. One technique, known in the Hebrides (Fenton, 1976), was to rub the corn head, called ''. The operator would stand with one bare foot on the knotted part of a sheaf of barley, and insert the other foot under the ears and rub until the grain had worked loose. This was a method better suited to barley owing to the difficulty in removing the grain from the chaff (Beveridge, 1911; Fenton, 1976). Oats generally fell out with a good shake, but if they did need loosening, a notched stick *'maide froisidh'* was banged against the upturned sheaf. Even more simple was for the whole sheaf to be knocked against a resistant object, possibly a stone designed to protrude from the wall of the barn (Fenton, 1976).

The winnowing operation needed a gentle draught of some sort in order to blow away the chaff and broken straw *'sheelings'* from the heavier grain (Fenton, 1976). This could take place in barns with two opposing doors, or a door and a wall opening, to produce a through flow of air, or outside in places where the breeze would not be too strong. On South Uist, the corn was taken out into the fields to be winnowed because the little barns had no back doors to let in the wind. In some instances they had no barns at all (Buchanan, 1793). The method of separating the straw from the grain was to let the threshed corn fall slowly from a sieve or basket, or by letting the grain and straw fall from the hands, whilst exposed to the draught. By doing this, the chaff was blown backwards and the clean grain dropped to a skin or cloth on the floor. Owing to the nature of barley, with the tough awns attached to the grains, a further process of *hummelling* was necessary to remove the awns (Fenton, 1976). This could be done with the feet, or by using a plunger of some sort, or even with a flail (Fenton, 1976).

Sieves were made out of sheep skin, and used during the winnowing operation or, after grinding, when the meal was sifted onto plates made of grass or onto large goat skins placed on the floor. This latter procedure was carried out in the evening and morning, when they had ground as much grain as their diets required (Buchanan, 1793 p.22). Buchanan (1793) noted the small size of the kilns used on South Uist for drying grain. In this area, rather than spread threshed and winnowed barley grain on a layer of straw inside the kiln, they cut the ears off the barley and lay them in order upon a framework of bare ribs, as Walker (1764-1771) also implies was the practice in North Uist. Once dried,

> *"they are hauled down on the floor, and immediately thrashed, and winnowed, and 'clapt' up hot in plates, ready for the quern"*
>
> (Buchanan 1793, p.22).

2.3.4.3 Grinding

Very often, especially when only small amounts of corn were produced, grinding was done at the farm house on the quern. Two distinct types of quern were noted by Beveridge (1911), the first consisted of two round flat stones, the upper one being turned by hand using a stick placed vertically in a peripheral hole, whilst the grain was poured in through a central hole. The second type was the 'saddle quern', formed of two oblong stones, the smaller, upper one of which was worked to and fro over the grain that lay in a hollow groove of the lower stone. A third variety, called *'abrach'*, was noted on North Uist. Smaller in form than the other two varieties, it also differed lithologically. The softer material in the stone could be washed out if set under a waterfall overnight, and left the surfaces roughened (Beveridge, 1911).

Later, the grinding was done at the mills, where the mill-stones were moved by water power. Mills were owned by the landlords, and tenants were 'thirled' (tied) to a particular mill and had to pay 'multures', a heavy payment which might amount to one twelfth of the unground corn, besides paying about one forty-eighth of the meal after grinding. The payment to the miller was separate and consisted of a certain quantity of meal out of every measure. That the miller was the most hated man in the parish is not surprising, especially as his opportunities for fraud were numerous. To dry oats in preparation for making oatmeal the straw, whilst in the sheaf, was burnt, which resulted in blackened grain but did not affect the taste of the meal (Buchanan, 1793).

2.3.5 Pasture and Hill Grazing

2.3.5.1 Organisation

The arrangements for the sharing of pasture land within townships in the Outer Hebrides are unclear, although it seems likely that, where cultivated land was held in common, so too would have been the pasture of the township (Shaw, 1980). The rough hill grazing and the sheilings were communally held and the move to the summer pastures was based on community organisation. Beveridge (1911) noted two alternative names for pasture in North Uist, that also occur in other places. From the Gaelic name *'buaile'* or *'cattle fold'* he inferred areas representing sheilings on a larger scale, and from the Gaelic *'gearraidh'* or *'garry'*, the enclosed area of land intervening between hill pasture and arable land, he inferred common grazing (Beveridge, 1911).

2.3.5.2 The '*Soum*' or '*suim*'

The '*souming*' or *sumachadh*' was the number of animals that any one tenant was allowed to keep, a figure fixed by tradition, in accordance with the size of the holding, and designed to avoid overgrazing of the township pastures and problems with lack of fodder in the winter months. The '*soum*' or '*suim*' was equivalent to a cow and her progeny, the '*Bo le h-al*'. The number of progeny the cow was entitled to keep, however, was not the same everywhere: only one calf; a calf and a stirk; a calf, stirk and two year old quey or a calf, stirk, quey; and three year old heifer (Carmichael, 1884). The number of soums a farmer could send to the communal grazings was fixed for each township individually. Each farmer's entire stock was known as '*leibhidh*'.

If a farmer was overstocked in one species and understocked in another, then the surplus in one species could be balanced against the deficit in the other, a process called '*coilpeachadh*' in Gaelic. The same process was applied to young and old stock and, if a farmer still had more animals than he was entitled to, he had to buy grazing rights from a farmer who was understocked. The coilpeachadh varied from one island to another, but Carmichael (1884) presented a table that he believed was representative of the whole of the Outer Hebrides:

1 horse was equal to	8 foals
	4 one year old fillies
	2 two year old fillies
	1 three year old filly **and** 1 one year old filly
	2 cows
1 cow ,, ,, ,,	8 calves
	4 stirks
	2 two year old queys
	1 three year old quey **and** 1 one year old stirk
	8 sheep
	12 hoggs
	16 lambs
	16 geese

(after Carmichael, 1884).

There were still more variations on this theme. The cattle and horses were never bred from until they reached full maturity, which was at four years of age, and the names applied to each age cohort of animals was changed on the first day of winter. The number of different types of animal is not extensive, but suited the needs of the farmers and their families. Most of the species were small breeds, generally because this equated to an ability to withstand the harsh environment. Horses occur more frequently in the Hebrides than the Northern Isles, because they are the traction and plough team animals, unlike in the Northern Isles, where oxen were traditionally used for pulling the plough.

The sheep on South Uist are described by Walker (1764-1771) as having 4 or 6 or even 8 horns. MacLean (1837) reported new sheep, the Cheviot and Blackface, introduced around the time of his writing, but noted that small tenants continued with the old breed of sheep, that were small, but yielded good flavoured meat and wool which, though small in quantity, was of fine quality. Goats were well suited to the hilly terrain of the Outer Hebrides, and were able to reach areas of the mountain pasture inaccessible to the other livestock. Another reason for the popularity of goats in the Outer Hebrides was that they were less vulnerable to the fox than sheep (Shaw, 1980). (This explains the absence of goats in the Northern Isles, where there are neither mountains nor foxes (Shaw, 1980).

2.3.5.3 Sheilings

The annual movement of stock to the sheilings was usually operated in two stages, beginning about midsummer. The first step was to move the stock over the head dyke to the common grazing immediately next to the toun. Once this was exhausted, there was the *'big flit'* to the hills.

In early June, when the cultivation of the fields was completed, the farmers, their wives and families took their stock and retired to the hills for the summer to live in the shieling huts. The stock would have consisted of cattle, native sheep and goats up until the seventeenth century but, thereafter, the main emphasis was mainly on cattle (Fenton, 1980). The different families brought their animals together, so that they could be treated as one herd. The sheep led the way, cattle followed, with the younger beasts preceding, and the horses went last.

The whole assemblage while on the move was known as the *'triall'*. The horses and men would carry the equipment (bundles of sticks, heather rope, and spades) necessary to repair and re-roof the huts, while the women carried the bedding, meal and dairy equipment. On arrival at the sheiling the stock of each farmer was inspected to check he had not exceeded his souming. The men would usually return to the main farmstead once the transport of the cattle and equipment was complete, to tend to repairs at the winter bases and also to fish.

The women and children remained, living in the temporary earthen huts, tending to the flock and making butter and cheese from the produce of these rich pastures. This was a prime opportunity for them to spend time spinning and weaving. The whole operation was embroidered with custom and folklore, songs being sung for different stages of the operation. By the time of their return to the common grazings outside the township, at the beginning of harvest, the grass around the fields was replenished (Buchanan, 1793) so that the higher yields of milk could continue for a while longer, before the scarcities of winter set in.

The summer grazing areas were an essential element of the open field, run-rig agricultural system, for the annual movement of stock meant that pressure on the winter grazings was alleviated and that the herd had a new source of plentiful fresh pasture. It also allowed the crops to ripen in their unenclosed fields with no threat of illicit grazing (Fenton, 1980).

The whole use of shielings and the rich hill pastures ties in with the production, or rather lack of production, of hay. In earlier times when the shieling system was fully functioning, and true run-rig in operation, little attention was paid in the Highland and Island areas to the making of hay for winter fodder. It is noted in a few instances, especially the tufted vetch noted by Walker (1764-1771) that grew naturally in South Uist, and was good for hay and pasture. The vetch apparently had the added advantage of making the cow take to the bull more readily and earlier in the season.

Such hay as was cut tended to be reaped after the grain crop had been harvested, from the areas of boggy ground near to the settlement but, even then, it was fairly haphazard, for it coincided with the potato work and the seasonal rain. The making of more hay, to help carry cattle over the winter season, is consistently one of the improvements recommended by the agricultural writers of the time. A sown hay crop needed to be enclosed to prevent the animals from invading the crop and, as such, this did not co-operate with the run-rig system:

"under unfenced run-rig conditions, there was little profit in artificial grasses, and the crofter's ultimate solution was to change over to an economy with the main emphasis on sheep"

(Fenton, 1980 p.106).

The shieling system, and with it run-rig, largely disappeared in the first half of the nineteenth century, as the grazing areas were taken over by sheep farming (less dependent on supplies of winter hay) that proved to be more profitable to the landlords. At Loch Skiport, on South Uist, and on Lewis, the summer sheilings were noted to still be in use at the beginning of this century (Beveridge, 1911). The two were so closely interlinked, however, that if one element was removed the other could not survive in the same form and, even then, only if the nearer grazings around the township could be developed (Fenton, 1980).

2.3.6 Regulation

2.3.6.1 Community Decisions

Each tenant was responsible for his own share of rigs and the produce from them, yet few individuals possessed the resources to work the land on their own, so it was inevitably held and worked in common. This dealt with the logistical problems created by landholding on a run-rig basis (Dodgshon, 1980). The type of crop, and dates of ploughing, sowing and harvesting on their intermingled strips had to be decided; the contribution of draught animals to the community's plough, and the nature of the grazing routine had to be agreed upon and adhered to. Respectful behaviour and 'good neighbourliness' alone were unfortunately insufficient for the smooth running of the system, and the regulations had to be enforced by the local Baron or birlaw court.

2.3.6.2 The Constable *'constabal'*

The Constable (Gaelic *'constabal'*) was elected from the resident farmers, one or even two for every township, to represent the proprietor and the crofters. The post was unpopular amongst the people, and apparently a man proposed for the position would sometimes decline and another would have to be elected. The same thing might recur, to the extent that lots would be cast in order to get a man to accept office, *"the duties of which are distasteful to them"* (Carmichael, 1884). Once elected the new constable would either remove his shoes and socks or take some earth in his hands, and recite a promise in Gaelic to the effect that, by bodily contact, he was conscious of being made of earth, to which he would return. This old custom disappeared along with the agricultural system.

The job of the constable was the same in essence as the birlayman, i.e. to oversee the execution of the community regulations; hence the distastefulness of the job, for it would undoubtedly enter a personal level at times. He could always rely upon the support of his fellows, however, as and when needed.

Duties included in his job were to mark out new peat bogs, when old cuts were exhausted. The constable would then divide this new area into the necessary number of stances for the tenants of the township. In the same way that they cast lots for the rigs of land, so too they would cast lots for the peat stances, and again these would be recast every three, five, seven or nine years in case of unfair advantage. It was the job of the constable to check that each tenant contributed the relevant number of free days work to build the new road needed to reach the fresh bog.

The constable had to oversee repair work to township roads and the ditches running parallel to them, again organised on a communal basis. When, after a storm, new seaweed had been washed ashore, no farmer was allowed to begin carting the weed until his neighbours had a reasonable chance to get there too, nor would he allow a crofter to cut the weed from wherever he chose. He had to check that no horses were worked too hard in the exhausting work of carting seaweed from the shore. When he ordered them to stop, they had to cease work there and then. The constable was also responsible for buying new stock, in order to bring fresh blood into the community's herd, and for checking that each tenant adhered to his allotted souming.

2.3.6.3 Stock Management

The management of the stock was the most critical area, needing strict and careful regulation through all the various sectors of the toun, at all times of the year. It was here that the role of the birlayman or constable became indispensable, arranging for the proper herding of the animals on the settlement's common land (Smout, 1969). The constable generally regulated herding, essential as few enclosures of any sort existed, except for the temporary earthen dykes that were fashioned from the soil as it was ploughed and were insubstantial as barriers. Animals wandered around the settlement and arable plots under the watchful eye of the herdsman who, at best, attempted to keep them on the allotted pasture and, at worse, off the crops.

Beef cattle and sheep spent the summer on the rough pasture, and in the hills, and were admitted to the stubble after the harvest. They could remain there all winter until spring, after which time all animals had to be removed from the arable lands lest damage be done to the crops. The dates for releasing and controlling the animals, and the areas where they could graze, had to be adhered to. Any selfish farmers who disregarded the community regulations were brought to reason by the constable.

The milk cows and horses were generally kept closer at hand nearly all the year round. They would be tethered, to the weedy baulks between the ridges, or put out to the pastures nearer the settlement, which were often of better quality (Fenton, 1976). The winter was the most desolate time of year for all the farm animals. A time when many were killed or sold, so that the meagre food resources could be stretched a little further. It was a case of eating anything that could be found, supplemented with a small amount of fodder or seaweed. The animals were so weak, when the grass on the pastures began to grow, that 'Lifting Day' became established as a date when the people would carry their animals from their homes and byres to the pastures.

The operations involved in the 'big flit' were made easier by regulating the souming and consequently the size of the common herd, thereby allowing better control of stock movements. This was especially important over the head dyke, the crucial line that separated the settlement and arable land from the common grazing, spatially separate units yet all essential components, the integration of which the economic balance of the farming communities relied on (Fenton, 1976).

Obviously the arable and pastoral activities were complementary to, and dependent upon, one another, and were not as primitive as many writers have implied, when looking at the system from the angle of 'improved farming'.

> *"It was a highly-sophisticated, long-evolved response to environment and resources"*
>
> (Fenton, 1987 p.18).

that had developed,

"a kind of ecological cycle that could conserve resources, as long as it was not pressed too hard by factors like population growth"

(Fenton, 1987 p.18).

All of the resources were channelled through the system in a cyclical manner, converting from food source to manure to food source again, the only items that left the system resulted from over-production, either surplus stock or crops which could be used to pay the rent and buy extra fodder and other necessities that could not be produced on the farmstead (Fenton, 1987).

2.3.7 Other Industries

2.3.7.1 Fuel

With the present almost total absence of any wood, other than drift wood, on the Western Isles, peat, plentiful on most islands, has recently formed the main source of fuel. An essential task of each family was the cutting of enough peat, approximately 50 - 60 loads, to maintain a single fire throughout the whole year. Beveridge (1911) estimates it would take one man a full month's work to cut, dry, and stack this quantity of peat. Usually, however, two neighbours would cut peat together for 10 days, using peat spades or *'treisger'*. These were specially adapted to the purpose of cutting uniform blocks of peat. Each man would then allow 4 days for the drying and turning of the fresh peats, and another 14 days to transport his own share home from the peat-hag.

Some low-lying, sandy islands such as Heiskeir, were relatively deficient in peat and, to compensate, the inhabitants were allotted peat stances on North Uist. In August boats were brought over from the islands to cut and collect peats for the following year. Fuel was sometimes still a problem, as noted by Martin (1716), who reports the burning of cow dung, barley straw and seaweed on Heiskeir, when fuel was scarce. On Heiskeir, bread baked with seaweed was considered superior in taste than when baked on a normal peat fire, and the ashes of barley straw were used for the salting of cheese (MacAlpin, 1969).

2.3.7.2 Fishing

Fish abounded around the shores of the islands and served to supplement the diets of the people, when time was available and the weather permitted. The latter was a perpetual problem, especially as landing on the west coast was hindered by the dearth of harbours, and consequently fishing was not established as a main industry until later years, and much of the fish for home consumption were caught close inshore and from rocks.

Rods with fixed lines, flounder spears or '*brod-leabag*', round '*poke-nets* ', conical nets called '*tabh*', and even blankets sewn end to end, were all used to catch fish from coves, river mouths and streams (Fenton, 1976). The *tabh* were placed within a '*cabhuil*' or dam made from small stones, piled in the bed of a narrow burn, into which the fish were driven as they swam downstream (Beveridge, 1911). The flounder spears were used by the women, who waded in the shallow tidal runs at the ebb of spring tide and used their feet to feel where the flounders lay half covered by sand (Beveridge, 1911). Commonly found upon the rocks were the 'shell-bait basins' or '*toll-solaidh*', which were hollows in the rocks 120- 150 mm wide, and 70- 120 mm deep, used for pulping the shellfish into suitable bait. Hammer stones were frequently associated with these places (Beveridge, 1911).

Species known to have been fished were herring, ling, cod, mackerel, turbot, skate, and flounder, but the coalfish were the main catch from the inshore regions where the '*craig-fishing*' or rock fishing was practised. The catches of these fish were especially good towards the end of harvest, and were noted to provide oil as well as food, as recorded for the people of Broad Bay and Canna in Lewis (Fenton, 1976). The lochs provided more accessible fishing grounds, and were also less weather dependent, the most common fish being salmon and trout. In general, July, August and the beginning of September were the most successful times to fish, according to MacLean (1837). Inhabitants on the east coast of South Uist, near Loch Eynort, were noted by Martin (1716) as using ashes from burnt seaweed as a substitute for salt, for preserving mackerel, which sometimes came into the sea lochs in large shoals.

There was also an abundance of shellfish such as lobster, crabs, cockles, oysters, mussels and spout-fish (Munro, 1798). Cockles were noted for their abundance on the shores of North Uist, Benbecula and South Uist. They were collected every summer, but especially in years of scarcity, when cockles may have been the only food for two months (MacLean, 1837). Cockle-shells were sometimes burned whilst encased within layers of peats, to provide lime and plaster on buildings (Beveridge, 1911).

Seals were also utilised by the islanders. The flesh, known as *'carr'* in Gaelic, as was whale meat, was eaten by the people of Uist in the past (Carmichael, 1884), and most likely by people from other islands. This is confirmed by an old proverb:

> *"Good food it is for sea-weed worker,*
> *Rye bread and blubber of seal"*
>
> (Carmichael, 1884 p.262).

The blubber was cut into long thin strips and had a weighted board placed on the top in order to press out the oil. The oil was used as lighting fuel, and the seal skin was used for making harnesses, bridles (Beveridge, 1911) and shoes (Buchanan, 1793).

2.3.7.3 Cloth

The making of cloth, mainly linen, was a cottage industry in the eighteenth century, but previously had been organised for family needs. Linen was woven from locally grown flax, and hemp was also cultivated and used for cloth, but the most commonly produced materials were woollens and tweeds. All stages of the operation were carried out according to local technique and tradition, from the plucking of the wool from the backs of sheep (noted for Lewis by Martin, 1716), through the carding, spinning and dyeing of the wool, to the weaving and waulking (shortening and thickening) of the cloth. Many descriptions of these processes occur in the historical literature.

The looms used for weaving were either horizontal, or of a smaller, upright design, which would have been easier for transporting, presumably on moves such as those to the summer grazing bases. The equipment was mainly wooden, except the little pirns that acted as bobbins inside the shuttles, which were commonly made of either sheep metapodials, quills or the stems of hog weed (Beveridge, 1911).

2.3.7.4 Plant Materials

Marram (*Ammophila arenaria*) was abundant on the sand dunes and machair regions of the west and north coasts of the islands. Good growth of marram was noted especially for Heiskeir, from where it used to be 'exported' to the main islands. The tough grass was used for many purposes including ropes, mats, baskets, chairs, roofing and for the padding in horse collars. It was also used for making sacks, *'plata-shil'* or *'plata-mhuilinn'*, which were still made and used at the beginning of this century on Heiskeir, for carrying grain and meal to the mills. Marram produced a thick fabric, that was particularly well adapted for this purpose, being impervious to the sea spray and rain (Beveridge, 1911). Marram was planted on unstable sand dunes, from at least the nineteenth century, to prevent blow-outs and sand drift, as recommended by many observers (Beveridge, 1911).

Sedge roots (*Carex flacca*) were used for thatching (Walker, 1764-1771), making tethers, which proved to be extremely strong, and the *'tabh'* fishing or poaching nets. The conical nets were woven with a 25 mm mesh, were 1.2 m long and 0.5 m wide at the top tapering to a point.

Heather was commonly used in thatch. When laid above marram it was considered a long lasting combination, but rushes and iris leaves could also be used. Heather was another plant material from which strong rope was twisted. This was preferred for the thatch fastenings, also used for boat ties, and general rope for use on the farm. Poaching nets could be made from heather rope, but this proved to be a time consuming operation (Beveridge, 1911).

Plants and plant by-products were used for dying the yarns and cloth produced on the islands. Lichen or *'crotal'* gave reddish brown colours; heather tips combined with iron sulphate, rue, and peat soot produced yellows; heather tips gave green; iris root, grey; and *'lus-mor'* meaning 'big herb' produced blues. Not indigenous, but used to produce pale greens, were tea leaves.

2.3.8 The Imposition of Crofting

The crofting system was created between 1814 and 1818, and was steadily introduced to the Western Isles during the first half of the nineteenth century. The aim was to improve agricultural standards by giving each tenant farmer a longer lease on his 'own' land for a 'useful' length of time, to encourage investment of time and labour in the new techniques believed to be beneficial to the farmer, the landlord and the land. The second purpose was to encourage the farmers to stay on the islands, in particular near to the coast, and thereby secure the landlord a workforce to process the lucrative kelp.

Blackadder, who was commissioned to survey the estate on North Uist, advised that:

"As kelp is the staple of the country, the encouraging of a number of the inhabitants to settle or remain in it, is the sure means of keeping up the advantages and Revenue to be derived from the manufacture of that Article. But the improvement of the land cannot be affected or brought about while the present system of run-rig possession exists......But if everyone had his separate share of the arable land inclosed with a comfortable house built on it, and......by ensuring the possessors the full enjoyment of their extra labour and improvement by terminating that careless method of dressing their fields, which now disgraces the Husbandry of the Island."

(Blackadder, 1800 pp.131-3 in Caird 1979)

This changed the traditional system, for the whole essence of run-rig, with the rotation of tenancies, meant that individual farms were never enclosed as separate units. Once the land was packaged into separate holdings, the traditional nature of the agricultural activities was altered, where previously it had been mainly communal, in terms both of the spatial organisation of the land, and the organisation of people. The whole tenure of the land was altered, each tenant being given his own strip of land to work that stretched from the blackland down to the machair coast and, in this way, giving each an area of both arable land types, but preventing any form of land rotation. An area of common grazing still existed on the hill side but was much reduced compared to the extensive grazings of previous years (Caird, 1979).

This arrangement was intended to give the incentive to the tenants to farm their land and maintain their property more 'conscientiously' but a lot of the tenants' time was taken up by processing kelp, which occurred during the summer and part of the autumn. The land also suffered, as there was less seaweed available for fertilizing the fields. Thus the good husbandry recommended by Blackadder (1800) was not carried out because, as kelp prices and cattle prices dropped after the Napoleonic wars, the new, and increased rents, were even more difficult to meet. Much of the old pasture land, within the former townships, was brought into cultivation, in order to cope with expansion in population (Caird, 1979).

The second change in the island way of life was the formation of many large farms in the nineteenth century, for the purpose of sheep grazing. This proved a more profitable way of raising money from the estates than by extracting rents from the tenant farmers via the tacksmen. The result was devastating, for whole families were moved, from their homes of centuries, and either squashed onto the crofts of relations, where there was insufficient land to support the enlarged number of people, or they were put onto crowded boats and sent to the new world, where many died in transit. For those who remained (and managed to survive the potato famine), there was a complete change in the organisation of their farming and previous economic system.

CHAPTER THREE

FIELD METHODS

The programme of field investigations comprised a dual methodology that incorporated the collection of ethnographic data, by interviewing farmers, and the collection of material for laboratory analysis, by sampling deposits representative of traditional agricultural activities.

3.1 Ethnographic Data Collection

Ethnographic data was required to further the understanding of the agricultural system characteristic of the southern Outer Hebrides, as developed in accordance with the particular environmental and social conditions unique to the region. Clarification of the remnant techniques and recent adaptations incorporated in the contemporary farming system would contribute to comprehension of the strategies and logic underlying the agricultural practices. Field observation and interview provided the means for primary data collection and a format was devised that delineated the relevant interviewees and subjects suitable for investigation. The information yielded in the verbal accounts would also contribute to site selection, for excavation and sampling, as outlined in the second stage of the field methods (section 3.2).

3.1.1 Interviewee Selection

To gain comprehensive information, a wide range of Hebridean farmers and croft occupants were interviewed. The interviewees were selected on the basis of experience and classified according to geographical situation, age and gender.

3.1.1.1 Geographical Situation

Interviewees were chosen who possessed direct agricultural experience from different geographical locations spanning the Uists and Benbecula. In particular, information was gathered from both the west and east sides of the islands in order to compare the agriculture practised in the two notably contrasted geographical areas. Consequently, the specific techniques evolved in response to different land types could be determined. To complement the information obtained by interviewing, the remnant fields and contemporary areas of cultivation were assessed in each of the geographical locations. Land types, crops and techniques were recorded by descriptive notes, illustration and photography to enable cross-reference with the verbal accounts.

3.1.1.2 Age

The depth and diversity of agricultural experience accumulated by an individual was influenced by the period and duration of farm occupancy and was, consequently, related to the age of the individual. Interviewees were selected from the older generation, to obtain information regarding the traditional techniques, many of which are now obsolete. The older generation, therefore, represented a unique source of valuable but diminishing ethnographic information, to which much of the inquiry was necessarily directed. Interviewees were also chosen from the younger generation of farmers, to obtain details of agricultural systems currently in operation. The information would clarify the remnant traditional methods, where these were incorporated, and detail the nature and logic of recent adaptations. A comparison of past and present techniques would indicate the most influential factors determining the development of the agricultural strategies, in relation to a fairly constant environment but dynamic economic and social forces.

3.1.1.3 Gender

Both male and female interviewees were selected to avoid the misinformation, regarding gender related activities, that differences in perception and experience may introduce. The details obtained from both parties were compared in order to clarify the specific roles of men and women on land and farmstead. In turn, the correct source from which to obtain the most direct information concerning each activity was identified and the inaccuracies introduced by biased perception were minimised.

3.1.2 Interview Techniques

To increase the reliability of information through repetition, the same questions were posed to many people. The same individual questions were also asked in several different ways to ensure that the correct answer had been obtained. The relevance of the interviewees was taken into account, with regard to the specific topic of interest. The first hand experience of the interviewee was of prime importance, particularly in an area where most people have general knowledge of all community activities. This problem is particularly acute in an area such as the Outer Hebrides which has been the subject of several historical and anthropological studies, of which the present inhabitants are broadly aware. Actual farmers, past or present, would provide more direct and reliable information regarding agricultural practices, than people indirectly associated with farming activities; older people would provide more reliable information regarding the older and obsolete techniques and the gender most associated with particular tasks would provide direct and more reliable information regarding those activities. It was often possible to interview two generations within the same family, which offered a particularly good opportunity to cross-check the experiences of individual interviewees.

3.1.3 The Interview

Three subject areas were outlined for investigation pertaining to, first, resource management, with specific reference to land treatment; secondly, cultivation regimes and, thirdly, the agricultural and domestic practices associated with the farmstead and produce management, with specific reference to crop processing, waste disposal and stock control. A framework of questions was established on which the interview was initially based. Many of the questions were closely inter-related and subjects commonly overlapped; tangential inquiry was also accommodated when new information warranted closer examination.

3.1.3.1 Resource Management

Questions were posed regarding land, crop and fertiliser types in order to establish the resource management and utilisation strategies. The availability of land resources was indicated by the composition and size of the croft, in terms of land type and respective acreage. To establish the influence of land type and environment on crop viability and selection, the range of crop species and their cultivation sites were recorded. The value of each crop type was assessed as indicated by the function, cultivation preferences and tolerances, and the time and period of growth. To assess the availability of fertiliser the source, quantity and labour requirements for each type were investigated. The value of each fertiliser type was indicated by utilisation in association with land and crop type.

3.1.3.2 Cultivation Regimes

To establish the relationship between the available resources and crop production, the cultivation regimes were investigated. The pattern of land utilisation was indicated by the location and acreage of land allotted to arable and grazing in each year. To establish the existence and nature of a system of rotation the crop type, method of tillage and method of fertilisation were recorded for each successive year of cultivation and for each land type. The importance of land type was, therefore, reflected by the frequency of cropping and the length of fallow, whilst the importance of crop type was associated with the year of cultivation in the rotation, the site, use and magnitude of production.

The calendar of agricultural events required investigation in order to relate resource management to cultivation strategies and, on a wider scale, to inter-relate crop production with the farmstead activities. The times of fertilisation, tillage, planting and harvest were recorded for each crop type, as were the methods of harvest and drying prior to storage of the crops on the farmstead. Land utilisation between periods of cultivation was investigated and, where possible, tied into the system of rotation. The investigation into resource utilisation and cultivation regimes was also directed at the movement of materials within the agricultural system in order to trace the cycling of resources and link production and consumption activities between the land and farmstead

3.1.3.3 The Farmstead and Produce Management

To establish the nature of produce management, the agricultural and domestic activities associated with the farmstead were investigated, with specific reference made to crop processing and stock management. The timing and duration of activities was recorded in order to construct a calendar of agricultural events. The movement of materials and by-products associated with the activities was also recorded, to trace the consumption and disposal of produce and, in turn, complete the record of resource cycling. For each crop type, the inquiry aimed to establish the precise details of the method and routine of crop processing, from the initial stages of storage on the farmstead, to the production of meal, fodder or seed corn. The location, time, length and frequency of activity, and the quantity, use and disposal of all related by-products, were recorded in each instance.

The method and routine of activities associated with stock management were investigated, including the grazing, stalling, feeding and milking of cattle, the disposal of byre waste and the subsequent midden formation. The number of animals; the location, time, length and frequency of activity, and the use or disposal of all related by-products, were recorded in each instance. The details of all other activities associated with the farmstead were investigated including the management of gardens, the maintenance of buildings and the acquisition of fuel and additional food. The provenance, use and disposal of all materials and by-products was recorded in each instance to complement the details regarding the cycle of resources.

3.2 Sample Collection

Samples were required which represented a range of deposits, accumulated as a result of known agricultural and domestic activities, and which possessed suitable properties which could be used to trace the cycling of materials through a traditional agrarian system.

3.2.1 The Selection criteria

The strategy devised for the evaluation of sample suitability incorporated three levels of criteria that defined the preferred attributes on which the selection of samples was based. The three categories of selection criteria pertained to sites, contexts and material types.

3.2.1.1 Site Selection Criteria

i) Traditional agricultural practices.

Sites which demonstrated traditional agricultural practices provided the opportunity to investigate systems that evolved in direct response to the local resources and environment and which, therefore, may provide greater comparability to ancient agricultural practices. Non-traditional farms also provided the opportunity to study specialised systems but the archaeological comparability was lessened by modern adaptations. Also, the farms must have been occupied for long enough to expect activities to be registered in the pedological record.

ii) Maximum contextual diversity.
Sites with a wide range of contexts represent a greater diversity of activities and, therefore, provide the opportunity to investigate the agricultural system more comprehensively. Duplication of contexts available for comparison increases the reliability of identification and differentiation between functional areas.

iii) Minimal re-use and contamination.
The re-use of activity areas, particularly buildings, during site occupation and post abandonment is common and would provide authentic archaeological comparison. Multiple function would, however, potentially mask the detection of characteristic soil properties and contexts which might distinguish different areas and activities. Multiple function and other forms of contamination were liable to introduce undesired analytical and interpretative complexity and, therefore, sites with a simplistic history of occupation were preferred.

iv) Maximum information regarding site history.
Detailed information regarding all activities conducted on the site, including agricultural and domestic practices, was essential to gain full comprehension of all factors influencing the process of site formation and, thereby, to complement the analytical studies pertaining to the cycling of materials. Information was required on the method and duration of agricultural practices and all other site related activities. Additionally, accessible and precise information was required regarding the post abandonment activities in order to establish the occupation and post occupation history. The personal experience of the site occupants was the preferred source of information but, where unavailable, details were obtained from alternative informants in possession of direct knowledge of activities specific to the site in question.

v) Maximum site accessibility.
Sites with limited physical obstructions were required in order to minimize the restrictions to excavation and sampling.

3.2.1.2 Context Selection Criteria

i) Traditional contexts.
Contexts which represented traditional agricultural and domestic activity areas were required, in order to trace the cycling of materials within a traditional agricultural system. Contexts with known correlates in the archaeological record would provide analogues with greater potential for use in the interpretation of ancient deposits.

ii) Minimal reuse and contamination.
Contexts demonstrating minimal re-use and contamination were required, in order to avoid analytical and interpretative complexities.

iii) Maximum contextual information.
Detailed information was required with regard to all context related activities, in order to complement the analytical studies pertaining to the cycling of materials and clarify the extent of re-use and contamination. The personal experience of the site occupants was the preferred source of information.

iv) Maximum accessibility.
Contexts with limited physical obstructions were required in order to minimize the restrictions caused to excavation and sampling.

3.2.1.3 Material Type and Soil Property Selection Criteria

i) Maximum levels of information from minimum investment of time and expertise.
The analysis of certain material types and soil properties represented a potentially rich source of information but required high investment of time and specialism. Many alternative analyses would provide equally useful data yet involve less specialised and, consequently, less expensive techniques. Material types were, therefore, selected that potentially yielded the maximum quantity and quality of information from the minimum time and expertise expended in analysis.

ii) Maximum viability.
Material types and soil properties were required that demonstrated least susceptibility to the many taphanomic and pedogenic processes in operation within the soil, in order to maximise the long term viability necessary for the formulation of reliable archaeological analogues.

3.2.2 Final Selection

On the basis of the selection criteria, the suitability of potential sites, contexts and material types/soil properties was evaluated for inclusion in the final sampling strategy. The inability to satisfy all proposed criteria was anticipated and, therefore, the final selection served to maximise the information potentially attainable yet incorporate an efficient and practicable field methodology.

3.2.2.1 Site Selection

A survey was conducted covering the Uists, Benbecula and Heiskeir to register crofts that demonstrated provisional suitability as the location for sample collection. On the basis of the defined criteria, the potential of both operating and abandoned crofts was initially determined. Traditional agricultural systems occurred most commonly on the older, abandoned crofts and were usually associated with a greater diversity of traditional contexts types. Conventional agriculture was practised by some small scale, currently operating crofts but the occurrence of a completely traditional system was infrequent. Semi-traditional agriculture was the common alternative, where remnant features of the older system were combined with modern, labour saving techniques, but the substitution of recent adaptations consequently limited the range of traditional context types.

The extent of re-use and contamination was less dependent on the nature of the agricultural system than the duration of occupation and farming. A longer period of occupation increased the opportunity for the functional adaptation of buildings. The ex-inhabitants of abandoned crofts represented a potentially less accessible and reliable source of information than the occupants of currently operating crofts, who provided contemporary details regarding agricultural and domestic practices. The current occupation of sites, however, presented an obstacle to the practicality of large scale sampling.

A potential diversity of contexts types comprising a system of traditional agriculture was presented by the older, obsolete crofts, and fewer restrictions to excavation and sample size were afforded by the comprehensive site accessibility that resulted from abandonment. In order to retain the advantages presented by site longevity and abandonment, yet maximise the opportunity to locate reliable ex-inhabitants and obtain necessary relevant information, recently abandoned crofts were considered the most suitable category of potential sites on which to base selection. The recently abandoned crofts that demonstrated potential suitability were finally evaluated according to the balance between the minimum of evident contamination and re-use and the maximum quantity and quality of available information.

An abandoned croft at Howmore, South Uist, was finally selected due to the practice of traditional agriculture at the croft, a diversity of context types, minimal contamination and the location of three ex-inhabitants, both male and female. The quantity and reliability of information that the three former occupants potentially afforded exerted most influence during the final site selection.

The village of Howmore is situated 1 km to the south-west of Loch Druidibeg, in the northern half of South Uist (see figure 2.2). Settlement extends laterally over approximately 1 km, spanning both machair on the west coast and the lochans and blackland inland, to the east. The site selected for study, Schoolhouse Croft, is situated on a peninsular of land that protrudes westerley into Schoolhouse Loch, grid reference 766,365 (figure 3.1). The low-lying peninsula is formed of ice abraded gneiss and glacial tills covered by a shallow, inconsistent mantle of immature soils, that results in irregular patches of exposed rock typical of blackland. The low diversity of vegetation reflects the immature soils, comprising mainly peaty gleys with some peaty podzols and peaty rankers. Grasses dominate on the higher ground and the abundance of sedges increases closer to the loch edge. Immediately to the east of the peninsular, the higher slopes of moorland begin.

Schoolhouse Croft was newly constructed at the turn of the century by Mr MacKinnon. No knowledge or history of any previous settlement is associated with the particular location. Three of the MacKinnon family, who lived and worked on the croft during childhood and teenage years, provided information regarding the construction of site facilities and details of the agricultural and domestic activities conducted on the site. The croft was abandoned by the original occupants, and the associated agricultural practices ceased, in 1938. The dwelling was inhabited by an elderly couple for five years after the original abandonment, but no agriculture or associated activities were practised. In later years the late Mr Donald MacLean inhabited the dwelling for two years, but no agriculture or associated activities were practised.

The farmstead comprised three buildings, the dwelling, the byre and the barn, with a kiln, for grain parching, incorporated within the barn. Other domestic and agricultural facilities were situated in close association with the buildings, as illustrated in figure 3.2. The dwelling was sited on the highest area of flat ground and the byre and barn were terraced into a downward slope to the west of the dwelling. A stackyard was situated adjacent to the house and barn and to the north of the stackyard, a small, naturally raised platform constituted an enclosure for the cattle during the summer nights. The midden was sited directly outside the byre, on lower ground. A wall, that incorporated the house, byre and barn, enclosed the farmstead along the east, west and southern edges and terminated at the loch edge on the northern side. An internal wall, divided the stackyard from the cattle enclosure. A walled vegetable plot was located to the east of the house, outside the limits of the farmstead perimeter wall.

3.2.2.2 Context Selection

On the basis of the defined criteria, the suitability of contexts for excavation at the Howmore site was evaluated according to field observation, the information available from the ex-inhabitants and the data available from archaeological sites.

The dwelling was excluded from the excavation and sampling strategy on the basis of inaccessibility and contamination. A concrete floor in the dwelling rendered excavation impossible and post abandonment re-use as a shearing shed and wool store negated the value of sampling floor litter overlying the concrete floor. The remaining stove inside the house had been emptied of ash and contained only rust and no soot was accessible within the chimney. A domestic rubbish heap and an ash heap were provisionally anticipated on the basis of archaeological and ethnographic data, respectively. The available information and field observation, however, indicated no specific location for the deposition of either type of by-product and consequently these context types were not included in the excavation and sampling strategy.

Six context types - the barn, the kiln, the byre, the midden, a stack base and the vegetable plot - were finally selected for excavation at Schoolhouse Croft, on the basis of accessibility, non-contamination, and activity specifications. Important archaeological comparability was provided by the midden, and potential archaeological comparability was apparent for the other five contexts types. The selected context types represented distinct functional areas, each of which was anticipated to comprise further contextual sub-divisions, according to the details of construction and the stratigraphy of accumulated deposits. Excavation would reveal the precise contextual nature of each functional area and samples were required, where possible, from all uncontaminated contexts constituting the selected areas.

3.2.2.3 Material Type Selection

All the material types and soil properties outlined in section 1.5 that demonstrated provisional suitability for inclusion in the sampling strategy and future analyses, were considered during the final selection. The suitability of material types was evaluated on the basis of the selection criteria, i.e. the anticipated viability, quantity, quality and attainability of information. The range and condition of environmental remains retrieved from archaeological sites provided a source of evidence for use in the determination of material viability. A similar source of evidence was provided by the results obtained from the provisional analyses of samples taken from an abandoned croft during a pilot study conducted on Heiskeir. Reference to standard pedological data, including both physical and chemical soil processes, provided additional information of relevance to the viability of materials. Furthermore, during the determination of suitability, the logistical advantages and disadvantages associated with each analysis were evaluated in comparison to the anticipated levels of information. The final selection was, therefore, based on maximising long term viability and information under the constraints imposed by limited resource availability.

Coleoptera remains were rejected on the basis of poor viability. The pilot study and archaeological remains indicated that preservation was unlikely when deposits were not waterlogged. Nitrogen, magnesium, calcium, potassium and trace elements (e.g. iron, aluminium and manganese) were also rejected on the basis of insufficient viability. Nitrogen is particularly transient in soil profiles and was less preferable to phosphorus as an anthropogenic indicator. Despite the potential demonstrated by calcium to indicate waste products and magnesium to indicate hearth sites and bone, both are relatively soluble and particularly liable to translocation in environments of low pH. On the basis of unreliable long term viability, corroborated by the predominance of acid soils at the Howmore site, calcium and magnesium were rejected from further analyses. Potassium also demonstrates high mobility in the soil profile and was consequently rejected on the basis of anticipated reduced viability. Furthermore, the information potentially provided by the frequency and occurrence of potassium replicated the evidence provided by the analysis of phosphorus.

Iron, aluminium and manganese potentially complement thin section analysis and the identification of pedogenic processes, particularly podzolisation, which may indirectly indicate anthropogenic activity. Iron, aluminium and manganese reflect the distribution of other soil properties such as pH and phosphorus which may assist the interpretation of pedogenic processes. Despite the potential interpretative advantage, however, these additional analyses were rejected on the basis of time and resource limitations and uncertain inclusion of thin section analysis. Isotope analysis was rejected on the basis of high analytical cost despite the potentially high interpretative value.

Twelve material types and soil properties were selected for inclusion in the sampling strategy on the basis that further analysis was justifiable with regard to the selection criteria. The plant remains, animal bones, molluscan and other faunal remains, phytoliths, diatoms and pollen were selected on the basis that high levels of qualitative and quantitative data were potentially achievable with feasible time and specialist requirements. Furthermore, each material type presented the opportunity to obtain qualitative data alone, with reduced time and specialist investments. Particle size and magnetic susceptibility were selected on the basis that a high level of quantitative data was potentially achievable with moderate time and specialist investment and due to the potential long term viability. Analysis of the pH, phosphorus and organic content were selected due to the potential to achieve high levels of quantitative data with moderate time and specialist investment and due to the potential long term viability. In each case, however, viability was more dependent on the associated pedogenic processes.

Thin section analysis was also selected on the basis that high levels of information were potentially available in association with potential long term viability. Due to the costly time and specialist requirements, however, the technique was considered of low priority and excluded from further laboratory analysis.

3.2.3 Excavation and Sampling

Excavation provided the means to establish the stratigraphic and constructional details regarding each functional area and to identify the contextual sub-divisions and areas of recent contamination. Consequently, samples could be collected from recognised and uncontaminated deposits.

3.2.3.1 The Excavation Procedure

Trenches were located in the zone of deposition anticipated to be most representative of the activity in the area under investigation (figure 3.3). The optimal zone was completely cross-sectioned in all areas except the kiln, where the excavation was constrained by structural limitations. The excavated areas were of a sufficient size to explore the vertical and lateral variation in stratigraphy and also to fulfil the anticipated sample volume requirements. Contextual information was recorded by description, illustration and photography for each functional area.

3.2.3.2 The Sampling Procedure

The quantity of soil required for the analysis of the selected material types and soil properties, defined the procedure adopted for the implementation of the sampling strategy. Techniques that required small standard quantities of soil for laboratory analysis were taken first and the remainder of the sample was used for techniques which required larger, but unstandardized, volumes (processed on site). On this basis the sample types were prioritised as follows:

A Samples - *ca.* 5 litres: a priority, composite sample, incorporating *ca.* 2 litres for molluscan analysis and *ca.* 3 litres for phytoliths and all chemical and physical soil tests. The precise quantities required for each analysis were extracted in the laboratory. With the exception of the mollusc retrieval, most of the techniques required very small quantities of sample, but the over-estimated composite sample was sufficient to accommodate repeat analyses or accidental loss.

B Samples - maximum *ca.* 50 litres (or the remainder of the deposit after removal of the A sample): a bulk sample, processed on-site primarily for the retrieval of botanical remains, but simultaneously providing material for alternative molluscan analysis. Processing of the maximum sample size was not always necessary and judgement was postponed until the processing stage (see below 5.2.2.4).

C Samples - Kubiana box sample taken from section, for micromorphology: these samples were taken to allow for the possibility of supplementary specialist analysis elsewhere.

The sections, matrices and soil descriptions that illustrate the stratigraphic relationship between contexts within each functional area are illustrated in figures 3.4 to 3.10 A list of the contexts from which the samples were taken, the sample types and the volumes of the bulk samples, are presented in table 3.1.

3.2.3.3 The Excavation and Sample Details

3.2.3.3.1 The Byre

A trench was positioned across the northern end of the byre. Four contexts were identified (figure 3.4) three of which formed basal deposits, overlain by the sub-surface deposits and the turf horizon. Context 202, a clay layer containing stones and gravel, overlay the denuding bedrock and abutted the wall at the western end of the trench. Adjacent and to the east, context 203, a reddish clay containing a larger proportion of gravel, also lay directly over the denuding bedrock. Further to the east, the dark loamy highly humic soil of context 204 filled a stone constructed drainage channel. A sub-surface layer of sandy loam (context 201) overlay all the basal contexts.

The observations were consistent with the information regarding the construction of the byre floor. Flat stones covered the floor of the byre and incorporated a sunken slurry trench longitudinally down the centre of the building. Turves of machair were lain over the flat stones on either side of the slurry trench, to form raised beds for the cattle. The stone free, dark humic soil of context 204 represents the waste material collected within the slurry trench. The irregular pockets infilled by the clay and stony layers of contexts 202 and 203 may represent the spaces once occupied by large floor stones. The sandy loamy layer overlying all three basal contexts (201) is consistent with incorporation of the remnant machair turves, left in place on the byre floor after the initial abandonment of the croft. Samples were taken from all contexts beneath the turf horizon (table 3.1)

3.2.3.3.2 The Barn

A trench was positioned across the centre of the barn. Four contexts were identified that comprised the floor of the barn (figure 3.5). The basal layer consisted of stones compacted within an orange, sandy clay and gravel matrix (context 231). The overlying layer of cobble stones was set within a compacted sandy clay matrix (context 230). Excavation was hindered by the compact nature of the two basal layers and, therefore, restricted to the western end of the trench. A layer of humic soil, containing a small proportion of sand and clay (context 220), overlay the compacted material and the sub-surface horizon consisted of very dark humic soil with a large proportion of rotted wood and visible plant material (context 218). The observations were consistent with information regarding the construction of the barn floor. The two basal contexts represent the solid construction of the floor layer. The cobbled surface was covered with beaten clay to form a smooth working surface that was either swept clean or covered lightly with sand. The humic material overlying the floor represents roof material, comprising turf and marram with large fragments of structural wood, fallen due to post abandonment collapse of the entire barn. Samples were taken from all contexts beneath the turf horizon (table 3.1)

3.2.3.3.3 The Kiln

The circular structure of the kiln bowl and the infilled tunnel of the kiln flue were both excavated in half section. The kiln bowl was a circular stone structure, approximately 0.9 m high and 1 m in diameter across the top edge of the bowl, tapering down to 0.6 m across the bottom. The bottom of the kiln had infilled with material to a depth of 0.2 m and the eastern edge of the bowl had collapsed slightly during abandonment. Five contexts were identified within the bowl of the kiln (figure 3.6). The basal layer consisted of small stones set within a compacted sandy clay matrix (context 262). In the central region, overlying the base, a layer of coarse gravel was set in a sandy clay matrix (context 223). Dark humic soil incorporating some sand was packed around the gravel layer (context 224). Both were overlain by a layer of relatively sand-free dark, humic soil, that contained a large proportion of rotten wood (context 222). The surface horizon of humic soil contained intrusive modern rubbish (context 215). The kiln flue had infilled with material due to the absence of the flat stones that comprised the roof of the tunnel. The stones used in the construction of the flue had been taken, on instructions from the Estate owners, and incorporated within the Howmore bridge. The kiln flue was truncated after approximately 0.8 m. Four contexts were identified within the kiln flue (figure 3.7). The basal layer consisted of small stones set within orange sandy gravel containing patches of clay (context 261). Overlying the base was a layer of coarse gravel set in a sandy clay matrix (context 229). Both contexts demonstrated similarities to the two basal layers within the kiln bowl. Dark humic soil, containing rotted wood and plant material, overlay the gravel layer (context 228), and the sub-surface horizon comprised humic soil with intrusive rubbish (context 226).

The constructional and observed stratigraphic details of the kiln bowl and flue were consistent with information regarding the function of the kiln. The basal layers represent the compacted material comprising the foundations for construction. The material in the kiln flue is distinctly orange, which may reflect the direct effects of heat associated with the fire in the flue end furthest from the kiln bowl. The place where the fire was made was not excavated, due to the premature truncation of the flue. The humic material within the kiln bowl probably represents fallen roof matter and possibly the remains of a stick platform used during the parching of grain. The humic material within the kiln flue would, similarly, represent the fallen roof matter. Samples were taken from all contexts beneath the turf and surface horizons (tables 3.1).

3.2.3.3.4 The Stack Base

A trench was positioned across the centre of one stack base. Four contexts were contained within a raised border of large stones and associated depression, that marked the outer edge of the stack base (figure 3.8). The basal layer comprised sandy clay and gravel and contained few stones (context 242). In the overlying horizon, clay is not present and the proportion of stones is greater (context 241). Moving up profile, the stones and gravel are incorporated with humic sandy soil (context 238). The sub-surface horizon contained a high proportion of straw-like and rooty plant material and very few stones within dark humic sandy soil (context 237).

The details regarding stack base construction related to the observed composition. Large stones were placed over the existing turf to create a raised platform, with small stones used as packing if the availability of large stones was restricted. Contexts, 241 and 242, are consistent with inorganic, weathered material that overlies natural. The original turf line is not apparent, but context 238 probably represents the humic remains of the turf incorporating stony packing material. The perimeter depression, observed in the profile, probably represents the source of the stony packing material. The stacks were placed directly on the free-draining, elevated surface. The bases were not cleaned other than to cut the grass that may have grown during redundant periods. The high proportion of plant material in the humic, stone free, sub-surface soil of context 237 is consistent with the incorporation of remnant vegetative fragments originating from the stack with the gradual accumulation of turf. The bases were occasionally sprinkled with sand as an alternative preparation for use which, due to the effects of filtering, is consistent with the presence of sand in all contexts. Samples were taken from each context in the centre of the stack base, beneath the turf horizon (table 3.1)

3.2.3.3.5 The Vegetable Plot

Owing to the large area of the vegetable plot, separate test pits were excavated at the west and east ends of the vegetable plot, to compare the horizontal stratigraphic variation. The two test pits demonstrated uniformity of stratigraphy and, therefore, details are only presented from the eastern test pit. Two contexts were identified within the profile (figure 3.9). With depth (from context 246 to 247), the sand content decreased and the stone content increased, within the dark humic soil. The observations were consistent with the input of wind blown sand, or from sand within midden material, to the surface layers and the incorporation of large stone fragments to the basal layers, from the underlying denuded bedrock. The high humic content of all contexts supports the practice of regular fertilisation with dung. The shallow depth of soil would support surface vegetables, but root crops may have been hindered. Samples were taken from each context beneath the turf horizon (table 3.1).

3.2.3.3.6 The Midden

The midden itself was unavailable for sampling, due to removal of the deposits after abandonment of the croft. An elongated trench was, therefore, positioned parallel to the western side of the byre, across the length of the indicated midden site, in order to explore the horizontal stratigraphic variation within the underlying deposits. The basic stratigraphy was uniform. The northern end of the trench was excluded from the sampling strategy, however, due to chemical contamination from the deposition of old batteries. The central area of the trench was selected for sampling in preference to the southern end, because the midden material was most consistently deposited at this location and, therefore, increased the potential of representative deposits.

Five contexts were identified within the profile (figure 3.10). The basal layer consisted of fine orange gravel with medium stones incorporated (context 260). Overlying this was a thin layer of dark humic soil, relatively stone free (context 259). The layer above comprised dark humic soil incorporating large stones, gravel and some orange speckles of clay (context 258). Overlying the stony horizon, was a layer of dark humic soil containing clinker (context 257) followed by a thicker layer of dark humic, clinker-free soil (context 256). The observations were consistent with minimal ground surface preparation prior to midden accumulation. Where available, large stones were deposited to provide a crude base, but no particular effort was invested. The large stones contained within the humic and gravel layer of context 258 may represent the prepared base on which the midden accumulated. The thin humic layer lying directly beneath the stony layer may represent the remains of the original turf, and the basal context is consistent with the natural, gravel dominant deposits that occur near to the loch edge. The clinker contained within context 257 lying immediately above the stony midden base, represents contamination consistent with post farming activities, during the second period of occupation. The dark humic soil above the clinker horizon may represent the rapid accumulation of soil in recent years. Samples were taken from all contexts beneath the turf horizon (table 3.1)

3.2.2.4 On-site Environmental Recovery

The bulk samples were processed on site. Where possible the samples were initially dry sieved through a 10 mm riddle, but this stage was omitted when soil was compacted due to the possibility of detrimental effect on fragile material. In these circumstances, the sample was allowed to soak prior to wet-sieving. Samples were wet-sieved using the wash-over technique (Kenward *et al*., 1980) using 1 mm and 250 micron sieves. Soil (*ca.* 5 litres at a time) was gently mixed with water from the near by loch, swirled, and the floating material and sediment in suspension were poured over 1 mm and 250 micron sieves. The process was repeated until there was no longer any material in suspension. The residue was then washed through a 1 mm mesh sieve. The 1 mm flot and residue were regularly scanned and the contents recorded to provide an approximation of material within each sample. If the sample appeared completely barren of macroscopic remains during processing, a minimum 10 litres of sample, where available, were processed. Due to the time consuming nature of the technique, if no remains were apparent in 10 litres, further processing was judged unprofitable and inefficient. If remains were found, the remainder of the sample was processed.

CHAPTER FOUR

ANALYTICAL METHODS

4.1 Laboratory Methods

4.1.1 Analysis of Charred Plant Remains (and Molluscs)

The wet sieving of bulk samples on-site was primarily for the recovery of charred plant remains but also resulted in the recovery of other types of environmental remains present in the soil sample, of which the molluscs were the most important. Three different fractions of material were produced (see section 3.2.2.4): the 'coarse flot' consisted of floating material >1 mm, the 'fine flot' consisted of floating material <1 mm and > 250 microns, and the heavy residue consisted of non-floating material >1 mm.

4.1.1.1 The Coarse Flot

The coarse material, recovered in the 1 mm flot sieve, was potentially the most interesting, as it was more likely to contain charred cereal remains than the fine flot or the residue, and was therefore analysed first. This fraction of material also contained mollusc shells, uncharred modern seed, twigs, both charred and uncharred, and pupae cases.

Most samples were sorted completely, with only a few exceptionally large examples being split using a riffle splitter (van der Veen and Fieller, 1982) to obtain an accurate fraction of approximately 250 ml which, in the case of the coarse flots, was never less than a half. The sample was sorted initially by naked eye, and then checked using a Kyowa microscope at x15 magnification. Material recovered was divided into different categories, the largest of which were the charred plant remains and the molluscs.

4.1.1.2 The Fine Flot

Sorting of the fine material from the 250 micron sieve was much slower and so a time-saving approach was necessary. Only fine flots from samples with productive coarse flots were examined, and the fine material was split into smaller fractions approximately 30-40 ml in size, using a riffle splitter, and one of the resultant sub-samples was sorted at x45 magnification. Depending on the size of the fine flot, the sub-samples were equivalent to fractions ranging from an eighth to a half.

The contents of this sub-sample and the contents of the coarse flot provided the basis on which to decide whether extra sorting was necessary. In theory, if in one-eighth of the fine flot no remains were present, and the contents of the coarse flot had not been rich, then it would be unnecessary to sort further fractions of the fine flot. If nothing was found in one-eighth of the fine flot yet the coarse flot had been rich in plant remains or molluscs, then another eighth of the fine flot should be sorted. If, however, any remains were present in one eighth of the fine flot, regardless of the coarse flot, it would be worthwhile sorting further fractions, in order to increase the number of items and also to lessen the margin of error introduced when results were multiplied in order to make them up to a whole.

4.1.1.3 The Residue

The heavy residues from wet sieving are often large in quantity, and it is therefore unrealistic to sort them completely. A riffle splitter was again used to split the sample into smaller sub-samples, one of which was sorted initially. A sub-sample approximately 200 - 250 ml in size was desired, which was most commonly equivalent to an eighth fraction but fractions ranged from one sixty-fourth to the complete residue in one instance. The contents of the initial sub-sample determined whether more should be sorted on the basis that, if any charred remains were present in the first fraction of the residue, then more fractions should be sorted until a reasonable number of items were obtained, or until at least an eighth had been sorted. If no charred remains were present in the initial fraction, as occurred in this instance, then no further fractions were sorted.

The same principles of sorting were applied to the molluscs retrieved from the same initial fraction of residue sorted. Molluscan remains were present in some samples and therefore, where necessary, further fractions were sorted, which resulted in total amounts ranging from one thirty-second up to the complete residue.

4.1.1.4 Identification

The botanical remains were identified by comparison with the modern reference collection in the Department of Archaeology and Prehistory, University of Sheffield. The molluscs were identified by use of European molluscan keys (Kerney and Cameron, 1979; Evans, 1972) and verified by comparison with the reference collection belonging to N. Thew.

4.1.2 The Recovery of Mollusc and Other Faunal Remains

Following standard molluscan recovery techniques, a two litre sample was wet sieved through a stack of sieves of mesh sizes: 5 mm (to remove large stones), 2 mm, 1 mm, 500 microns and 200 microns. Once clean, the fractions were air dried. The 2 mm and 1 mm fractions were sorted completely at x10 - x20 magnification. The 500 micron fraction, potentially containing a separate suite of smaller sized molluscs, was sub-sampled using a riffle splitter, and sorted at x45 magnification. The initial sub-sample sorted was no smaller than one eighth. If nothing was found in this sub-sample, then no more was sorted, but on the basis of even one mollusc shell, further fractions were sorted until half of the complete residue had been examined.

To verify the sub-sampling technique both fractions from the coarse flot of a bulk sample were sorted separately, and a comparison of the results showed no major differences. Due to the low numbers of molluscs from the two litre samples, such a test would have proved less effective. The molluscs were identified by use of European molluscan keys (Kerney and Cameron 1979; Evans 1972) and verified by comparison with N. Thew's reference collection.

Slug plates and slug/worm granules were also extracted during the sorting, but not identified to species due to the lack of distinguishing morphological features. (The presence of *Spirobis*, a seaweed indicator which prevailed in some of the pilot samples from machair sites, was incorrectly anticipated from the samples analysed here.)

The 200 micron fraction was collected to facilitate the recovery of micro organisms such as *Foraminifera* although these were excluded from further analysis. Examination of the 100 micron residue, from the defloculation of material for pollen analysis (section 4.1.5.1) however, revealed that micro organisms were in such low concentrations that examination of this fraction would be fruitless. Moreover, the light nature of the material means that it could have been blown in from a distant source. The animal bone remains consisted of one deciduous cow tooth from the byre.

4.1.3 Pollen Preparation and Analysis

4.1.3.1 Sample Preparation

1. 10 cm^3 of filtered water were put into a measuring cylinder and, by watching the displacement of the water, 2 cm^3 of the soil sample were added.
2. Deflocculation of the sediment matrix was achieved using the potassium hydroxide treatment (Moore *et al*., 1991). The sample and water mix were made up to 150 ml with a 10% aqueous solution of potassium hydroxide (KOH) and heated for 20 minutes. Sufficient filtered water was added to balance any liquid lost through evaporation and thereby avoid an increase in the concentration of the solution.
3. The liquid was discarded and the sample washed through a 100 micron sieve and collected in a 7 micron sieve (Cwynar *et al*., 1979). The >100 micron residue was later scanned using a high powered binocular microscope for micro-marine remains such as *Foraminifera*. Owing to the sparse concentrations of such organisms the data were not included.
3. To remove any fine silt or sand in the sediment of the 7 micron sieve the swirling technique was adopted as described by Hunt (1985) and Traverse (1988). The sediment was washed from the sieve onto a concave watch glass and then swirled with a circular action in order to create currents in the liquid which moved centripetally along the bottom of the watch glass, rose in the centre and continued centrifugally across the surface of the liquid towards the edge. This action served to move the heavy particles to the bottom and centre of the glass and thus separate them from the suspended pollen and spores. Once the suspension of light material had been decanted the heavy residue was discarded. The process was repeated three to five times. The resultant suspension was centrifuged to separate off any remaining water.
5. Cellulose was removed from the sediment by following the standard acetolysis treatment devised by Erdtman (1943) and described by Faegri and Iversen (1989). The sediment was washed in glacial acetic acid (CH_3COOH), mixed with nine parts acetic anhydride ($(CH_3.CO)_2O$): one part sulphuric acid (H_2SO_4), heated and rewashed in glacial acetic acid. The supernatant was discarded and the sediment washed twice in filtered water, twice in alcohol and once in tertiary butyl alcohol.
6. The sediment was transferred to a small vial containing silicone oil, the preferred mounting medium, and left in a drying cabinet for 24 hours.

4.1.3.2 Slide Preparation and Analysis

1. A small amount of the oil mixture was transferred to a microscope slide.
2. An Olympus binocular microscope with transmitted light was used to examine the slide, using magnifications of x200, x400 and x600.
3. The pollen was identified by using the identification keys in Moore *et al*. (1991) and Faegri and Iversen (1991) and verified by comparison with the modern pollen reference collection in the Department of Archaeology and Prehistory, University of Sheffield.
4. Initial scanning of each sample revealed little pollen and further examination was deemed unworthy.

4.1.4 Phytolith Preparation and Analysis

4.1.4.1 Sample Preparation

The preparation of the samples for phytolith analysis was based on the extraction technique described by Powers and Gilbertson (1987). All apparatus was cleaned using Lipsol solution. The exact technique used was as follows:

1. Approximately 20 g of sample was put into a marked beaker and oven dried at 50° C for 24 hours.
2. The sample was sieved through a 1 mm mesh and, using the 'cone and quarter' technique; 1 g of the <1 mm fraction was decanted into a beaker.
3. 50 ml hydrochloric acid (2N HCl) was added to disaggregate the sample and the beaker simmered gently in a sand bath until the volume was reduced to 5 ml. Once cooled, this was transferred to a test tube.
4. 10 ml of filtered[1] water was added, the mixture shaken and then centrifuged at 2500 rpm for 2 minutes.
5. The supernatant was carefully discarded and stage 4 repeated.
6. The supernatant was again carefully discarded and 10 ml of methanol added to the sediment. The test tube was shaken gently and centrifuged at 2500 rpm for 2.5 minutes.

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[1] * Filtered water, with palaeontological purity, was preferred over distilled or deionized water, which possess chemical purity (Powers and Gilbertson 1987).

7. The final supernatant was discarded and the sediment emptied into a small crucible using methanol to wash out the test tube and cover the sample.
8. The sample was ignited and left to burn in a fume cupboard. This process destroyed any organic material that might be present and resulted in a fine ash.
9. A Lycopodium tracer aliquot was prepared (see Table 1 in Powers and Gilbertson, 1987 p.531). 3 ml of stirred tracer aliquot was added using a class A pipette and left to evaporate overnight in a sealed drying cabinet.

4.1.4.2 Slide Preparation

The preparation of slides for phytolith analysis was also based on Powers and Gilbertson (1987). The preparation was conducted in a fume cupboard owing to the extremely light nature of the material.

1. Once the methanol had completely evaporated, the remaining ash was disaggregated using a mounted needle.
2. Triplicate slides were produced for each sample following the procedure outlined in Powers and Gilbertson (1987, Table 3 p.532). Styrolite was used as a fixative in this analysis.
3. The slides were left to harden for approximately a week at room temperature.

4.1.4.3 Counting The Slides

1. Slides were examined at a magnification of x1000 using phase contrast microscopy.
2. Where possible, 250 phytoliths were counted, per slide. Powers *et al*. (1989) found that, above 250, new phytolith types were rarely encountered.
3. The phytoliths were identified using the classification compiled by Powers *et al* (1989) together with reference material at the Department of Archaeology and Prehistory, University of Sheffield. Three main criteria were used to classify the phytoliths: shape, size and texture (see table 4.1).

4.1.5 Diatom Analysis

The slides prepared for phytolith analysis were also examined for any diatoms that may have been present in the samples, as the phytolith extraction technique equally facilitated the recovery of diatoms.

1. Whole and fragmented diatoms were recorded whilst phytolith counts were conducted.
2. A rough classification was constructed based on shape, fragmentation and internal sculpturing of those diatoms encountered, but very few were recorded that could be identified further. Further analysis was abandoned at this stage.

4.1.6 The Determination of Soil Particle Size

The methodology used for particle size analysis was based on the sieving technique outlined in Gale and Hoare (1992).

1. 20 - 30 g of sample was air dried and disaggregated using a pestle and mortar.
2. A clean set of sieves was assembled as follows (phi-unit figure in brackets):
1.7 mm (-0.75), 1.18 mm (-0.25), 0.85 mm (0.25), 0.6 mm (0.75), 0.5 mm (1), 0.425 mm (1.25), 0.355 mm (1.5), 0.25 mm (2), 0.18 mm (2.5), 0.125 mm (3), 0.106 mm (3.25), receiver = <0.106 mm
3. The sample was weighed to 0.01 g and shaken in the sieve stack for 15 minutes.
4. The contents of each sieve and the receiver were weighed to 0.01g.

4.1.7 The Determination of Magnetic Susceptibility

The technique used to determine the magnetic susceptibility of the sample followed the standard practices outlined in Gale and Hoare (1992) and Thompson and Oldfield (1986). A Bartington MS2 Magnetic Susceptibility system was used to take the measurements.

1. 10 g of soil was oven dried at 50° C for 48 hours, homogenised using a pestle and mortar and then sieved through a 2 mm sieve in order to remove material >2 mm.
2. A clean sample holder was weighed to 0.01 g (M4), packed tightly with the <2 mm sample and then reweighed to 0.01 g (M5).

3. The susceptibility meter was checked according to the manufacturers instructions and the reading of the *volume magnetic susceptibility* (see 4.2.1.6) of the sample was measured (M6).

4.1.8 The Electrometric Determination of pH

The methodology was based on standard procedures for the determination of pH values of soils (HMSO, 1992).

1. 50 g of soil was air dried, homogenised using a pestle and mortar and then sieved through a 2 mm sieve in order to remove material >2 mm.
2. 30.0 $\pm$ 0.1 g of the soil was weighed and decanted into a wide necked bottle.
3. 75 $\pm$ 1 ml of UHP (ultra high purity) water was added, the bottle capped and shaken for 15 minutes.
4. A Jenway 3030 pH meter was standardised according to the manufacturers instructions, using pH 4.000 and pH 10.000 buffer solutions.
5. Thorough dispersal of the sediment was ensured using a magnetic stirrer, the electrode immersed in the sample and the reading taken after 30 seconds.

Triplicate results were obtained for each sample.

4.1.9 The Estimation of Plant Organic Content by Loss on Ignition

The methodology was based on the technique outlined in Gale and Hoare (1992).

1. A clean crucible was weighed to 0.001 g (M1).
2. 10.0 g of sample was weighed into the crucible and dried in an oven at 50° C for 24 hours.
3. The crucible was removed to a desiccator for cooling and storage between subsequent stages. This was essential in order to minimise exposure of the sample to laboratory humidity and a possible increase in the mass of the sample.
4. When cool, the crucible and sample were removed from the desiccator and immediately weighed to 0.001 g (M2).
5. The crucible and sample were then placed in a Gallamkampf furnace at 400° C for 18 hours, followed by cooling in a desiccator.
6. When cool, the crucible and sample were reweighed to 0.001 g (M3).

4.1.10 The Determination of Phosphorus Content

There are several techniques, which vary in time and complexity, for the measurement of different forms of phosphorus. The simple spot test (Eidt, 1973) is quick, cheap and easy to use, although results are rudimentary. Available phosphorus is the most easily extracted form, although this usually represents the smallest proportion of the total phosphorus in the soil. The measurement of total phosphorus and the determination of phosphorus fractions require more complicated laboratory methods. The advantages and disadvantages of different techniques and their application have been widely discussed (Proudfoot, 1976; Bethell and Máté, 1989; Walker, 1992).

4.1.10.1 Molybdenum Blue 'Rapid Test'

The methodology was based on a rapid field test developed by Grundlach (1961) and simplified by Schwarz (1967).

1. A small quantity (O.1 g to 0.5 g) of air dried soil was placed on a phosphate-free filter paper.
2. 3 drops of a 5% aqueous solution of ammonium molybdate ($(NH_4)_6Mo7O24.4H2O$) mixed with 35 ml concentrated nitric acid (HNO_3) were added, followed by 3 drops of a 5% aqueous solution of ascorbic acid (C6H8O6).
3. Presence of phosphorus is indicated by a blue stain with striated edges. The increasing intensity and extent of these features respectively can be approximately equated with an increasing concentration of phosphorous in the soil. After two minutes, the appearance of the stain was recorded on a scale from 1 to 5 (none, weak, average, good, strong).

Values can be calibrated by measuring the intensity and extent of the molybdenum blue formed by soils of known phosphorus content, and without such calibration the values can only be used for comparative purposes. In this instance, comparison of qualitative data was in theory adequate, but this technique is considered by some as only suitable for detecting high levels of phosphorus, which negates the usefulness of those soil samples with 'average' and even near-'average' values. Moreover, the use of nitric acid for colour extraction is criticised by Eidt (1977, p.1328).

In order to check the results from the 'rapid test', and also produce a set of quantitative data, the tests were repeated in the laboratory using the more sophisticated technique outlined below.

4.1.10.2 The Colorimetric Determination of Sodium Hydrogen Carbonate Extractable Phosphorus

4.1.10.2.1 The Extraction Technique

The methodology was based on a technique for the extraction of sodium hydrogen carbonate extractable phosphorus developed by Allen (1989). Phosphate-free detergent was used for washing all apparatus.

1. 5 litres of sodium hydrogen carbonate extractant was prepared in advance by dissolving 210 g of sodium hydrogen carbonate ($NaHCO_3$) in 4.0 $\pm$ 0.5 litres of UHP water. The pH was adjusted to 8.50 $\pm$ 0.05 using 1.0 M sodium hydroxide (NaOH). The solution was diluted to 5.0 $\pm$ 0.1 litres with UHP water.
2. 10 g of soil was air dried, homogenised using a pestle and mortar and then sieved through a 2 mm sieve in order to remove material >2 mm.
3. 5.00 $\pm$ 0.01 g of the soil was transferred into a wide-necked shaker bottle and 100 ml of the prepared extractant added. The bottle was shaken for 30 minutes on an 'end-over-end' shaker.
4. The shaken sample was filtered through Whatman No.40 paper into a sample bottle. A blank sample, using the 100 ml of the same extractant, shaken and filtered in the same manner, was prepared with each batch of samples.
5. 1 litre of reagent (stock solution) was prepared by dissolving 20 g of ammonium molybdate ($(NH_4)_6Mo_7O_{24}.4H_2O$) in 300 ml of UHP water. 450ml of 10N sulphuric acid (H_2SO_4) was slowly mixed in, followed by 100 ml 0.5% antimony potassium tartrate solution (C4H4O7SbK.O.%H2O+aq). UHP water was added to bring the solution up to 1 litre.
6. 1.5 $\pm$ 0.1 g of L-ascorbic acid ($C_6H_8O_6$) was added to 100 ml of stock solution (see step 4) to give a mixed reagent. This was prepared no more than 24 hours in advance of absorbency determination which follows below (4.1.10.2.2).
7. 5 ml of the extractant was measured into a 25 ml volumetric flask and 20 ml UHP water added. 2.5 $\pm$ 0.1 ml of the mixed reagent was added and then UHP water to bring the level up to 25 ml. The sample was left for 30 minutes before the absorbence was determined.

4.1.10.2.2 Absorbency Determination

A Varion Cary 1 UV-Visible Spectrophotometer was used at 810 nm for the colorimetric determination of the absorbence of phosphorus as orthophosphate in the extracts. The technique was based on that used by Allen (1989) and John (1970).

1. 0.4393 g of oven-dried potassium dihydrogen orthophosphate (KH2PO4) was dissolved in 1 litre of UHP water (1 ml = 0.1 mg phosphorus) This was diluted 20 times to obtain a working standard which contained 0.005 mg/ml (5 ppm) phosphorus.
2. The working standard was used to prepare a series of standards, including a blank, with which to calibrate the colorimeter. The six standards had phosphorus concentrations of: 0.00 (the blank); 0.20; 0.40; 0.50; 1.00 and 2.00 mg/l and were each made up to 25 ml in accordance with the original extractant.
3. The standards were used to produce a calibration curve, which was used to measure the absorbence of phosphorus in the sample aliquots from which the concentration of phosphorus in mg was determined.

Triplicate results were determined for all samples.

4.2 Statistical Methods

4.2.1 The Data

4.2.1.1 Raw Counts (Plant Remains, Molluscs, Phytoliths)

The data generated from the botanical, molluscan and phytolith analyses were in the form of counts of each taxon or morphotype present, and were used in this form for the statistical analyses. Two sets of mollusc data were generated: one from the bulk flotation samples and one from the two litre wet-sieved samples. This enabled a statistical comparison of the two different mollusc recovery techniques.

4.2.1.2 Analysis of Particle Size Data

The Microsoft Excel version 4.0a (Microsoft Corporation, 1985 - 1992) was used to calculate and plot the percentage of particles collected by each mesh. This facilitated the visual comparison of samples on the basis of particle size alone, and also enabled the determination of the mode and inter-quartile range, which were used in statistical analysis. The relative proportions of the different sized particles were used to identify the specific soil texture of the sediment, based mainly on the classification system used by the United States Department of Agriculture, but with minor adjustments dictated by the mesh sizes available for the analysis. Soil textural classes were defined accordingly (table 4.2).

4.2.1.3 Calculation of Mass Susceptibility

The extent to which a material will become magnetised when a magnetic field is applied, is the material's magnetic susceptibility. This is the ratio of the magnetisation induced in a material to the strength of the applied field. Therefore, volume magnetic susceptibility is equal to the volume magnetisation induced in a material divided by the strength of the applied magnetic field (Gale and Hoare, 1991).

To obtain mass susceptibility the volume susceptibility must be divided by the bulk density of the soil sample. As the MS2B sensor is calibrated against water, the volume susceptibility must be divided by the bulk density of the sample relative to the density of water. The volume of soil and that of water are the same (10 cm^3), therefore, the relative density of the soil sample may be calculated simply by dividing its mass in kilograms by the mass of an equivalent volume of water (0.01 kg) (Gale and Hoare, 1991).

The mass susceptibility of the sample was calculated from:

$$\chi lf = \frac{M6}{[(M5 - M4) / 0.01]}$$

where: χlf = the initial, reversible low frequency mass susceptibility (units 10^{-8} m^3 kg^{-1})

M4 = the mass of the sample pot and lid

M5 = the mass of the sample pot, lid and sample

M6 = volume susceptibility reading of the sample pot, lid and sample.

4.2.1.4 Calculating Mean pH Values

The relative proportions of base-forming cations compared to H^+ and associated ions is expressed as the 'percentage base saturation', and it is this percentage which determines the pH value. Table 4.3 illustrates the range of pH values commonly occurring in soils accompanied by the appropriate verbal description. (It should be noted that the pH is technically a negative logarithm of the concentration of H^+ ions ($-\log [H^+]$) in the soil solution, and therefore every unit change in value is equivalent to a tenfold change in the concentration of hydrogen and hydroxide ions (Brady, 1990). The pH values were determined in triplicate and therefore the mean for each sample had to be calculated to produce a figure for further statistical analysis. There were no instances of extreme results within any group of three figures.

4.2.1.5 Calculating Percentage Organic Content

The percentage mass lost on ignition was calculated as follows:

$$\% \text{ loss-on-ignition} = \frac{100 \times (M2 - M3)}{(M2 - M1)}$$

where: M1 = mass of the crucible
M2 = mass of the crucible plus dried sample
M3 = mass of the crucible plus ignited sample.

4.2.1.6 Calculating Percentage Phosphorus

The results of the molybdenum blue field test were not included in the statistical analysis, because more accurate results could be obtained from the sodium hydrogen carbonate extraction technique. The readings that resulted from the colorimetric analysis were converted into percentage phosphorus according to the following formula:

$$P = X \times \frac{E}{S} \times D$$

where: X = mg/l P read from the standard curve
E = initial volume of extractant (ml)

S = weight of soil (g)
D = dilution factor (= 50 = 0.5 ml extractant diluted to 25 ml).

The result was converted from 'micrograms per gram' to a percentage (i.e. mg per 100 mg). The phosphorus content was determined in triplicate and so the mean of the three percentages was calculated.

4.2.1.7 Data Omitted From Statistical Analysis

The preliminary scan of the pollen slides revealed little pollen with the same limited range of species types from each context, representing the background flora of the environment. A complete palynological examination was therefore abandoned and the data was omitted from statistical analysis. The number of whole diatoms was also very few and the fragmentary nature of the majority created problems with identification in the time available. Moreover, those species that had been identified indicated a background aquatic fauna, most probably representing the nearby loch. This data was also omitted from statistical analysis.

4.2.2 The Statistical Techniques

4.2.2.1 Correspondence Analysis

Correspondence analysis is an indirect ordination technique particularly suitable for data in the form of 'counts': it arranges samples along axes on the basis of the taxa or morphotypes in the samples (Hill, 1979; Jongman *et al.,* 1987). As with other ordination techniques the first axis accounts for most of the variation in the data, the second for most of the remaining variation and so on. Correspondence analysis of the molluscan and phytolith data facilitated the simultaneous comparison of the variables comprising the data matrix, in this case 'samples' (rows) and 'species/morphotypes' (columns). Ordination scores were calculated for all samples and species/morphotypes, thereby representing the individual compositional differences of each variable in relation to all the other variables. When the results of a correspondence analysis are displayed graphically, it is possible to determine the relationship of each sample relative to all other samples and to all the species/morphotypes, and likewise of each species/morphotype relative to all other species/morphotypes and to all samples (Lange, 1990). The association of a specific sample or species/morphotype point in relation to other points on the graph is indicated by the direction and distance of movement of that point away from the origin. The direction of movement indicates the "diversion" of that sample or species/morphotype in relation to the distribution of the sample group or species/morphotype group as a whole.

When two points have moved in the same direction they are positively associated, and will therefore have a negative association with points in the opposite direction. A positive association between two samples indicates similarities in composition, and similarly, morphotypes positively associated with samples (as indicated by removal in the same direction) are more dominant in the composition of those samples than in the composition of samples situated elsewhere, although not necessarily absent from the composition of the other samples. The distance by which a point is removed from the origin of the diagram indicates the amount of separation in composition from the other points, so removal of a sample distinctly from other samples indicates it has fewer compositional features in common with the rest. The distance between samples and species/morphotypes cannot be directly interpreted as indicating that the species/morphotype is particularly common in that sample - it may be more common in a sample which is further away but in the same direction from the origin. When comparing samples or comparing species/morphotypes, therefore, proximity indicates similarity of composition or a tendency to occur in the same samples but, when comparing samples with species/morphotypes, it is only the direction from the origin which is important.

The statistical package used for correspondence analysis was CANOCO (ter Braak, 1988). The results were plotted using CANODRAW (Smilauer, 1992).

4.2.2.2 Discriminant Analysis

Discriminant analysis (or Canonical Variates Analysis) is an ordination technique which maximises the statistical distinction between two or more groups of samples by searching for linear combinations of the discriminating variables. Discriminant analysis was used to distinguish samples from different functional areas using, in various combinations, the densities of materials, the results of the correspondence analyses and the results of physical and chemical soil analyses. A number of discriminant functions are derived by the analysis, and discriminant scores represent the relative contribution of each variable to each discriminant function. The number of groups determines the number of functions derived or, if the number of variables included in each analysis is less than the number of groups, this determines the number of functions.

The greatest amount of variation between groups is accounted for by the first function and so on. The relative amounts of variation accounted for by each function can be gauged from the eigenvalues and the percentage of variance. A high eigenvalue indicates high between group variability compared to within group variability, an effect graphically represented by tight clusters of samples within relevant groups. An alternative measure of the variance is the value of Wilks' lambda. On a range of 0 to 1, a low value indicates small within group variation compared to between group variation. As information is removed by successive functions, so the value of Wilks' lambda increases. After each function is removed, the significance of the remaining discriminating potential provides an important measure of the complete discriminating power of any one combination of variables. Values of less than 0.05 were taken as significant. Samples can be reclassified into the predefined groups on the basis of the discriminant functions derived. The percentage of correctly reclassified samples may be used as an indication of the success of the discriminant analysis.

The statistical package used for discriminant analysis was SPSS (SPSS Inc., 1990).

CHAPTER FIVE

RECENT AGRICULTURAL PRACTICE: THE RESULTS OF INTERVIEWS

The results of interviews with Hebridean farmers and inhabitants are presented in this chapter. The first section describes strategies of resource management, followed by a review of cultivation regimes and then of farmyard activities relating to product management. In conclusion, some attempts are made to quantify some critical interactions within the agricultural system.

Interviews were all conducted on the Uists and Benbecula and so the following account strictly concerns this part of the Outer Hebrides. The basis on which interviewees were chosen is set out in Chapter 3. Interviewees ranged in age between *ca.* 35 and *ca.* 85. The period of time documented in this chapter, therefore, covers roughly the last 100 years, beginning with experiences related to the oldest informants in their childhood by their own parents or grandparents. Most of this chapter, however, is based on informants' testimony of their own personal experiences and so relates to the period from *ca.* 1920 to the present. Questioning was particularly directed to the earlier part of this period (1920s and 1930s), when the Outer Hebrides were still producing grain for human consumption. Younger interviewees provided three main types of information: (1) details of traditional farming practices still current in the recent past, (2) insights into appropriate questions to ask older informants, and (3) examples of changes in husbandry strategy which might highlight the changing constraints and goals of agricultural production in the Outer Hebrides.

In this chapter, phrases like 'in earlier years' and 'in more recent times' are broadly used to refer, respectively, to the period between World War 1 and World War 2 and the period after World War 2. It must be stressed that this chronology should not be taken too literally, both because informants were often understandably vague or contradictory about dates and because the practices described changed gradually and at a rate which varied between localities and individuals.

In all *ca.* 25 individuals provided lengthy and useful interviews, with several shorter contributions. The number of interviewees responsible for any individual piece of information naturally varies. Some general information was offered by almost all interviewees. Information relevant to particular areas or periods or genders is usually derived from about five informants. Some details are inevitably based on individual testimony and this was, of course, deliberately so in the case of information gathered concerning the origin of samples taken for laboratory analysis.

5.1 Resource Management

5.1.1 The Croft

The traditional township on the Outer Hebrides comprised a nucleated group of individual farmsteads that formed the base for the communally organised run-rig agriculture (sections 2.2.2 and 2.2.3). Each farmstead consisted of small, thatched, stone buildings that were either attached to one another, forming an integrated unit, or slightly separated as a cluster of individual buildings. The dwelling house was normally the largest of these structures, traditionally divided in two and shared by the family and their livestock whilst in later years the byre comprised a separate building, possibly accompanied by a stable. There would also have been a barn for crop storage and processing, a walled stackyard and a small plot of ground that acted effectively as a vegetable garden, although this was also used for tethering the milk cow.

With the imposition of crofting (section 2.3.8), the allocation of land on a permanent basis caused the nucleated township to disperse due to investment in the long term convenience of farmstead and farmland proximity. A typical croft comprised the apportioned unit of land and an integral farmstead, often termed 'croft' by itself, the arrangement of which remained consistent with previous times. The land was commonly divided into elongated strips, that radiated from the central spine of the islands to the west coast, in order to incorporate both blackland and machair. Less commonly, some crofts were situated on the east side of the islands with the arable fields on the peatland but, in all cases, the moorland towards the east coast remained as the communal grazing area and main source of peat for fuel. The quantity of the different land types designated to each croft varied from one place to another, ranging from those on the west coast where machair predominated to the all peatland east coast crofts.

5.1.2 The Land Resources

The type and quality of available land was a predominant influence on the cultivation regime. The blackland is the low lying central ground on which the farmstead itself is normally situated, hence the alternative term 'croftland'. Areas of loamy and peaty blackland are moderately fertile but frequently difficult to work, as ploughing was impeded by the intermittent nature of suitable rock free, unwaterlogged ground, with sufficient depth to support a ploughshare. Spade cultivated lazybeds may be constructed on ground inaccessible to ploughs and provide intensive conditions suitable for any crop. East of the blackland the ground becomes increasingly peaty and wet. The peatland can be cultivated, or reclaimed with correct management techniques, but will not support successive years of cropping. The lime-rich machair, on the west coast, is fertile in the first year of cultivation but becomes rapidly exhausted without regular fertilisation. The moisture and humic content of the machair can vary dramatically and two extreme types are particularly recognisable, a dry sandy machair near the coast and a wet and/or loamy machair further inland. The gently sloping, sandy expanses are more easily worked than the blackland but generally the light soils require careful management and aid to maintain overall stability.

5.1.3 The Crops

Three main crops were traditionally grown on the islands; barley, oats and rye. Natural grass was sometimes cut for hay, but the deliberate sowing of supplementary seed became increasingly popular in later years. The emphasis and importance placed on the production of barley and oats as staples was removed when the greater accessibility of imported flour allowed the shift away from a relatively self-sufficient existence. The increased popularity of the potato, which required no processing, paralleled the decline in the production of cereals for home consumption and in recent years cereals have only been grown for fodder. The home production of wheat flour was not successful and wheat cultivation remained experimental regardless of recommendations from visiting agricultural improvers.

Barley was traditionally produced for meal and liquor. The barley grown on the Hebrides was known as 'bere', a hardy variety which was good for grinding and seemed better adapted to the islands than to the mainland. As the staple crop, the barley received most attention in terms of husbandry, normally sown in the first year of the rotation and treated with the most fertiliser. It was predominantly grown on the loamy and peaty soils of the blackland, with particular success on the lower slopes rather than the higher areas. Barley would grow on the machair where the moisture content was not extreme, but the majority of this land was too dry.

Oats were mainly grown for animal feed but were sometimes grown for human consumption, to supplement the barley meal. Oats needed more moisture than the barley to grow well and were not tolerant of the very dry conditions prevalent on some areas of the machair although the wet areas of machair, the blackland and peatland were all very suitable. It was possible to grow small oats (*Avena strigosa*) on the machair, the blackland or the peatland; successful crops could be produced on the blackland when treated with lime but, if too much shell sand was added, the crop would fail. It was difficult to grow big oats (*A. sativa*) on the islands, however, of a suitable size and in suitable quantities to warrant grinding; in particular, the machair was deficient in manganese and in later years the land was sprayed with a supplement to produce a successful crop, although good crops were still not guaranteed on the dry, sandy ground. Big oats grew most successfully on the peatland.

Rye was produced for fodder and flourished on the very dry areas of machair that the other cereals would not tolerate. Conversely, rye was less suited to the loamy and wet areas of machair or the blackland, although the remnant potato lazybeds did provide generally quite dry conditions, owing to the elevated cultivation bed.

A mixture of oats and rye was also grown for fodder, most commonly cultivated on the machair, where it was successful in most places. The opposing moisture tolerance of the oats and rye proved less suitable on the extreme areas of machair. The equal balance of the original seed was concealed when oats choked rye on very wet ground and rye choked oats on very dry areas and the potential harvest could be reduced by half. The same effect resulted from the weather; oats would flourish in a wet summer and rye would flourish in a dry summer. The oat and rye mix was also cultivated on the blackland and the hilly areas of peatland towards the east coast, in the ground that had previously taken barley or potatoes but, again, the rye was not successful if the ground was too wet.

Once home production of meal had ceased, pressure on resources lessened and cereal cultivation was only required to produce sufficient fodder and seed grain. The most efficient strategy, to gain maximum calorific value from the minimum investment of time and labour, whilst incurring least risk, involved machair cultivation of barley, oats and rye. The strategy was based on three principles:

1) Barley was considered the most nutritionally valuable of all the cereals but was generally less successful on the machair.

2) Oats and barley were successful on the blackland but cultivation involved greater labour investment.

3) Rye flourished in the dry machair environment unsuited to barley and oats.

The combination of all three cereals as a single crop, therefore, presented a range of species tolerances that encompassed all areas of the machair to provide a reliable and nutritious fodder from the most easily worked ground and avoided cultivation of two land types. Any loss that resulted from differential productivity due to extreme moisture content, could potentially be absorbed by the surplus production made possible by the greater ease of cultivation on the machair and the reduced pressure on both fertiliser and land. If a mixed cereal crop was successfully cultivated, however, differential ripening made the harvest difficult and so mixed crops were less common in earlier years when losses could not be afforded.

Barley was generally considered a valuable source of nutrition, but in some cases it was believed to cause a reduced milk yield, particularly when over-ripe. Barley was most commonly over-ripe when grown as part of a mixed crop, due to a short growing time as compared to rye and oats. The different harvest times of the three crops forced a compromise harvest date that aimed to save barley from dropping grain whilst not cutting the rye and oats under-ripe.

In earlier years making hay was not common - a relict of traditional stock husbandry in the years when transhumance was still practised (section 2.3.5.3). Additionally, unploughed ground was often left as grazing in preference to the increased labour required to cut grass. The popularity of making hay gradually increased, but making hay was always difficult because of the changeable weather - ideally dry, sunny and windy weather was required. Cutting was restricted to the blackland due to the inability of the dry unstable machair to support further cropping during the fallow. The hay naturally consisted of wild grasses, which provided good quality fodder, but in later years the designated hay fields were planted with seed, containing rye grass, timothy and clover, to supplement the natural crop. In recent years, many crofters have produced silage in preference to hay which is nutritionally superior but can only be produced from a clean crop of rye grass.

Potatoes have in recent centuries formed an important part of the diet and were cultivated quite intensively. The potatoes depleted the cultivation bed of more nutrients than the cereals and required the largest quantities of fertiliser. The potatoes would grow on either machair or blackland, provided that adequate fertiliser was applied, and the intensive conditions provided by lazybeds were particularly suited to potato cultivation.

5.1.4 Methods Of Fertilisation

Land became quickly exhausted after it was initially broken-in and regular application of sufficient and adequate fertiliser was essential to enable long term cultivation and produce worthwhile crops. This was especially important on the sandy machair, where the addition of fertiliser not only provided the nutritional supplement necessary to support a worthwhile crop but also provided moisture and aided the physical stability of the land. The two principle fertilisers were dung and seaweed.

5.1.4.1 Dung

5.1.4.1.1 Variety and Availability

Cattle dung accumulated in the byre during the winter months when the animals were stalled inside. On Lewis, there was a hole in the floor of the byre in which urine was also collected for use on the fields. The dung and bedding were cleared from the byre to form a pile outside, the midden, onto which other rubbish could also be added including straw waste, chaff, sweepings, ashes, household waste or remnant food (section 5.3 and 5.3.6). The exact composition of the midden varied from one household to another but the predominant component was always the dung and, therefore, the final size depended on the number of animals and period of stalling.

Horse manure was considered a better quality fertiliser than cattle dung because it was clean of straw and, therefore, it was normally accumulated in a separate heap to facilitate specific application of each type. Fewer horses than cattle were normally kept which restricted the quantity of horse manure that accumulated and, therefore, application was confined to the most valued crops, chiefly the potatoes. On the islands of Heiskeir, the horses often remained outside all winter owing to the mild climate, and quantity limitations were accentuated. Similarly, sheep were rarely kept inside on any crofts and little dung accumulated in any one place.

5.1.4.1.2 Utilisation

The midden was predominantly used to fertilise the blackland and associated lazybeds, a strategy based on three principle reasons:

1) The blackland was considered most suited to the application of dung. The friable nature of the dry sandy machair was considered unsuitable because sufficient binding was not afforded, although the use of dung on the loamy machair adjacent to the croftland was conducive to successful cultivation. The dung could become quite wet from standing outside unprotected and excessive moisture was considered disadvantageous to the sandy machair.

2) Dung was considered a vehicle for the dispersal of weed seed, particularly wild mustard (Gaelic '*sgeallan*') and couch grass, the latter of which was prolific around the farmstead and fields. If dung was taken to freshly ploughed machair the couch grass would spread quickly and compete with the cereal, which resulted in a bulky crop but with no increase in the nutritional value. Restricting the use of dung to the blackland was believed to contain the spread of weeds and benefit the quality of fodder crops produced on the machair.

3) Most importantly, it was more efficient to transport the dung a minimum distance. The logistics of transporting bulky material are a dominant factor, as illustrated by the proximity of the midden, on the farmstead, to the principle areas of application, on the blackland.

The quantity of available dung was the main factor limiting its utilisation. In most cases the dung was quickly exhausted but, if any remained after treatment of the blackland and lazybeds, it was normally used on the machair to supplement the seaweed. Local anomalies reinforce the importance of land type, however, as illustrated at Iochdar, on the north-western coast of South Uist. Here, dung is dumped on the shore rather than used to fertilise the machair, despite the increase in quantity made available in recent years due to the abandonment of blackland cultivation. The machair is too light and wet for crop quality to benefit from dung and so, despite the convenience of dung from the midden, the additional labour involved in the collection of seaweed, as an alternative fertiliser, is considered preferable. On occasion, surplus dung is dumped on areas of the sand dunes to prevent destabilisation, although this practice was less common in the past when all resources were highly valued due to greater agricultural intensity.

5.1.4.2 Seaweed

5.1.4.2.1 Variety and Availability

Seaweed was considered a good all-round fertiliser, which both complemented and supplemented the more limited resources of the midden. Two main varieties of seaweed were used on the land; tangle (*Laminaria* sp.), and wrack or bladderwrack (*Fucus* sp.), of which tangle was considered a stronger and superior fertiliser.

Tangle occurred most commonly on the west coast, where it was thrown up onto the shore from the sea bed by strong waves. A westerly wind was needed to bring the tangle ashore, washed up in irregular clusters along the coast and concentrated in larger quantities in bays or in the lee of headlands. Collection was mainly restricted to the winter and spring months when storms were most frequent and ferocious. The tangle appeared on the beaches from October onwards but the main collection began around New Year and continued until spring, during which time the coast was under constant surveillance, as noted historically (section 2.3.2.2). A sense of urgency surrounded the collection and removal of the tangle from the beach. The priority was to secure the seaweed from the reach of waves in case of removal in subsequent storms, but this was dependent on the availability of people, horses and carts. In recent years, labour availability has become a less limiting factor due to the ease of access to the beach by tractors.

Bladderwrack was found predominantly on the east coast, where the numerous sea inlets provided rocky sites, and hence a suitable habitat for attachment. The availability of bladderwrack was not directly weather dependent, for it was present at the growing site on a permanent basis. Availability was limited by the inaccessibility of growing sites, however, and furthermore the bladderwrack needed to be cut, a demanding and labour intensive task. Growing sites occurred along the rocky edges of the sea inlets, which were accessible by foot, and on rocks in the middle of sea lochs although these were only accessible by boat. Once cut, the floating weed was netted and trawled back to the shore whilst avoiding the strong tidal currents. A large mass of seaweed could break loose from the boat and get swept on to a lee shore, from where it could be rescued, but when the wind was in a certain direction the seaweed could be swept out to sea and never retrieved.

5.1.4.2.2 Utilisation

In general, tangle and bladderwrack were used on different land types. The utilisation strategies were influenced by:

1) Logistics. The most important factor determining use was the proximity of the source to the area of cultivation and an east-west division resulted linking seaweed variety, provenance and application with land type.

2) Availability in any given year.

3) Fertilisation potential.

The tangle was always applied to the machair land on the west coast and as far inland as quantity and labour permitted. Tangle was preferred for the machair due to the convenience of access and procurement, plus the provision of essential nutrients and moisture whilst aiding and maintaining the sustainability of ground which was otherwise easily destabilised when under cultivation. The quantity was also convenient for, despite availability being restricted to winter months, sufficient tangle was normally washed ashore to fertilise the designated arable land for that year. Tangle was equally suited to the blackland and applied when availability permitted, but usually there was insufficient time to collect enough tangle for both the machair and the blackland. Bladderwrack was used most commonly by east coast farmers because the proximity of the rocky growing sites to the cultivated areas of peatland made bladderwrack a convenient form of fertiliser.

On occasion the correct wind did not occur and the tangle failed to beach. The farmers were deprived of a valuable resource and consequently required an alternative method of machair fertilisation. Bladderwrack represented an alternative fertiliser with the added advantage of permanent availability. Labour investment was greater, however, due to the inefficient logistics of using bladderwrack, derived from the east coast, on the machair stretches situated on the west coast. The problems were compounded by the labour intensive nature of bladderwrack collection, particularly if sufficient was required for a large area of cultivated machair, and the final labour costs were severely increased. Bladderwrack, therefore, was only cut for the west coast when the tangle did not arrive on shore and when the dung was either not suitable for the land or when there was an insufficient quantity. Similarly, despite the convenient location of bladderwrack for use on east coast crofts, the labour intensive methods of collection were demanding and, therefore, when dung was available it usually took priority over the bladderwrack for reasons of convenience.

The provenance and labour requirements of the two seaweed varieties mainly influenced the utilisation strategy, but the fertilisation potential of each type also determined the specific pattern of seaweed utilisation. For example, tangle was used on the east coast because it was considered a superior, more powerful fertiliser, necessary for cereals and suited to any land type. When resources permitted tangle was brought over from the west coast to fertilise cereal crops on the east coast, despite the additional labour requirements. Conversely, bladderwrack was preferred over tangle specifically for potato cultivation on the east coast owing to the reduced risk of spoiling the crop by over fertilisation or 'burning'.

5.1.4.2.3 Treatment

The seaweed was either layered directly onto the land, when fresh, and left to dry or decompose before cultivation commenced, when it was ploughed into the ground, or it was heaped and rotted prior to application. The formation of heaps caused the seaweed to rot which reduced the moisture content, encouraged decomposition and decreased the high salt content of the fresh seaweed. The rotted seaweed represented a highly concentrated form of fertiliser that, when necessary, could be spread thinly to avoid over-fertilisation. The loss of moisture during decomposition greatly reduced the original bulk of seaweed. In one week the volume could decrease by fifty percent and might ultimately be reduced to as little as ten per cent of the original bulk.

Traditionally, the seaweed was spread more or less fresh, where possible, given the labour intensive nature of collection, in order to conserve the original bulk. The seaweed tended to be spread directly onto the fields if the cultivated areas were close to the shores where the tangle was washed up or the bladderwrack was cut. Heaps were usually made when the seaweed was intended for those fields further from the shore, when it was more efficient to cart the fertiliser in a concentrated form. Rotted seaweed was essential, however, to fertilise potatoes due to the decrease in salt content. A well rotted seaweed resulted in a firm and dry crop of potatoes whereas fresh seaweed caused sponginess.

The formation of heaps and the process of rotting was mostly associated with tangle owing to greater availability and utilisation. Furthermore, the stalks of tangle were very long, tough and awkward to manipulate and rotting was warranted on the grounds of practicality. In more recent years, the process of rotting prior to application has become a necessary adaptation to the inability of modern machinery to cope with fresh seaweed, particularly tangle. The seaweed rotted more quickly if the weather was warm, but normally three weeks was sufficient to produce a manageable slush which was suited to application by tractor.

The whole process of seaweed collection, treatment and application was started as early as possible in winter, to anticipate the sowing of potatoes and cereals in the spring. Usually at the end of each day, one cartload of seaweed was taken from the shore for use on the croft, where it was either spread directly on the fields or heaped into a pile to rot. If the seaweed was spread too late, the tangles had insufficient time in which to rot and would possibly impede ploughing. Furthermore, by March, less time was available for working the seaweed owing to the demands of other tasks such as the removal of dung to the fields.

Barley was less restricted by early sowing dates due to its unusually short ripening time. It was feasible to sow until late in May, whilst the tangle continued to be washed ashore, and the crop would still be ripe at harvest time. During the peak period of kelp manufacture this option was denied the farmers, for the laws governing the accountability of the seaweed stipulated a set date (for example 12.00 o'clock on the 28th May for Baleshare) from which time no more seaweed was allowed on the croft. With all the seaweed allocated to the manufacturing process after the designated time, none remained available for cultivation of those crops that were able to ripen late.

5.1.4.3 Dung and Seaweed Combined

The midden and seaweed were commonly prepared in combination, particularly for use on the potato crop. The method of preparation varied, but usually the heap consisted of alternate layers of dung and seaweed applied on a daily basis, from the farmyard and the shore respectively. Alternatively, seaweed that had previously rotted in a separate pile was mixed with dung and the combination left to rot further. When the potatoes had been treated, the remaining fertiliser was used on the cereal crops.

5.1.4.4 Alternative Fertilisers and Land Management

Hen droppings were used in some places as an additional or alternative fertiliser. No preparation was necessary and the droppings could be applied directly to the fields, but often the hen house was cleared to the midden and the hen droppings would mix with the cattle dung.

The crumbled peat dross that collected at the base of the stack would accumulate over the years to form a small platform. Occasionally the platform was levelled and the peat dross or dust was sometimes used as a supplement on the dry machair, counteracting the alkalinity of the sandy soil, increasing the humic content and thereby providing beneficial moisture retentive properties. This activity was not purely incidental, for the peat debris was often collected separately in a heap especially for this purpose. This was the converse of treating the peatlands with shell sand from the shore or machair on the west coast. The alkaline material was extremely beneficial on the acidic peatland, both as a fertiliser and as a method of land management, to encourage grass on areas of grazing. When applied to moorland the heather died back and the grass had an opportunity to come through with no additional seed required. In this way, the use of sand had the same effect as heather burning.

The application of mud slurry also increased the humic content and water retentive properties of the dry sandy machair. During the winter, when the ground around the farmstead was particularly wet and easily churned, a large quantity of mud was generated. If time was available, the mud was gathered using a hoe into small heaps close to the byre. Later in the year, when some of the liquid had evaporated, the heaps were carted to, and spread on, the nearby machair. The top soil from new building sites was used in a similar way.

The mud banks of the tidal inlets on the east coast also provided an abundant source of fertile slurry which proved a useful addition to the peatland, as previously recommended in one nineteenth century development plan (section 2.3.2.3). The mud was only used for the grass and hay and not put on the lazybeds. Occasionally fish guts were used as a fertiliser on the peatland. The practice was infrequent, owing to the small quantities of guts available and their common use as food for the dogs and hens. The freak occurrence of large shoals of fish sometimes provided an excess which would be spread on the peatland. In later years on the east coast the use of imported guano became popular. It was mixed in with the cattle manure, not on the midden, but actually at the lazybed. The guano was not considered to be superior to the bladderwrack, but it was used increasingly to avoid the labour investment required to cut the bladderwrack.

Soot was recognised as beneficial to the land but, on Uist and Benebecula, it was mainly used for pest control on the garden plots, sprinkled around the growing vegetables. The soot was collected from the chimneys using a heather brush (Gaelic '*froach sguab*') once annually or whenever the chimneys required sweeping. Only a small quantity of soot was produced from peat fires.

5.2 Cultivation Regimes

The agrarian regimes and management techniques were determined by the specific requirements of each land and crop type and the availability of resources. Land type predominantly influenced the extent and method of cultivation that was feasible within the limitations of crop suitability plus labour and fertiliser availability. The distribution of land types on each croft varied dramatically over the islands and consequently influenced variation in the associated agricultural regimes but, in general, distinctive strategies were developed in accordance with each particular land type.

5.2.1 The Blackland

The blackland (where the crofts were located) was treated as the infield, normally fertilised with the whole of the midden and cultivated more regularly for cereals than other arable land. Traditionally, the blackland was used for the production of the staple crop, barley, in association with oats and hay. Typically, cereals were produced for three or four years followed by two or three years of fallow during which grass was grazed or hay was cut. The potato was commonly cultivated in lazybeds on the blackland, owing to the suitability of intensive cultivation and the prime conditions that were provided. Potatoes were usually cropped for one year, after which the lazybeds were incorporated into the cereal cultivation.

The blackland was ploughed where possible, but on areas that were unsuitable the ground was either spade dug or lazybeds were constructed. The blackland was traditionally ploughed with one or two horses. One horse, however, could walk on the uncultivated grass adjacent to the ploughed land and avoid sinking into the newly turned, wet ground in the furrow. The ground was most productive in the first year of cultivation after the fallow period ('strong' ground). With each successive year of cropping, nutrients were depleted and the ground was less able to withstand further cultivation. Barley, the most demanding crop, was always grown in the first year of the rotation to take advantage of the rested ground, and always received the largest quantity of fertiliser, as traditional on the infield with the staple crop (section 2.2.6.1). Dung was used to fertilise the blackland and, on average, two tons of dung were required on one acre of barley in the first year of blackland cultivation. The dung was spread prior to ploughing for the best results. If insufficient dung was available to fertilise the blackland, any rotted seaweed that remained after the treatment of the potatoes and the machair would be used as a supplement, either applied separately or rotted together prior to spreading. If dung was in very short supply seaweed may have been used alone on some patches of cultivated ground. Sand and hen droppings were also beneficial for the cultivation of barley and oats on the blackland.

After the first year, less fertiliser was normally applied and a less demanding crop, oats, was planted. The oats usually received one and a quarter to one and a half tons of dung on one acre of blackland. The barley, therefore, received on average fifty percent more fertiliser than oats grown on the same land in the second and third years of the rotation, which reflects the importance placed on the staple crop (and the less demanding treatment of the land once the initial crop was taken. The oats would grow reasonably well on the blackland without additional fertiliser, particularly as the crop was normally intended for fodder. Similarly, rye could be cultivated on the blackland without additional fertiliser, but the heavy wet soils were not well suited to rye and it was only grown as convenient fodder. Occasionally the oats and rye were grown on the blackland as a mix, using whatever dung or seaweed remained after fertilisation of the barley. Usually the oats and rye were cultivated on the higher areas of blackland, whilst the barley was suited to the lower slopes.

Furthermore, by not applying any additional fertiliser in the second year, the development of a heavy crop was avoided. In the soft ground that resulted from the second year of ploughing, a heavy crop may have flattened or 'lodged' in bad rain and wind, and the ground was, therefore, better suited to a light crop. When unfertilised, oats and rye were advantageously light and able to withstand the rough weather. Consequently, valuable fertiliser was relinquished, which complemented the demands of the staple crop in the first year of cultivation.

In the fourth or fifth year the ground was not cultivated and the grass provided grazing or hay. The hay consisted of good quality natural grass, unless seed was planted. The planted hay fields were planned in advance for maximum efficiency, as the seed needed to be under-sown with the last cereal crop of the rotation. In the first year, the grasses comprising the hay crop did not develop seed heads and, therefore, did not get in the way when the cereal was flailed, during crop processing. When the corn was cut, the grass roots were left so that the hay came up the next year, a practice which would not have been possible when crops were uprooted, as was common in the past in some places (section 2.3.4.1). In the second year, when no cereals were sown, the hay developed fully and a good crop could be cut for at least two years.

The loamy blackland was sufficiently fertile to produce hay without the addition of fertilisers although, when available, dung or peat dross were applied as a top dressing. In later years, if dung was in short supply, artificial fertilisers were applied to the hay fields. Fresh seaweed was unsuitable as a top dressing for it dried on the unploughed surface and hindered the equipment during cutting. Two or three acres of blackland were put over for hay each year, with a return of two or three stacks from each acre. If the ground was left for grazing during the fallow, no top dressing was applied.

Potatoes were either grown in lazybeds or the drier areas of ploughed land on the blackland, but they were most commonly associated with the lazybeds. Potatoes were the most demanding crop and, therefore, normally received more fertiliser than barley and took priority in the rotation. Regardless of technique, however, the potato crop was always fertilised with care; under-fertilisation produced a generally small crop, but over-fertilisation was also avoided due to the risk of 'extreme' produce, where the resultant crop consisted of both very small and very large potatoes. Potatoes were usually treated with horse dung or with pre-prepared fertiliser that consisted of layered and rotted seaweed and horse manure or, if insufficient, cattle dung. The horse dung was always saved for the potatoes because they were a demanding crop that required preferential treatment.

Potatoes were extremely successful when grown in lazybeds, due to the intensive cultivation conditions that were provided and, although the technique was hard work, the crops were often ready before those grown on the machair. Potatoes were cultivated in the first year, owing to a great need for nutrients and also because the potato tubers fragmented the ground in the lazybeds and provided more suitable conditions for subsequent cereal crops. Once the potato crop had been lifted, two lazybeds were merged together and formed a bed approximately 2 m to 2.5 m wide, that was more convenient for cereal cultivation. Barley was usually grown following the potato crop for one year, whether in lazybeds or on the ploughed ground, after which the blackland was left to fallow. Descriptions of lazybed construction closely match those reported in the published literature (section 2.2.5.2).

The exact cultivation regime employed on the blackland was dependent on the quantity of available land. For example, a croft at Howbeg that possessed twenty acres of blackland in total, had fifteen acres designated as grazing land. The grazing was usually on the blackland because the animals would be tethered close to the farmstead and because the grass was good and more dependable than on the machair, particularly in dry weather. The five acres under cultivation comprised scattered patches, each at a different stage in the rotation. One of barley and four acres of oats were usually sown annually. Approximately one stack of barley was taken from an acre (by this time grain was also imported). A one-eighth acre patch of potatoes was also grown, although a further two patches were grown on the machair. At Baleshare, the croft possessed fifteen acres of blackland, of which half was designated for grazing and half cultivated by rotation.

5.2.2 The Machair

The sandy machair was easy to work in comparison to the blackland, but exhausted rapidly with repeated croppings. A fallow period was preferable and fertilisation was essential. Seaweed was preferred as a fertiliser due to proximity to the shore, the provision of the necessary moisture and stability, and its greater suitability over dung. The machair was traditionally used for the cultivation of the fodder crops, oats and rye, which were cultivated either separately or combined. Potatoes were also grown on the machair and, if sufficiently fertilised, benefited from the dry sandy conditions.

The machair was traditionally ploughed with two horses, using a plough that was able to cut very shallow swathes of turf (150 mm to 200 mm deep). Shallow ploughing was necessary on older ground that was matted with roots (section 2.3.3.1). The modern, hydraulic ploughs were not adjustable and cut the ground too deep, (0.45- 0.6 m deep), and on the old ground the turf would not remain folded over. Furthermore, the shallow ploughing was less likely to destabilise the ground than furrows cut deep into the machair. Arable fields on the machair were preferably rotated, to allow the easily exhausted ground time to recover, but the cultivation regime was determined by the quantity of available land. For example at Howbeg, on a croft with only two or three acres of machair, the pressure to produce cereals forced continual cultivation whereas, at Howmore, on a croft possessing six acres of machair, the land was divided in two and cultivated in alternate years. The township of Peninerine in South Uist comprised eight crofts. The machair designated to the township was divided into three patches, each divided into eight strips of a half to one acre in size. Each croft had approximately three acres in total of permanent machair, covering three different areas, plus 30 acres of blackland. The machair land was usually worked on a three to four year rotation.

In general, rye and oats required three or four tons of fresh tangle on one acre of machair, the equivalent of a ground cover approximately 0.25 mm deep. A ton of rotten tangle may also have been added as a boost prior to ploughing. The different kinds of machair, however, required different treatment and the very dry machair near to the coast needed more fertiliser than the moist areas.

Tangle was usually spread directly onto the land and left to rot until the ploughing began. A specific date was set for each township at which point the crofters were allowed to begin cultivation. At Howbeg, for example, the ploughing began on the 15th of April, but an earlier start was possible on very dry areas of machair. When the ploughing started, any dung that remained from treatment of the blackland was also taken to the machair if the seaweed was insufficient. Dung was spread directly onto the fields using links towed by horses. The sowing began as soon as ploughing had finished. The seed corn was traditionally broadcast, and the ground may then have been harrowed if the weeds were prolific. The whole operation could span from the end of March to early May, depending on township regulations, land type and labour availability.

Barley would grow on the machair as long as it was neither too wet nor too dry. Barley was, however, better suited to the blackland and, therefore, required twice the amount of fertiliser to produce an adequate crop when cultivated on the machair: four tons of dung to one acre of machair. In later years, when production concentrated on fodder crops, barley was included with the rye and oats for cultivation as a mixed crop (section 5.1.3).

The cultivation of potatoes on the machair depended on correct fertilisation. Dung and seaweed were normally used. A layer of fresh tangle was often spread on the machair at New Year or before the end of January, depending on availability, for early application spread the work load later in the year and allowed sufficient time for the seaweed to rot. The pre-prepared, composted fertiliser was then applied as a boost a few days prior to planting. Alternatively, rotted seaweed and dung were applied as separate layers prior to the planting. The relative proportions of dung and seaweed used in the fertiliser for the potatoes varied, although the amount of seaweed was often more than double that of dung. The quantity of fertiliser required for the potatoes was generally considered to be twice the amount used to fertilise the oats and rye on the same patch of machair. On poor land, the quantity was increased according to the amount of available fertiliser.

Prior to the introduction of early-maturing varieties of potato, a split crop was sometimes planted. A small patch was planted to provide early potatoes without risking the loss of the whole crop in a late frost, a particular problem on the islands. The main crop of potatoes was not planted until mid-April, after the cereals had been sown. The potato beds were cleaned by hand using a hoe, which was essential to avoid the crop being choked by weeds, wild mustard in particular. The weeding continued until the shoots of the potato plants were high and, later, the sand was lifted up around the growing potatoes. Cereals were not weeded other than by ploughing and harrowing, for the weeds had usually withered away before the harvest. On continually cultivated ground, or areas that had not been fallowed for more than one year, the weeds, particularly wild mustard, were especially bad due to re-seeding. Rye often followed the potato crop, because the potatoes were cultivated in dry ground to avoid rotting, and the dry soil was more suited to rye. During the fallow period the machair was grazed but not seeded for hay.

On the all-machair islands of Heiskeir, the cereal crops were cultivated in the first and second years of the rotation, followed by the potatoes in the third and then three or four years of hay. This regime reflects the absence of blackland on which to support the staple cereal crops. On Heiskeir, an individual cottar's plot was *ca*. 4-5 acres, divided into rigs 6.4- 7.3 m wide by about 45 m long. The plot gave 4-5 cornstacks for a family.

5.2.3 The East Coast

The methods of cereal cultivation on the east coast were similar to the those used on the blackland, but the ground was generally less fertile and, therefore, cultivated less intensively. The peatland was cultivated in the first year for either barley, oats or rye, and grass seed was undersown at the same time in order to produce hay in the following three years. Barley was usually fertilised with pre-rotted dung and seaweed, either tangle or bladderwrack, but over-fertilisation was avoided. Hay and grazing grass were fertilised with a mix of well-rotted bladderwrack and sand.

Potatoes were usually grown in lazybeds on the east coast owing to the drier conditions that the drainage channels provided. The lazybeds were approximately three times the width of those sited on the blackland because a larger and deeper drain could be dug, an essential requirement in the wetter ground. The ridges produced when ploughing were the same width as for the large lazybeds but the drains resulting from ploughing were often insufficiently deep and so the ground was not drained correctly, as indicated by the presence of rushes. The potatoes were fertilised with pre-rotted bladderwrack and dung and although sand was incorporated with the seaweed, more was often added after planting.

5.2.4 Recent Adaptations

Crops were selected in accordance with the local environment and available land type and the cultivation regime was developed to satisfy the requirements of each crop type and land type. The decrease in the production of crops for human consumption caused a reduction in the intensity of barley cultivation with consequent adaptations to the methods and decisions that tailored the agricultural system. The blackland frequently hindered or precluded the use of ploughs, so traction and cultivation requirements were more labour intensive than on the easily worked machair. With less pressure to produce barley, cultivation of the blackland was rapidly abandoned. Barley was produced on the machair, but quantities were greatly reduced owing to some land suitability problems whereas the machair was particularly well suited to oats and rye for the production of good fodder. A balance was sought, therefore, between the production of fodder with sufficient calorific value and ease of production, taking into account the logistical and environmental constraints. The range of cultivated crops remained unchanged, despite the reduced pressure on resources, which illustrates the dominant influence of environment and land type over crop selection. The magnitude of production reflected the change of emphasis in the use of cereals and the associated modifications to the cultivation strategy.

5.3 Product Management

5.3.1 The Farmstead

Pivotal to the cultivation regime was the farmstead, where the crop and stock were stored, protected and eventually processed. As with the cultivation regimes, the domestic activities conducted on the farmstead were resource and labour dependent and, therefore, also required prioritisation and timetabling in a manner complementary to the agricultural calendar. Domestic operations concerned the collection and consumption of resources, both nurtured and natural. The associated activities resulted in valuable by-products which were frequently recycled.

5.3.2 The Harvest

The harvest began in mid August and continued until September. The rye ripened before the oats, when the two were grown separately. The date of ripening of barley was variable, depending on the time of sowing. The crops were traditionally reaped by hand and close to the ground to harvest the valuable straw. The rye and oats were reaped using a scythe (Gaelic '*speal*' or '*faladair*'), a fast and efficient means of reaping the crop, and sheaves were tied using the cereal itself.

More time and attention was paid to the cutting and binding of the barley as the grain was considered more valuable. The barley was reaped with a sickle (Gaelic '*corran*') because the crop could be cut with care and less grain was lost than with a scythe. A more fussy type of binding was used for the barley when making sheaves (Gaelic '*cainal*'); a tie was prepared by twisting together the ears of a few strands of barley. The sheaf was lain across the tie on the floor and fastened with a particular twist, turn and tuck.

Once bound, the sheaves were built into stooks and left to dry for 7 days. The number of sheaves in a stook varied from 4-6 in Benbecula to 6-8 in South Uist. In Benbecula, the stooks were constructed into a 'hut', which would contain approximately 16-18 stooks, and would be left to dry for at least a further 14 days. Alternatively, in South Uist, when the stooks were dry a semi-stack was built (Gaelic '*toiten*'), that would protect the crop if it rained.

In recent times, the hay was cut in July and August (in earlier times, hay making had to be delayed until after the cereal harvest - section 2.3.5.3). The hay stacks, called '*dias* ' or '*dash*' , were made differently from those built for the cereal crops. The stacks resembled a corn stack laying on one side. The hay was not tied down tightly but remained loose, with some ropes to weight it down. Alternatively, two smaller, round stacks could be constructed. When all reaping was completed and the sheaves had been left to dry for a sufficient length of time, the crop was carted to the stackyard.

5.3.3 The Stackyard

The stackyard consisted of a walled or fenced enclosure which surrounded a series of stack bases. The number of stack bases depended on the size of croft but would be sufficient to provide solid and dry foundations to the incoming harvest. On average, each croft would store ten stacks of cereal. The stackyard was situated very close to the dwelling and other farm buildings, and it was quite common for the barn to form part of the stackyard wall. The design and position of the stackyard was based on three factors regarding crop protection and logistics:

1) The wall of the enclosure was designed as a physical boundary to separate the crops from the threat of straying animals.

2) The proximity to the dwelling afforded regular observation of the stackyard and the opportunity to minimise loss through the interception of animals that did manage to intrude and the pre-emption of imminent storm damage.

3) The incorporation of the barn into the wall decreased the distance over which crops were moved, and possibly lost, when the stack was opened, and the dual function reduced construction requirements.

Stack base construction varied between the different crofts. Stones were most commonly used, with large stones delineating the outer line of the base and the middle filled with smaller stones or shingle from the beach. Alternatively, the base could consist of a circle of peat, with or without the addition of sand. Improvisation was legitimate, such as the use of discarded cart wheels and wheel rims which provided an aerated base to the stack.

Once constructed, the more permanent stack bases required little or no preparation prior to use. The removal of any plants growing between the stones or a scatter of sand was sufficient although, in some cases, a slight ditch was dug around the base to aid drainage. Where peat was used, attention and mending may have been required. In some cases no base was prepared and the stack was formed directly upon the ground. The bases, and consequently stacks, were spaced approximately 0.6 m apart to avoid the danger of rain draining from one stack to the next.

Two people were necessary for making the stack. Ten 'good' huts made one stack, or alternatively five or six '*toiten*'. The stacks were covered with rushes, marram or even hay to form a thatch that was weighted down with heather ropes. This provided a dry cover and adequate protection from the hens. Netting was used as an alternative and more convenient covering in later years.

5.3.4 The Barn and Crop Processing

The barn usually fulfilled three functions associated with three spatially distinct areas: one end of the building acted as a temporary crop store, the opposite end contained the kiln, which represented the parching facility and the middle area provided a work space for crop processing. In the summer months, when the barn was not in use, the clay floor was covered in sand and when the processing operations resumed the sand was cleaned out.

Winter was the busiest time of year on the farmstead. In December the cattle were brought into the byre and fodder was required until the spring growth of grass. The stalling of the cattle also signalled the beginning of the crop processing operation, whereby meal was produced from the barley grain. When the grain processing and stock feeding began, a stack was broken open and the sheaves were stacked at the storage end of the barn. Usually half of the stack would fit into the barn and the remaining half was re-covered, possibly with turf, for continued protection. Mildew could develop on the basal layer of the sheaves whilst in the stack despite the use of the base. The mildewed corn was simply cut off using a sickle, before taking the sheaves into the barn for the crop processing, and the spoiled corn was fed to the cattle.

5.3.4.1 Plucking and Initial Cleaning

The first stage involved separating the barley grain from the straw. Most commonly whole ears were plucked off by hand (plucking in Gaelic *'spilluge')*. In some places the ears were also trampled on a tarpaulin outside the barn in order to loosen the grain but not completely destroy the form of the ear. An alternative method to plucking involved threshing the barley to free the grain, using a 0.9 m long stick with a sharpened end or a flail constructed from two pieces of wood and a sheep skin lace (flail in Gaelic '*sarsdgh')* . The flailed grain was then winnowed using a coarse sieve usually made from pierced sheep skin or cow hide (sieve in Gaelic '*criathar*').

If the weather was dry and the wind light the grain was winnowed outside the barn. If the wind was too strong, however, then the corn was riddled inside the barn, using the air vent specifically built into one side of the barn wall and the open door to create a through flow of air. The air vent (Gaelic '*feadon*') was usually built into the wall facing the prevailing wind, and when the wind blew from the west it "blew good" for the winnowing. The plucking technique was commonly associated with the South

Uist crofts, as referred to in the historical documentation (section 2.3.4.2), whilst on Heiskeir and North Uist the grain tended to be separated by flailing.

The initial stages in the operation were usually conducted in the winter evenings although, in slack periods, the daytime was also invested in crop processing. The flailing was commonly performed by men and the winnowing by women. Only one person could work the flail at a time, owing to the danger of injury, but the flailing and winnowing could be conducted simultaneously and two or three people could process a whole stack through the primary stages in just a few days, if time were available. As the ears and hulled grains were released, they were saved in barrels or covered bags until enough had been accumulated for the more elaborate parching and milling operations, both of which were only conducted once annually.

5.3.4.2 The Kiln and Grain Parching

Once the ears or the grain had been prepared the barley was ready to be parched, a process necessary in order to dry the grain and facilitate effective grinding (and to malt the grain as part of whisky production). Purpose-built kilns were used to parch the grain (Gaelic '*ath*' or '*asoul*'). In the Uists, Benbecula and Heiskeir, a smaller, internal kiln was common, compared to the large external versions found on the Northern Isles. The use of small kilns was also noted in the late eighteenth century on South Uist (section 2.4.4.2) and may reflect the smaller scale of grain production in the Outer Hebrides. Kilns did not occur on all crofts, and several families may have shared in the use of one kiln. The kiln bowl and flue were built into a solid rectangular block situated at one end of the barn. The kiln bowl was *ca.* 1 m in diameter across the top and tapered down to *ca.* 0.6 m in diameter across the flat bottom, the complete depth was *ca.* 1m. The flue consisted of a long tunnel constructed of large flat stones, which led from the base of the kiln bowl to an opening in the side of the block. The stone used in the construction of the kiln flue was often reused by the estates in later times, owing to its high quality and the saving on masonry costs.

A small, peat fire was made in the entrance to the flue which, until all the other preparations to the kiln were completed, was kept quite low. The fire had to be watched overnight, once the intensity had increased, due of the risk of sparks which posed a serious threat in a building with a combustible roof and dry stored crops. Peat was, therefore, the preferred fuel for the fire, because timber usually produced more sparks. Only on rare occasions were small bits of wood used with the peat. The fire tending and most kiln-related activities were performed by the men.

The kiln was prepared by constructing an umbrella shaped frame or wigwam structure of sticks built up above the kiln bowl, as described by Fenton (1978b) for Lewis. Straw, of any variety, was usually placed on top of the stick construction to form a layer 25 mm to 50 mm in depth. The layer needed to be sufficiently thick to prevent the ears from falling through, but thin and loose enough to allow the heat to pass through. Wooden pallets were used as an alternative platform to the stick and straw construction.

The barley ears were placed on top of the straw to form a layer *ca.* 150 mm thick. The ears were then parched until crisp to the touch, at which point they were removed by hand. If the corn had been flailed previously, a thinner layer of grain (*ca.* 25 mm thick) was placed on the straw, for any thicker and the smoke would have been prevented from passing through. The grain or ears took about one hour to harden, whilst being turned by hand throughout the operation.

The entire operation was extremely smoky, which necessitated the conscientious smoke proofing of the entire building. All the barn wall and kiln joints were packed with turf instead of mortar, owing to the smoke proof property of the former. The walls of the barn were thicker than other buildings, on average 1 m thick, in order to hold sufficient turf packing. There was a hole in the roof of the barn which allowed the heat and smoke to leave the building.

When the parching was completed, the kiln was cleaned using a long brush made from tough heather. The peat ashes from the kiln fire were thrown to the wind, the ash heap or the midden depending on personal preference and the weather. The kiln sweepings, comprising corn waste and chaff, were thrown outside where they would usually blow away or get eaten by the cattle and hens. In some instances this rubbish was thrown onto the midden, but the sweepings never amounted to much and did not usually warrant an intentional trip to the midden. The straw from the parching platform may have been thrown onto the midden, but more commonly it was reused as bedding in the byre, particularly for the calves. Any straw could be used for bedding as long as it was dry and the pressure on resources was usually too high for materials be thrown away when further usage was still feasible. The sticks tended not to suffer damage and were adequate for reuse in subsequent parching operations. The grain parching was still in operation on Heiskeir in 1921 and on South Uist in the 1930-40's.

5.3.4.3 Flailing, Winnowing and Sieving

Once hard, the ears were threshed on the floor, with particular care taken to keep the corn dry. The ears were broken up two or three times. In some areas the grain was pounded in a secondary threshing stage, particularly effective for removing the tough barley awns. The ears were placed in a tub (Gaelic '*tuba*'), half barrel or tea chest and mashed or pounded with a spade until the spikes had loosened.

Afterwards the rubbish was cleaned out using a sieve, either inside or outside the barn, as with the previous winnowing. The threshed ears or grain were gently riddled onto a tarpaulin, allowing the grain to be separated from the waste. The chaff, dust and sweepings that resulted were not intentionally thrown on the midden, but blew away outside the barn or were eaten by the hens. In some places the chaff was never fed to the cattle, especially if they were in calf, owing to the danger of the animals choking on the dry husks. In other places, however, the chaff was fed to the cattle, or soaked in water to soften the awns and fed to the horses. The barn was always kept clean to protect the seed. During each different stage of processing the corn was either bagged up or covered when left on the floor so as to avoid the risk of any contamination from rats.

5.3.4.4 Grinding and Storage

Once winnowed, the grain was ready to be ground into meal. Traditionally the grain would be ground a little at a time on a hand operated rotary quern (Gaelic '*brath*' or '*bra*'), but in later years water powered mills were built which could grind the year's grain as one operation. Although laws were passed which required all hand querns to be broken and thrown away, the use of querns occasionally continued in times when all the meal had been used and in emergencies. Then, if necessary, enough grain could be processed from sheaf to meal, and made into bread, all in one day. Grinding by hand was a time consuming operation and the use of the water powered mills did ease the required labour investment. By the early spring, enough grain was processed to warrant the annual visit to the mill. The miller would take one bag out of every five he was given to grind, a share often begrudged by crofters and one which perpetuated the common rumours regarding dishonest millers.

The meal was cleaned of any remaining chaff when it returned from the mill. The very light chaff, 'car', was removed by using a fine sieve (in Gaelic '*cearoc*'). This stage in the processing was performed inside the house, and may have taken place piecemeal, as required, or alternatively the meal may have been sieved as one operation and stored clean. The sieving was not a lengthy operation and at quiet times it was possible for all the meal to be sieved in the same day. The winnowing and sieving were tasks usually performed by the women. If time was available the men would also help clean the grain and meal, but by the spring the seaweeding and field preparations consumed most time and slack periods were quite rare.

The meal was stored in containers such as barrels or chests, trampled in by men and women both to ensure 'vacuum' packing and to fit more meal into the available space. The chests were stored inside the house, in the kitchen. Two chests of meal were commonly produced by each household, but some families did need to buy extra meal. The decline in barley production was initiated by the increased accessibility of imported flour. The cargo boats would arrive at harbours such as Loch Eyport, in North Uist, and the crofters would take carts to collect the 'Indian meal' (maize) and oatmeal that were sold.

5.3.4.5 Seed Grain and Fodder

Parallel to the barley processing, was the setting aside of grain for re-seeding the following year and the preparation of fodder. The barley grain that was required for reseeding was taken to one side after the plucking stage and then flailed and winnowed whilst the rest of the barley was parched in the kiln (parching would render seedcorn unviable). The straw that resulted from the crop processing was used as feed, and what remained in the manger was used as bedding, primarily beneath the calves.

Less care was taken when collecting grain for re-seeding, than with the activities involved in the processing of the grain for meal. A stick was used with a downwards stroke to knock the seed off the sheaf, or the whole sheaf was simply knocked against an angled plank, a wheel or a similar object. The grain was flailed and sieved to separate the chaff and then stored until there was sufficient seed for replanting. These operations were also conducted little by little, as and when barley was liberated from the sheaves during the processing for meal.

Oats and rye provided the bulk of the fodder crops. Grain was knocked off each sheaf and collected as seed, but some grain was purposely left on the cereal. In this way the sheaves still had grain left on them when they went to the cattle, and remained palatable to the animals. Barley was also used as fodder, both the straw by-products from the grain processing and seed collection and occasionally some of the surplus barley grain. The fodder was either fed directly to the animals or it was first prepared by bruising using a stick. The barley was 'strong' and therefore only a little was used in the feed. Two good handfuls of bruised grain and some straw were given to every cow twice a day, when the animals were outside. If the weather was bad they were given an extra two handfuls of grain. The animals were given barley straw when this was available. It usually still held some seed and, if not, treacle was put onto the straw to make it more palatable to the cattle. Approximately one stack of fodder was required per cow per year, and double the quantity for each horse (horses were fed oats all year round). If the barley straw was not used for feed, and eventually bedding, it was sometimes used as thatching in times when marram was unavailable.

On the north eastern side of Benbecula, the cattle were given seaweed to supplement the grain and straw during the winter months. The seaweed was collected from the rocks and boiled in water prior to feeding. It was considered very beneficial owing to the rich iodine content which was thought to prevent disease, particularly in the calves. Occasionally, the cattle were also fed raw potatoes.

5.3.5 The Byre and Stock Care

Prior to the early nineteenth century, animals and people lived in the same building, but laws were passed to reform living conditions and a separate door was demanded between the people and animals. Continued reforms led to the construction of completely separate byres although, on many parts of Uist and Benbecula, the isolation of the byre had preempted changes to the law, whereas the old building tradition persisted for much longer on Lewis and Harris. The reuse of buildings was very common, particularly the conversion of the original dwelling into the byre when a new dwelling house needed to be built.

The byre often contained both the horses and cattle, kept separately in the different ends of the buildings. A separate stable may have been constructed on larger crofts where a greater number of animals were kept. The byre was sometimes semi-partitioned with wooden panels as a means of separating the individual horses and cattle and, to prevent the cattle from straying, they were tethered to an iron peg or stake attached to the wall.

The floor of the byre was usually made of flagstones or cobbles, which incorporated a slurry trench to aid drainage. The byre floor was covered with absorbent materials to provide bedding and to act as a urine soak. Machair turves were commonly used to provide a warm and dry bedding. Turves, *ca.* 0.5 m long, were cut every winter from areas of tough grass on the machair to cover the floor. The turves remained throughout the period of stalling with only occasional repairs or replacements required. Straw or hay left over from the feed may have been added to the turves, or alternatively they may have been used in isolation, as on Heiskeir, in which case frequent renewal was required. At Baleshare the byre floor was also covered with sand, weekly. On the east side of the island sand, ferns and turves cut from the peatland surface were commonly used as bedding materials.

5.3.5.1 Stock care

The cattle and sheep were free to graze on the stubble fields once the harvest had been secured inside the stackyard at the end of the autumn. On the islands of Heiskeir the cattle were free to roam from island to island when the tide was out. Cattle and sheep would commonly browse seaweed from the shore as an alternative to grass. This was particularly common when the grazing was limited, but the animals would also browse seaweed during times when grass was plentiful. The cattle remained outside until the beginning of winter when the grazing was no longer sufficient and the wet ground was more likely to incur damage from trampling. The cattle were stalled inside the byre at night over the winter period, where they were fed twice a day (the remnant fodder was taken from the manger and used as bedding). The cows were milked twice a day inside the byre and were fed bread to keep them still. The sheep remained outside during winter and grazed any available vegetation, with occasional supplements of fodder when the natural resources were particularly scarce.

By the end of March, April or May, depending on the weather, the grass had rejuvenated and the cattle were returned to the land. Later, in the summer months, during the period of crop growth through until harvest, the cattle were taken off the arable fields and herded on the common grazing . The practice of transhumance had stopped at the end of the last century on Uist and Benbecula, although it persisted to a later date on Lewis (section 2.3.5). In place of transhumance, a bothy man was employed by each township to mind the cattle from all crofts between the officially agreed dates. For example, in the township of Illeray on Baleshare, the stock were banished from the arable land from the 28th May until the 24th October (between 1st

May and 1st November at Peninerine). An enclosure was situated next to the head dyke and bothy which could contain about one hundred head of cattle. In the morning, a girl from each household would go to the enclosure to milk the cows. At 12.00 noon they were led out, under the care of the bothy man, to graze on the common land or on machair designated as fallow until 7.00 pm when they returned for the second milking. In the summer time the milk was kept in large, covered, enamel basins in the barn, as this was the coolest building. After two days, the cream was removed and the butter made.

The traditional system of souming was no longer applicable when the crofters stopped farming on a self-sufficient basis but the original specifications were realistic estimates of the grazing capacity of land used also for regular cultivation (section 2.3.5.2). The decline in barley cultivation in recent years has freed more land and stock grazing is less structured. Furthermore, the emphasis on sheep farming reflects the inclination towards less labour intensive activities and as such the part-time nature of contemporary crofting.

5.3.6 Midden Formation

In previous years, when the cattle were over-wintered, the dung was left to accumulate over the entire period of stalling and emptied from the byre in the spring when the cattle returned to the grazing. Such deep litter stalling was considered advantageous as no nutrients were washed away through exposure to rain and the dung was less waterlogged, a problem for utilisation on some areas of land. In later years, the dung was mucked out on a daily basis to form a midden in front of the byre. On most crofts, a stone platform *ca.* 1.0-1.2 m wide, along the front of the byre, provided a slightly elevated, and consequently dry, path. The dung was thrown to the lower ground beyond the platform but was still close to the byre, thereby minimizing the distance over which it had to be carried. The loose materials such as straw, remnant fodder and broken fragments of turf, that were included with the dung, contributed to the formation of the fertiliser. When the cattle were returned to graze in the spring, the byre was completely cleaned out to the midden, including the broken and disintegrated machair turves. These represented a sizeable addition of alkaline material to a fertiliser which was predominantly used on the acidic blackland. The use of machair turves in the byre, therefore, represented a technique of land management that combined technical advantage with logistical efficiency.

Turf from the blackland was not dug specifically for the midden on Uist, Benbecula or Heiskeir and was usually only deposited on the midden if it had been used as bedding material in the byre, as on east coast crofts. Shell sand was also commonly applied to the middens on east coast crofts to provide beneficial lime for the heavy acidic soil although it was more efficient, and therefore usual, for the sand to be applied directly to the fields. Regardless of method, the operation was a necessary adaptation to substitute for the absence of machair turves in east coast byres, a practice that was neglected due to the increased distance from the west coast.

The midden was usually removed from the farmyard some time in March or April, after the animals were returned to graze and stalling had ceased. By this time of year, the land had dried sufficiently to support narrow cartwheels without incurring too much damage, a less significant factor with the use of tractors. The other materials that were added to the midden, both intentionally and incidentally, were consequently spread on the land along with the dung. Additional materials could include the chaff and straw waste products from crop processing and floor cleaning, food waste and ash. The midden was vital to the treatment of the land and, therefore, accumulation of the midden was a managed operation. The deposition of additional organic materials was fairly haphazard but nothing that may have proved detrimental to the land was thrown on the midden.

5.3.7 The Use and Disposal of Other Resources

5.3.7.1 Fuel

Peat was the main fuel used on the farmstead. Each croft was designated an area of bog from which peats were cut in July to supply the following year. The peats were left scattered next to the peat hag (cutting) for a few weeks to dry out, and were then carted back to the farmstead to be stacked.

The peat ashes from the household fire were, in some instances, thrown onto the midden but this was rarely intentional and depended on the distance of the midden from the house, the quantity of ash produced and the weather. A separate ash heap was usually used in preference to the midden, for it was more practical to deposit the ashes somewhere nearer to the house, in accordance with the principle of least effort in relation to distance. Furthermore, it was safer to walk the shortest distance with red hot ashes, when the buildings all possessed combustible roofing materials. It was usual to wet the ashes before going outside, to reduce the danger of sparks blowing onto the roof from the embers. Peat cut from shallow hags resulted in large quantities of heavy red ash, whilst peat cut from deep hags produced a small amount of very light, white ash. About one bucketful of the heavy ash was produced daily, and it was likely to be deposited in a separate heap owing to the sheer quantity produced over the winter period. The very light ash, occurring in small quantities, was most likely to be blown away before any specific heap was reached. If accumulated, the light ash may possibly have amounted to one quarter of a ton, or less, all winter.

The cutting and collection of peat was very labour intensive and often there was insufficient time to collect enough for the whole year. When the peat stack was exhausted in the summer months, the stalks from heather were used as alternative fuel, which provided enough heat to boil a kettle, usually the only requirement in the summer months. The stalks were derived from the very old tough heather that thickened with age as the top growth decreased. When heather was burnt as part of moorland management, in an attempt to encourage a new growth of grass, the fire would spread quickly over the sparse new growth and fail to ignite the woody stems. The remaining stalks broke easily when pulled from the ground, leaving the root behind, and special journeys were made to the hills in order to gather bundles of this excellent fuel.

The domestic fire was the main source of light in the dwelling and the heather sticks burned with a bright light, particularly suited to the summer months when a source of light without heat was preferred. Prior to the days of paraffin and oil lamps, only poor light was available from seal and fish oil which was used to fuel rush wicks. Timber was not usually used as a fuel on the islands because it was such a valuable resource for construction. The nearest source of wood, apart from drift wood, was Greenock, Mallaig or Oban and the distance increased the cost. The sweepings from the dwelling floor may have been thrown onto the fire, but in some cases may have been thrown outside or on the midden.

5.3.7.2 Roofing Material

The roofs on Uist, Benbecula and Heiskeir were made from various combinations of turf, heather, marram, straw, rushes, bracken and/or ferns. The roofs were designed as permanent features which were added to, rather than replaced, when repairs or renewal were necessary, in contrast to the deliberate annual stripping of roofing material for fertiliser from the Lewis croft buildings (section 2.3.2.3). Every second year, new turf, followed by marram, straw, or another material, was added to the existing roof, and consequently it was rare for old roofing material to be discarded. A roof made of marram alone would need annual additions. Marram was an extremely versatile and valued resource and, on occasions when it was unavailable for roofing, heather was the preferred alternative. A well constructed roof was expected to last for years, up to twenty or thirty years if made of durable heather. On Heiskeir, the stacks were similarly protected with marram, and this was eventually thrown to the midden when the stacks were disassembled.

Roofing material was not usually thrown onto the midden due to the infrequent occurrence of discarded material, and the deliberate use of the roof as a fertiliser was unnecessary due to the accessibility of seaweed to virtually all parts of the islands. The larger internal area of Lewis resulted in restricted access to the coast for many townships and greater competition for a more limited quantity of available seaweed, whilst the rocky coastline restricted access by carts for those within reach of the shore. An alternative system developed that placed reliance for fertiliser on a different source of greater reliability and convenience - the roof.

5.3.7.3 Food- animal and plant by-products

The barley meal provided the means of making bread, scones or porridge. Similarly, although less common, the oatmeal was used for oatcakes or porridge. Waste chaff and straw and sweepings from the different crop processing operations were rarely thrown intentionally to the midden, being either blown away or used in the byre. Sweepings from the house were infrequently added according to the same principle of least effort (section 5.3.4).

Potatoes provided a valued food in addition to the grain crops, with little preparation necessary and minimal waste. The potatoes were stored in a special shed, which was usually half buried. In earlier years this may have been constructed from peats, but in later years concrete was widely used. Little waste resulted from the potato shed, and may or may not have been added to the midden. The potato peelings were boiled to provide an additional source of food for the dogs and hens. Vegetable remains were treated in the same way as the potatoes: the remains were mashed and the preparation waste was boiled up.

Almost all edible food remains, including bones, bread, meal and potatoes, were beaten by the dogs and chickens, and it was unlikely that any waste would be thrown onto the midden. The larger bones that were not completely edible were either burnt or buried at the end of each week in pits dug into the beach or shoreline. On Heiskeir, in later years, rabbits were caught for their pelts, although the meat would not sell, and as a result many waste bones were buried in pits dug specifically for the carcasses.

5.3.7.4 Fowl

The hens were usually kept in a separate hen house, but may also have lived in the rafters of the byre. The hen house was cleaned out less frequently than the byre, only once a week. The rubbish, which included the droppings, straw, and any remnant food, although rare, was usually added to the midden or taken directly to the land where it was to be used. The hens ate scraps of any unguarded food, but were also fed a mash of potato peelings, and maybe some oatmeal. The seeds of dock (*Rumex*) were also collected for the hens from the plentiful growing sites around the croft and on the land. Boiling water was added to the dock seed, and later it was mashed with spare meal or the left over potato. The hens provided valuable food in the form of eggs and meat, but the hens were also considered a nuisance and threat to the stored crops, frequently flying up on to the top of stacks and causing damage as they scratched at the corn. For this reason, on Heiskeir, the hen house was situated away from the farmstead, on the shore of a nearby bay. The hens were free to wander the shore and peck at the maggots and flies living within the seaweed and were a suitable distance from the crops. On the remote islands of Heiskeir, however, there was no threat of foxes which would explain the need to keep the hens around the farmstead on the mainland crofts.

Some crofts also kept ducks, which were tended in a similar way to the hens. Wild birds, such as seagull, eider duck, wild duck and geese, were hunted for meat and the nests were raided for eggs. The wild duck and geese were trapped in the cereal fields which they invaded to eat the crops. Sea birds, such as the fulmar, were mainly considered a source of eggs, but some were caught for oil.

5.3.7.5 Fish and Shellfish

Fish was a common part of the diet. Fresh herring supplemented the summer diet and salted mackerel dominated the winter diet. The fishing tradition was associated with the east coast, although crofters on Heiskeir would catch plentiful supplies of fish such as flounders, cod and lithe. The fish were tied on to lines and dried outside, then commonly stored inside the house, hung up in the rafters to receive heat and smoke. In Baleshare, around late August, dogfish were dried and salted and then stored within the corn stacks as they were constructed. Remnant fish and fish bones from meals were thrown to the dogs, cats and hens and were seldom deposited on the midden. On the majority of west coast crofts, salt herring or salt mackerel was bought in bulk to supply a whole year. A half barrel or ferkin was sufficient for most families. Occasionally salmon or sea trout were poached from the inland lochs.

Shellfish were collected whenever time was available. Limpets, cockles, winkles, mussels and razors were gathered on the west coast, and oysters and clams from the muddy inlets of the east coast. The shells from shell fish were not usually dumped on the midden, but on the shore or near the edge of a loch. Occasionally, pure shell middens were created near to the crofts and the shells were burnt, using peat, or ground to a dust, and then mixed with water to make lime for use as mortar in building. The process was still in operation on Heiskeir at the beginning of this century, but was abandoned on Uist and Benbecula in earlier years. In more recent times the shellfish have been collected for sale rather than home consumption. In one tide, a person can gather up to one hundredweight of cockles, which represents a useful source of cash.

5.3.8 The Garden

Most crofts possessed a vegetable garden which provided an accessible area for the cultivation and protection of carrots, cabbages, turnips, some salad and rhubarb. The garden plot was most commonly fertilised with the midden, owing to the proximity of this resource. Horse dung was preferred to cattle dung, as with the potatoes, owing to the rarity of straw. If dung was in short supply, due to the higher priority of the potato crop, then seaweed was used on the garden. Vegetable plots dug on the sandy machair soil also tended to be fertilised with seaweed due to greater accessibility, although the crop was considered less successful than vegetables grown on blackland plots, which mimics the general pattern of cultivation. On Heiskeir, chicken dung was sometimes used on the vegetable plot. In some places, Heiskeir and South Loch Boisdale in particular, soot was used as a pest control in gardens. The soot was collected from the chimneys during the annual chimney sweep using heather brushes, although the quantity produced by burning peat was small.

5.4 Conclusion and some quantitative considerations

The various off-farm and farmyard activities described in this chapter tie together into an annual timetable. Different activities competed for limited labour and time and so were necessarily prioritised as illustrated in table 5.1.

This chapter has emphasised the central importance of fertilisers in maintaining the viability of agriculture in the Outer Hebrides and in shaping both the agricultural regime and many farmyard and off-farm activities. The use of different fertilising agents is strongly influenced by three sets of constraints.

First, the qualities of different fertilisers and the requirements of different land types, crop types and crop uses help to determine which fertilisers are used where and when. For example, other things being equal, dung tended to be spread on blackland, which was regarded as the best arable land and was used most intensively, and so tended to be used for barley staple grain crops. Owing to the relatively long-lasting effects of dung, it tended to be applied particularly in the first (i.e. barley) year of a rotation.

Seaweed tended to be applied on the machair, partly because its gelatinous quality was thought to bind the friable machair and to hold water more effectively than dung. In addition, seaweed was richer than dung in potassium, in which the machair was deficient, while the application of dung to the light machair tended to pose problems of weed infestation. Through preferential application to the machair, seaweed tended to be used to fertilise fodder crops, particularly oat and rye. Owing to the relatively short-lived effect of seaweed fertiliser, it tended to be applied annually.

When barley grain crops were sown on the machair (usually on the loamier inland areas of machair nearest the blackland), however, they were fertilised with either seaweed or dung, reinforcing the association between dung and the staple grain crops and between the latter and good arable land. Conversely, when the amount of dung available exceeded requirements for fertilising the blackland, it was sometimes dumped on the beach rather than being applied to the machair. This underlines the association between land type and type of fertiliser.

Secondly, the distances over which fertilisers had to be transported were an important consideration. The machair was near the shoreline and so near to the sources of seaweed, while the crofts, and so the farmyard middens where dung was accumulated, were located on the blackland. In general terms, therefore, the tendency to apply dung to the blackland and seaweed to the machair coincides with the location of the sources of these two types of fertiliser. Similarly, crofts located on the peatland of the east coast tended to use a mixture of dung and seaweed, both of which were available nearby, although here the most accessible seaweed was the less valued and more labour-demanding bladderwrack. Considerations of location and distance alone, however, do not explain the application of dung and seaweed to different land types. Counter-examples have already been noted of the use of dung on machair, for barley grain crops, and of the dumping of surplus dung. Moreover, it is possible that a preference for applying dung to the blacklands, and a desire to minimise transport costs, helped to determine the location of the crofts on the blackland rather than *vice versa*.

Thirdly, the use of fertilisers was strongly constrained by availability. The scale of arable production necessary to support a family obviously depends on several factors, including the size of the family and the degree of dietary dependence on other foods such as milk. One informant estimated that a croft producing *ca* 10-12 stacks of grain would need four of these stacks for human consumption. With yields of *ca* 1 stack per acre (section 5.2.1), this implies *ca* 4 acres sown with barley for family consumption. At two tons of manure per acre, as recommended by older farmers for barley grain crops in the first year of a blackland rotation (section 5.2.1), some 8 tons of manure would be needed. In addition to the low fertility of soils, the climatic obstacles to ripening also make manuring highly desirable. Based on recent Board of Agriculture and Fisheries estimates (cited in Barker, 1985), 8 tons of manure might represent the output of 2-3 cattle stalled for 6 months.

In traditional Outer Hebrides economy, it has been normal for a family to keep a few milk cows, but feeding these animals over winter has also made demands on the arable sector. Farmers have suggested a rule-of-thumb figure of one stack of grain (including straw) per cow (section 5.3.4.5) plus pasture or hay. Thus the required 2-3 cattle would need an additional 2-3 acres of grain crop and land devoted to pasture or hay. These additional grain crops would also require manuring, however, and the break-even point would only be reached at c 8 cattle per family (4 stacks/family + 8 stacks/8 cattle = 12 stacks = 12 acres of grain = 24 tons of manure = 8 stalled cattle). In practice, a croft producing 10-12 stacks of grain is said to have allocated four stacks to human consumption, one to seed corn and 5-7 to feeding livestock, implying the keeping of 5-7 cattle (or equivalent) and cultivation of an additional 5-7 acres of grain.

These figures are obviously extremely tentative and should be taken only as order-of-magnitude estimates for illustrative purposes. *Inter alia*, dung requirements might be lower if cattle were fed oats grown with little fertiliser after a well manured barley crop on the blackland; conversely, substantially more manure would be needed if much barley grain had to be grown on the machair. These figures do, however, expose the delicate balancing act involved in an agricultural economy where arable production is dependent on regular manuring and where the overwintering of the livestock which produce the manure is difficult.

Before the shieling areas on the east coast were lost to sheep from the estates, cattle were grazed well away from the arable fields. This transhumant system left insufficient labour at the settlements for large-scale hay making, but also meant that land near the settlements was preserved for winter grazing. The ending of transhumance placed greater pressure on winter pasture, forcing more intensive land use for the production of fodder grain and hay. This in turn demanded more fertiliser, but the keeping of animals was restricted by the availability of land and of labour for hay making.

In this context, the importance of seaweed as an alternative fertiliser becomes clear. Not only is the production of seaweed independent of the availability of land, but it is also gathered during winter at a slack period in the agricultural year (table 5.1) when farmers cannot get onto the land because it is too wet. The collection of seaweed is extremely laborious, particularly the cutting of weed which could be undertaken at any time of year. The gathering of seaweed thrown up by winter storms is less difficult, but nonetheless time-consuming and must be undertaken immediately, which again is only practicable in the winter slack period. The coincidence of large quantities of seaweed being thrown up by storms during this slack period was critical in enabling the bulk collection of this category of fertiliser (see section 5.2.2).

The most accessible seaweed was thrown up by winter storms and its availability, therefore, varied from year to year depending on the wind direction etc. One farmer recalled the difficulties he encountered when storms failed to throw up seaweed for three years in succession. The abundance of both pasture and fodder crops also varied from year to year and, perhaps partly for this reason, the availability of manure also varied. Descriptions of the earlier part of this century frequently stressed that how much dung was applied, and where, depended on availability. For example, grain barley on the machair could only be manured when the supply of dung exceeded the requirements of the blackland. Such accounts underline the extent to which fertiliser was a limiting factor on agricultural production in the recent past.

CHAPTER SIX

ANALYTICAL RESULTS

The presentation of the analytical results is divided into three sections. First, the results from the analyses of each variable are presented and discussed separately and, where appropriate, the associated correspondence analyses are also included. Secondly, variation within each functional area is discussed. Thirdly, variation between the functional areas is explored using discriminant analysis.

6.1 Individual Variables

6.1.1 Plant Remains

The plant macrofossils extracted from the bulk samples are listed in table 6.1. Carbonisation was the predominant means of preservation except for the four examples of mineralised seed. The quantity and diversity of plant remains is extremely low, thereby limiting the extent of interpretation.

The assemblage was dominated by cereal crops (84%), of which oat *(Avena* sp.*)* was the most common and barley (*Hordeum* sp.*)* the second most common. Hulled barley was identifiable in some instances, but determination of twisted or straight grains, and hence the presence of either two- or six-row species, proved impossible. Other cultivated species represented in the assemblage, but in extremely low numbers, were rye (*Secale cereale*) and possibly one example of wheat (*Triticum* sp.). No chaff was recovered. Grape seeds (*Vitis vinifera*) were also found.

The dominance of cereals in association with little weed seed and no chaff, may indicate 'clean grain', possibly connected with food preparation (Hillman, 1981; 1984, Jones, 1984). The unidentifiable cereals in the assemblage included some with contorted features characteristic of carbonisation at extremely high temperatures. The total destruction of chaff and small weed seeds is possible in such conditions, which would result in under-representation of these more fragile components and the artificial appearance of a 'clean' crop accompanied possibly by robust weeds seeds (Boardman and Jones, 1990).

Wild plants make up only a small proportion of the assemblage and include a few fruit capsules of the Cruciferae family. Cruciferae species commonly occur as weeds of cultivation. The unidentifiable wild plant material was represented by charred roots or twigs and mineralized seeds. No seeds of *Calluna* or other moorland plants were present in the assemblage, despite the known use of peat and heather at the croft.

The largest concentration of all plant remains was recovered from the byre (91.2%). A small number of charred roots or twigs were recovered from the uppermost vegetable plot sample, but each item is small enough to have been wind borne. Negligible numbers of items were recovered from the barn, kiln and stack base and no remains were recovered from the midden. The bulk samples from the byre were generally larger than those from the other contexts and, therefore, the greater total volume of byre sediment processed (128 litres) may partially account for the concentration of plant remains. The volume of sediment processed from other contexts on site was smaller, but by no means insignificant. Comparison of the density of plant material (number of items per litre) corroborates the concentration of material in the byre, and also serves to highlight a similar concentration of material from the vegetable plot. The distribution of cultivated and wild plant species represented by their relative proportions in the byre is displayed in figure 6.1.

Insufficient data was available to use the types of plant remains in either correspondence or discriminant analyses, so the number of items per litre (including twigs and mineralised seed) were used in the discriminant analysis to investigate the distribution of the plant remains.

6.1.2 Molluscs

Two sets of data resulted from the different retrieval techniques employed in the molluscan analyses. The first data set resulted from the examination of the wet sieved two-litre samples and the second from the analysis of the bulk samples processed on site.

The numbers of shells from different samples in these analyses is highly variable, with most samples producing no shells at all. Alkalinity and shelter are considered the two most important environmental factors that control distribution, abundance and preservation (Boycott, 1934). When compared with the pH values of samples (section 6.1.5), the irregular distribution of molluscs can be ascribed to habitat and preservation factors. Remains predominantly occur in the byre and kiln samples, which represent the only two alkaline/neutral areas sampled. Low pH is associated with all other samples, representing conditions unsatisfactory for mollusc preservation. Additionally, more shelter is provided by the remnant walls of the byre and the bowl of the kiln than compared to the other areas.

Each set of results is presented separately in both numerical form (tables 6.2 and 6.3) and graphically (figures 6.2 and 6.3). It is most probable that the brackish water species *Hydrobia* sp. is introduced to the samples via the loch water used for on-site wet sieving. *Hydrobia* sp. is, therefore, omitted from the statistical analyses.

Differences exist between the bulk and two-litre samples, first, in the volume of sample processed (the bulk samples are larger) and, secondly, in the size of material recovered. Two-litre samples contain all material greater than 500 microns, whilst the bulk samples contain all floating material greater than 300 microns but only material greater than 1 mm from the heavy residue.

The assemblages that resulted from the two sets of samples are broadly similar in species composition, despite the methodological differences. More shells were yielded by the bulk samples than the two-litre samples, as anticipated from a larger volume of sediment, although in some cases, the density of molluscs (number per litre) is greater in the two litre samples. This is likely to reflect loss from the bulk sample residues, i.e. non-floating molluscs, smaller than 1 mm. Indeed, the small species that do occur in the bulk samples are present only in small numbers (e.g. *Punctum pygmaeum*, *Vertigo* cf. *pygmaea)* but the same species are totally absent from the two-litre samples, suggesting low frequency of occurrence rather than under-representation in bulk samples due to loss (and reflects the small size of the two-litre samples). The species that do occasionally occur in greater numbers in the two litre samples (i.e. *Lauria cylindracea*, *Oxychilus cellarius*, *Balea perversa*, *Cochlicella acuta*, slug plates and marine gastropods) are, however, all well-represented in other bulk samples and in the fine flot of the bulk samples. Overall, this indicates the loss of the small and heavy individuals or juveniles of commonly occurring, well-represented species rather than the loss of small species *per se*. Bulk samples, therefore, present the advantage of a greater number and more diverse range of species, and the increase in information which this affords, outweighs the slight disadvantage of the loss of some heavy items.

A correspondence analysis was carried out using the data that resulted from examination of the bulk samples. Based on only byre and kiln samples (i.e. those samples with sufficiently large quantities of shells), the analysis incorporated eleven samples and eighteen species. Figure 6.4 illustrates the results plotted on the first and second axes, with symbols representing the functional areas.

The first axis serves to separate the kiln from byre samples. The kiln samples cluster on the left of the diagram in the same direction as *Vallonia excentrica* (VE), *Punctum pygmaeum* (PP) and *Oxychilus cellarius* (OC) (and to a lesser extent *Lauria cylindracea* (LC)). *Oxychilus cellarius* is an important component of rock rubble faunas (Evans and Jones, 1973), including subterranean or cave deposits amongst its wide range of preferences for moist and shaded places, like the enclosed environment of the kiln. *Punctum pygmaeum* also reflects the moist conditions provided by the micro environment of the kiln. *Vallonia excentrica*, of which only one specimen was retrieved, is, however, indicative of sand dunes and machair and, therefore, represents an intrusive element, possibly incorporated during construction. *Lauria cylindracea* characterises the favourable, moist and shaded conditions provided by the remnant walls and tumbled stones of the kiln. Although *Lauria cylindracea* can also indicate grassland environments, having colonised the calcareous machair of Oronsay, Colonsay and Orkney, it will not dominante in the presence of *Cochlicella acuta*.

The byre samples do not cluster, but are sub-divided by the second axis. The lower floor samples (102 and 103) lie in the same direction as Vitrina *pellucida* (VP), *Cochlicella acuta* (CA) and *Helicella itala* (HI) (and to a lesser extent *Pupilla muscorum* (PM), *Vertigo cf. pygmaea* (V), *Vallonia costata* (VC), *Oxychilus alliarius* (OA) and *Balea perversa* (BP). The zerophile species *Cochlicella acuta* and the obligatory heliophile and calciole *Helicella itala* (HI) are recent introductions that characterise the calcareous sand dune and coastal grassland (Kerney and Cameron, 1979). *Cochlicella acuta* is dominant over *Helicella itala* and other zerophile species in this assemblage, which reflects the distribution pattern in the Uists in recent years (Welsh, 1979). The catholic species *Vitrina pellucida*, although found in a wide range of moist places, is sometimes abundant in the moist grassy hollows of coastal sand dunes (Evans, 1979). *Pupilla muscorum*, *Vertigo cf. pygmaea* and *Vallonia costata* are open country species which predominantly characterise dry (or slightly damp), calcareous short-turfed grassland and associated coastal dunes.

The presence of these species in the byre can be explained by the cutting of turves from the calcareous machair for use as animal bedding. This resulted in the importation of the zerophile and associated species *in situ* in the machair turves and the creation of an alkaline microenvironment, conducive to shell preservation, in an otherwise naturally acid blackland. Shells from the bottom of the machair turves are incorporated within the lower floor samples. The rupestral, geophobic species (*Balea perversa*) and the catholic species (*Oxychilus alliarius*), probably characterise the walled, slightly shaded, damp and vegetated environment provided by the byre.

The ditch sample (104) is separated in the same direction as marine gastropods (MG) and slug plates (SP) (and to a lesser extent *Cochlicopa lubricella* (CLA) and *Cochlicopa* spp. (CSP)). The first is likely to derive from the machair turves and may represent natural inclusion of beach-derived material or the use of seaweed to fertilise areas of machair previously cultivated. Slugs, as represented by the internal shell or plate, are commonly associated with moist ground, vegetation and buildings, as characterised by the organic rich deposits accumulated within the byre. All *Cochlicopa* species are catholic in their preferences.

Sample 101 which represents the uppermost floor sample, is positioned very close to the origin and apparently combines elements of both floor and ditch. The assemblage characterising the upper floor is, therefore, most likely to represent the amalgamation of imported machair species with those exploiting the immediate micro-environment of the byre.

Nesovitrea hammonis (NH) and *Cochlicopa lubrica* (CL) are positioned between the kiln and the byre samples and are both catholic species.

Despite the practice of cleaning the animal bedding, including the old broken machair turves, from the byre on to the midden, no molluscs representative of the byre assemblage were found on the midden. This may reflect the unsuitable preservation conditions (moderately to slightly acid), or the subsequent removal of the midden to the fields. Prior to spreading, whilst in an accumulating heap, the midden would not necessarily provided suitable conditions for colonisation. Inside the heap, temperatures would be too high and organic acids would be concentrated and during normal accumulation, i.e. daily application of byre waste, the surface of the heap would not have remained sufficiently stable for exploitation.

The surface left after the final removal of the midden to the fields would presumably still have incorporated some dung, which may have encouraged colonisation by species associated with gardens, rubbish and decaying matter, such as the zonitid species *Oxychilus alliarius* and *O. cellarius*, or the synanthropic species *Vallonia costata*.

The absence of these molluscs may, therefore, be due to poor conditions of preservation.

The number of molluscs per litre in the flot of the bulk samples and the scores on the first two correspondence axes were used in discriminant analyses. The number of calcitic granules of *Lumbricus* sp. /*Arion* sp. ('worm granules') per litre were also used in the discriminant analyses .

6.1.3 Phytoliths

The raw phytolith data are given in table 6.4.

Phytoliths are more abundant and widely distributed than the plant remains and molluscs. Variations in phytolith concentration highlight differences within functional areas. In general, larger concentrations occur in the upper levels as compared to the lower levels, which reflects the difference between organic and inorganic deposits, respectively. This is in accordance with the expected association of plant derived phytoliths with organic materials, particularly with faecal remains and peat, and their dearth in sterile windblown sand and vegetated machair deposits (Powers and Gilbertson, 1986; Powers *et al.*, 1989). The paucity of phytoliths in less organic deposits is primarily due to absence of plant material but may be connected to the availability of silica, which is involved in complex recycling, possibly sensitive to low pH, although the process is not fully understood (Piperno, 1988). This may account for the very low concentrations of phytoliths in the vegetable plot samples, where organic content is high but pH is very low.

An increase in phytolith concentration is usually paralleled by an increase in the variety of morphotypes, which is consistent with the findings of Powers *et al.,* (1989). Variations are apparent in the relative frequencies of morphotypes (the phytolith suite composition), that highlight differences between and within functional areas. The relative frequencies of morphotype occurrence are summarised as percentage histograms, with samples grouped according to functional area in figures 6.5 to 6.10.

A correspondence analysis of the phytolith data was carried out using all twenty six samples and all twenty-four morphotypes. Figure 6.11 shows the samples and morphotypes plotted on the first and second axes, with symbols representing functional areas.

The clearest separation is shown by the midden samples, positioned in the upper left quadrate in the same direction as the morphotypes hybrid dumb-bell (HD), short-coarse wavy rod (SCWR), short trapezoid (ST) and convex short dumb-bell (CSD). The association of trapezoids with the midden samples is consistent with the high proportions found in the ancient midden deposits, as compared to modern peat and faecal remains (Powers *et al.*, 1989).

The two vegetable plot samples are very close together, also in the upper left quadrat, although separate from the midden samples, in the same direction as the morphotypes convex long dumb-bell (CLD) and flat long dumb-bell (FLD). The association of the three dumb-bell morphotypes (CSD, CLD and FLD) with the midden and vegetable plot samples is consistent with their occurrence in ancient midden and cultivated deposits and modern peat and sheep dung, as opposed to their absence from, or rarity in less organic and machair deposits (Powers *et al.*, 1989). The same association, however, does not support the general absence of dumb-bells noted in modern samples of cattle dung (Powers *et al., 1989*) despite the known predominance of cattle dung as a midden component and a garden fertiliser at the Howmore site, an inconsistency which can be explained by the dilution with other materials. Contamination from the dung of grazing sheep or from peat, originally stacked adjacent to the vegetable plot, may account for the greater association of dumb-bells with the vegetable plot samples.

The clustering of samples according to functional class is less distinct elsewhere in the plot. Instead, samples and morphotypes are plotted as one large group, which spans the remaining three quadrates in diametric opposition to the midden and vegetable plot samples. The four byre samples are close to one another, positioned in the middle of the large group. The presence of the two trichome morphotypes (SHT and LOT), indicative of some cereal species and particularly the glume and rachis of barley (Harvey, 1990; Parry and Smithson, 1966), in association with the group including the byre samples, is consistent with the greater proportion of charred cereal remains in the byre, and the presence of cereals as fodder and bedding. Other samples in this large group may also be characterised by the trichome morphotypes, especially 129, 124, 123 from the kiln and 130 from the barn which is consistent with the crop processing activities conducted in these buildings, despite the absence of charred remains.

Of the byre samples, samples 101 and 104 are positioned in the same direction as CR, SHT, BR, OT, LSR and D while samples 102 and 103 are positioned in the same direction as morphotypes LOT, SS, LT, CO and MSR. Samples 101 and 104 represent the higher, finer, organic deposits whilst samples 102 and 103 represent the lower, coarser inorganic deposits. The barn, kiln and stack base samples in this large group separate on the same basis as the byre samples, with samples 124, 129, 122, 118, 120, 137, 138 and 141 representing the higher, organic deposits and samples 123, 161, 162, 130, 131, and 142 representing the basal, inorganic deposits. The clustering is not, therefore, according to functional class but, rather, the pedological character of the deposits is the dominant influence.

The physical similarity of the samples in each sub-group is reflected in phytolith composition. The wavy and spiny rods (FWR, CWR, FSR and CSR) characterise the organic samples. Short smooth rods (SSR) characterise the inorganic samples.

The association of the wavy and spiny rods (FWR, CWR, FSR and CSR) with the cluster of organic deposits from the stack base, barn, kiln and byre is consistent with the occurrence of wavy and spiny rods in all ancient and modern organic deposits (Powers *et al.*, 1989). More specifically, the association is mainly consistent with the characterisation of straw components by smooth and wavy rods, and ear components by spiny rods, in certain cereal species including barley, whilst dumb-bells are totally absent (Harvey, 1990) and with information regarding the storage, processing and use of barley on the stack base, and in the barn, kiln and byre. The use of straw as thatch, as demonstrated by the high proportion of roofing material contained in the upper barn and kiln samples (118, 120, 122 and 128), is also consistent with the association of wavy rods.

The association of the smooth rods (SSR) with the cluster of inorganic deposits and sandy byre deposits is consistent with the predominance of smooth rods in the windblown sand and unvegetated dune deposits noted by Powers *et al.* (1989). Furthermore, the samples in this group most probably represent materials of construction and may, therefore, incorporate imported coarse sands for use as floor and foundation.

The third correspondence axis, which is not plotted, does not distinguish either functional areas or different pedological deposits.

Correspondence analysis of the phytolith data was repeated using only the fourteen most commonly occurring morphotypes to see if the patterning was maintained or, indeed, improved without the influence of the uncommon morphotypes. The results are displayed in figure 6.12 and illustrate the consistency in the patterning.

The midden samples are unaffected by the omission of the morphotypes HD and SCWR and display clustering in association with the morphotypes ST and CSD. The vegetable plot samples also show no change. The dumb-bell morphotypes FLD and CLD are now in an intermediate position between the midden and vegetable plot samples. The remaining samples also show little change in their relative positions and overall it can be concluded that the less frequently occurring morphotypes contribute little to the positioning of samples.

The number of items per litre and the scores on the first three correspondence axes derived from the analysis of the full data set, were used in the discriminant analyses.

6.1.4 Soil Particle Size

The absolute weights of the twelve different particle size fractions ('separates') are given in table 6.5. For each functional area, histograms of each sample were plotted to highlight any variations in the particle size distribution through the stratigraphic sequence within each area and to assist the comparison of the different functional areas (figures 6.13 to 6.18).

The percentages of material occurring within each textural class are given for each sample in table 6.6. The amalgamation of particle size fractions into soil textural classes can obscure peaks which are obvious when the 'separates' are plotted individually. This problem can be avoided by reference to the modal point for each distribution. The modal particle size and inter-quartile range for each sample (exclusive of the fractions at the extremes of the distributions) are listed in table 6.7.

All the samples display relatively high percentages for the extreme size classes (figures 6.13 to 6.18), which may indicate that further division of the material at these extremes would give better resolution of the particle size distribution within the sediment. A high proportion of material in the >1.7 mm fraction does, however, indicate the gravelly nature of the sediments. A high percentage of material in the <0.106 mm category indicates samples which contain a larger proportion of very fine sand, silt and clay.

Overall, the distribution patterns displayed in figures 6.13 to 6.18 show no obvious differences between the functional areas, but all display a lack of conformity to typical particle size distribution patterns for dune, beach and machair deposits (Ritchie and Mather, 1977) and no known studies have been conducted on the particle size distribution of blackland soils. Interpretational difficulties are introduced, and an atypical distribution may result, however, when a deposit represents more than one agent of sedimentation (e.g., fluvial reworking of aeolian sediments, or post-depositional decalcification) or where there is physical disturbance by post-depositional processes (e.g. biological, animal and anthropogenic activity).

In all functional areas, the upper levels contain the largest proportion of very fine particles and fine sand whereas the lower levels are dominated by coarse sand and gravel. Despite the dominance of coarse material in all midden samples, the upper levels still contain the highest proportion of very fine material. The byre samples, particularly those from the upper floor and ditch, are dominated by fine, medium and coarse sand and contain smaller quantities of very fine particles than any other functional area, although the proportion of very fine particles still decreases with depth. The uppermost samples from the stack base and vegetable plot also contain larger proportions of fine, medium and coarse sand than very fine particles.

The deposition of material transported by the wind (either in suspension - aeolian dust - or by traction or saltation - aeolian sand) and by water (through overland flow or sheetwash) introduces a high proportion of very fine and fine particles to the soil surface. Surface vegetation inhibits further movement of material by aeolian or fluvial transport and accelerates the process of particle accumulation. Additionally, the mechanical breakdown, of coarse material and soil aggregates into finer constituent particles, is intensified at the soil surface by direct exposure to the agents of weathering (wind and rain), and to trampling by animals and humans.

The lower levels are closer to bedrock and, consequently, coarse particles are introduced to the deposits through incorporation of the coarse material liberated through weathering processes such as freeze-thaw. In addition, the use of imported materials for floor construction will introduce some coarse materials to the lower, foundation levels.

Sand particles are introduced to the deposits through the direct importation of machair turves and beach sand from the west coast and include the medium sized grains, which characterise 80% of all beach, dune and machair deposits (Ritchie and Mather, 1977) yet which are normally less susceptible to long distance aeolian transportation (Courty *et al.,* 1989). The predominance of sand particles in byre deposits reflects the use of machair turves to provide 'dry' (free-draining) bedding for the stalled animals. The predominance of sand particles in the upper level of the stack base, reflects the use of loose sand as a preparatory application prior to stack construction, whilst the dominance of sand grains in the upper level of the vegetable plot may reflect fertilisation with dung, incorporating some sand derived from the machair turves on the byre floor.

The particle size mode, representing the dominant particle size, and the inter-quartile range, representing the variation in particle size, were used in the discriminant analyses.

6.1.5 Magnetic Susceptibility

The magnetic susceptibility values for the samples are given in table 6.7. The variations in the magnetic susceptibility values within each functional area are illustrated in figure 6.19.

The pattern of variation for each functional area is not absolutely consistent, although an inverse correlation with organic content is displayed by a large proportion of the samples. The lowest magnetic susceptibility values resulted from the organic rich vegetable plot samples (0.012 and 0.018). The byre, stack base and kiln samples produced medium magnetic susceptibility values (0.85 to 0.143; 0.133 to 0.178 and 0.78 to 0.177 respectively). The magnetic susceptibility values of the barn and midden samples were the most variable, (0.093 to 0.268 and 0.063 to 0.531 respectively), incorporating medium values and the highest values within each range, although the high values of midden samples 156 and 157 may represent some modern contamination. With the *exception of the vegetable plot and midden* samples, the magnetic susceptibility values increased with depth and generally mirrored the fluctuations and overall decrease in organic content with depth.

The magnetic susceptibility data were used in discriminant analyses.

6.1.6 pH

pH values are listed in table 6.7 and illustrated graphically in figure 6.20. The pH values of the samples ranged from strongly acidic to slightly alkaline. The highest pH values, representing the only slightly alkaline to neutral samples, resulted from the byre (7.02 to 7.19), and the kiln (6.32 to 7.36). Samples from the barn were all within the slightly acidic range (6.19 to 6.53), and the midden samples were moderately to slightly acidic (5.87 to 6.11). The vegetable plot samples ranged from moderately acidic to strongly acidic (4.94 and 5.12), whilst the lowest pH values, representing strongly acidic soils, all resulted from the stack base (4.46 to 4.86). In general, pH increased with depth within each functional area, despite slight fluctuations in the lower levels of the barn, kiln and midden.

The pH values were used in discriminant analyses.

6.1.7 Organic content

The data for organic content of the samples are given in table 6.7. The variations in organic content within each functional area are illustrated in figure 6.21.

The organic content of the samples varied considerably. The vegetable plot samples contained high percentages of organic content (13.57 and 22.54), whilst the byre, kiln and stack base each incorporated samples with low-medium levels of organic content (4.31 to 10.39; 2.09 to 17.59 and 3.51 to 12.61 respectively). The midden samples displayed variable levels of organic content that ranged from low to high (1.11 to 23.89), whilst the barn samples were sub-divided with the two upper samples, containing the highest levels of organic content (25.82 and 29.50) and the two lower samples containing low levels (1.93 and 2.97).

Overall, the profiles for each functional area display high sub-surface organic content and a decrease with depth, which represents the normal pattern in most soils. Discontinuity in the organic content within a sequence may take the form of peaks, due to the importation or formation of organic rich deposits; or troughs, owing to the depletion or dilution of organic matter possibly in association with a mineral deposit. Either may be characteristic of anthropogenic activity.

The percentage organic content data were used in the discriminant analyses.

6.1.8 Phosphorus content

Two sets of data resulted from the different methods for the determination of phosphorus content. Qualitative data resulted from the molybdenum blue rapid test and quantitative data resulted from the total available phosphorus. Both sets of results are presented in table 6.7

The spot test successfully identified the areas with higher phosphorus content (the byre) as opposed to those areas with very low levels (the vegetable plot and the stack base). This test would, therefore, be suitable as a means of identifying anthropogenic/animal activity, where phosphorus levels are high, against a background of relative sterility, e.g. windblown sand. Comparison of the two sets of results, however, does highlight large inconsistencies, particularly for samples with average/mid-range values.

The colorimetric results, which are a reliable measure of the total available phosphorus, are illustrated in figure 6.22. The highest percentages of phosphorus content resulted from the byre samples (0.145 to 0.170), in contrast to the lowest percentages from the vegetable plot and stack base samples (0.007 to 0.013 and 0.011 to 0.020 respectively). The midden and kiln samples contain intermediate levels of phosphorus (0.042 to 0.093 and 0.045 to 0.106 respectively). The barn samples are clearly sub-divided, with high percentages of phosphorus in the two upper samples (0.126 and 0.129) and low-intermediate percentages in the two lower samples (0.041 to 0.051). The byre, stack base and midden samples display an even decrease in the phosphorus content with depth. The phosphorus content within the barn also decreases with depth, despite the disparity between upper and lower samples. The kiln flue samples demonstrate an overall, but uneven, decrease in phosphorus content with depth, but in the kiln bowl and vegetable plot, phosphorus content increases slightly with depth.

The percentage phosphorus data produced by the colorimetric tests were used in the discriminant analyses.

6.2 Differences within Each Functional Area

6.2.1 The Byre

The upper floor and ditch sample in the byre can be distinguished from the lower floor samples on the basis of the physical and chemical soil properties (figure 6.23), the phytoliths and both the density and species composition of the mollusc remains. The uppermost sample in the byre floor is characterised by high organic and phosphorus content; neutral pH and low magnetic susceptibility and by the dominance of sand in the particle size distribution. This represents the direct accumulation of organic and phosphorus rich straw and faecal remains over calcareous sandy machair turves, imported for use as animal bedding. The concentration of diamagnetic, organic material is reflected by low magnetic susceptibility although, overall, organic content is lower than expected, in a sub-surface deposit receiving a high input of organic material, probably due to the concentration of sand within the machair turves. pH is high due to the calcareous shell sand present in the machair turves, but the pH of the sub-surface deposit is lower than underlying deposits due to the high proportion of organic content and associated water retention.

In the lower floor samples, the organic and phosphorus content are lower, whilst the magnetic susceptibility and pH values are correspondingly higher, which reflects the inorganic nature of the *in situ* material underlying the byre floor. The basal material is probably composed of denuded bedrock and glacial till, as indicated by the dominance of coarse particles. The higher magnetic susceptibility reflects less organic material and probably more ferro- and/or ferri-magnetic material and the higher pH indicates translocation of base forming cations from the overlying calcareous turves. In comparison to the floor deposits, the ditch has the highest organic content but the lowest phosphorus content and pH. This may reflect the inhibition of organic decay due to retention of water in the ditch depression which, in turn, correlates with slight acidification and lower phosphorus content and magnetic susceptibility. Sand particles are dominant in the ditch due to infiltration from the machair turves and a dearth of coarse particles due to the barrier effected by the stone lining of the ditch.

The difference in the organic content of the upper and lower deposits is demonstrated in the phytolith correspondence analysis, in which the upper floor and ditch samples are associated with other organic rich, surface deposits, whilst the lower floor samples are associated with other inorganic, basal deposits. Similarly, in the mollusc correspondence analysis, the upper samples are distinguished from the lower samples. The uppermost sample is characterised by a high density of molluscs, and an assemblage which represents both an imported machair fauna and an *in situ* fauna exploiting the micro-environment of the byre. Molluscs are less abundant in the ditch sample, which may reflect poor preservation due to intermittent episodes of wet and dry conditions, but the ditch is associated with the upper floor sample due to compositional similarities. In contrast, the lower floor samples are characterised by lower densities of molluscs which represent, almost exclusively, the imported machair fauna, filtered down from the overlying machair turves, at the exclusion of those molluscs which exploit the byre micro-environment. A higher density of worm stones also distinguishes the sub-surface and ditch sample from the lower floor samples, which reflects the humic soil and neutral pH of the upper byre deposits.

6.2.2 The Barn

The two upper barn samples contrast very sharply with the two lower samples on the basis of the physical and chemical soil properties (figure 6.24), and the phytolith suite composition. The two upper samples in the barn are characterised by high organic and phosphorus content, due to plant rich roof fall combined with humic soil in the process of formation, and accordingly with low magnetic susceptibility, and slightly acid pH. The low magnetic susceptibility reflects the large proportion of diamagnetic material derived from the organic matter. The slightly acid to neutral conditions, in which the phosphorus is most soluble, is consistent with high phosphorus content.

The presence of worm stones in the upper samples, but their absence from the underlying samples, probably reflects the higher organic content and pH of the former. The dominance of very fine particles and very small proportion of coarse particles reflects the presence of wind blown material and inwashed silts, plus any silt included in the roofing turf. The organic rich character of the upper barn samples is demonstrated by the phytolith correspondence analysis, due to the association of these deposits with the other organic rich, surface deposits. Furthermore, the dominance of wavy and spiny rod morphotypes in the uppermost samples is consistent with the use of straw in the roofing material, as present in these samples, if these morphotypes are characteristic of modern cereal components.

The two lower samples in the barn contrast sharply with the overlying deposits. Organic content and phosphorus content are very low, due to the absence of organic matter in the cobbled floor material. Magnetic susceptibility is very high, which is consistent with the effects of trampling, a negligible amount of diamagnetic material and a high proportion of ferro- and/or ferri-magnetic material released from the inorganic floor deposits. The orange staining, observed in the these samples, is indicative of iron oxides such as goethite and haematite, both of which are ferrimagnetic minerals. The dominance of coarse sand and gravel in the lower floor samples reflects the coarse nature of the imported materials used in the construction of the floor. The reasonably large proportion of very fine material in the lowest sample, however, represents the compacted clay matrix into which the cobbles and coarser material are set. The inorganic nature of these samples is demonstrated by the phytolith correspondence analysis, whereby these deposits are associated with the inorganic, basal deposits from other functional areas.

6.2.3 The Kiln

Differences are evident between the upper and lower kiln samples on the basis of the physical and chemical soil properties (figure 6.25) and the phytolith suite composition. Differences are also apparent in the density of molluscs, but not on the basis of species composition. The uppermost samples of the kiln bowl and flue are characterised by high organic content and, accordingly, low magnetic susceptibility, due to the presence of plant matter in fallen roof material and the humic soil in the process of formation. The phosphorus content is average and the pH slightly lower than the underlying samples, in accord with the higher organic content. The dominance of very fine, fine and medium sand, compared to the dearth of coarse particles, reflects the input of aeolian material to the surface deposits. The high organic content of these samples and the presence of cereal components, possibly derived from the roofing material, is reflected in the phytolith correspondence analysis, by the association of these samples with the other organic rich, surface deposits. Furthermore, the density of molluscs is higher in the uppermost samples of both the kiln bowl and flue than the lower samples, although no differentiation is apparent on the basis of species composition.

In contrast, the underlying samples are characterised, by overall lower organic content and higher magnetic susceptibility and pH, which reflect correlations in accordance with the usual trend. Phosphorus content increases with depth down profile, however, which is inconsistent with the trend in organic content and may represent downward translocation. The dominance of coarse particles in the lower deposits, represents the materials used in the construction of the floor of the bowl and flue, and the reasonably large proportions of fine and medium sand constitute the finer, compacted matrix material. The inorganic nature of the basal deposits in both the kiln bowl and flue is also demonstrated in the phytolith correspondence analysis by the association of these deposits with other inorganic basal deposits.

6.2.4 The Stack Base

The uppermost samples in the stack base can be distinguished from the basal samples on the basis of the physical and chemical soil properties (figure 6.26), and due to differences in the composition of the phytolith suites. The uppermost sample is characterised by the highest organic and phosphorus content, which corresponds with the lowest magnetic susceptibility and pH values. These represent the humic, loamy sub-surface soil of the stack base. The dominance of sand particles and the dearth of gravel reflects the loamy nature of the deposit and also the use of sand for preparation of the base surface prior to stack construction. The similarity and greater organic content of the three uppermost samples is demonstrated by their association with the organic rich, uppermost deposits from the byre, barn and kiln, in the phytolith correspondence analysis. Once again, the dominance of wavy and spiny rod morphotypes is consistent with the storage of cereals on the stack base immediately above the uppermost deposits, if the comparison with phytolith suites from modern cereals is justified.

In the underlying deposits, the organic and phosphorus content are both lower; pH and magnetic susceptibility are accordingly higher and gravel dominates in the particle size distribution. This represents the coarse, inorganic material imported to construct the base and, possibly, other coarse material denuded from the *in situ* bedrock. A larger proportion of ferrimagnetic materials released from the inorganic basal material in combination with the smaller proportion of diamagnetic material probably accounts for the enhanced magnetic susceptibility. The inorganic nature of the basal sample is demonstrated by the association of this deposit with other inorganic, basal deposits from the byre, barn and kiln in the phytolith correspondence analysis.

6.2.5 The Vegetable Plot

The upper level of the vegetable plot can be distinguished from the lower level on the basis of the physical and chemical soil properties (figure 6.27), most clearly by organic content and particle size. The uppermost sample is characterised by higher organic content and magnetic susceptibility and lower phosphorus content and pH than the underlying sample. A dominance of fine sand particles also characterises the upper level and reflects inwashed and aeolian material and, possibly, sand derived from the machair turves in the byre. Coarse sand and gravel dominate the lower level and reflect coarsely weathered material derived from the bedrock.

The high organic content and the low magnetic susceptibility of the upper level are consistent with the anticipated humic rich soil and use of dung, as a fertiliser to enrich the growing bed. Conversely, the generally low phosphorus content, particularly in the surface sample, does not reflect the known application of dung. The dearth of phosphorus, therefore, in conjunction with low pH, indicates post abandonment acidification. This, in association with water inhibition of organic decay, is equally consistent with the high organic content and low magnetic susceptibility and with the peaty nature of the deposit (particularly in the upper level) as observed in the field. The higher phosphorus content in the lower sample is consistent with leaching down profile.

6.2.6 The Midden

The upper samples in the midden can be distinguished from the lower samples on the basis of the physical and chemical soil properties (figure 6.28). The uppermost sample from the midden is characterised by higher organic and phosphorus content, lower pH and a larger proportion of very fine particles than the underlying samples. The lower samples are characterised by lower organic and phosphorus content, higher pH and are dominated by coarse sand and gravel, which represents the usual trend in soil properties. Contrary to the normal inverse correlation with organic content, magnetic susceptibility is very high in the surface sample and low in the underlying samples, but these values probably reflect artificial enhancement due to modern contamination.

The high organic content of the uppermost sample may represent remains of the midden material incorporated with humic soil in the process of formation and, therefore, corresponds with the highest proportion of very fine material. The vertical trends in phosphorus and organic content correspond but, overall (and particularly at the sub-surface), phosphorus content is less than expected at the site of dung accumulation, when compared to the phosphorus content of the byre. This may reflect the annual removal of the dung heap, but it is also consistent with the formation of insoluble hydroxy phosphates with iron, aluminium and manganese, elements which are more abundant in acid soils.

6.3 Differences between Functional Areas

The classification of samples into six groups, representative of area function, predisposed the data for discriminant analysis. The results from preceding analyses comprised a series of variables, each with different potential to discriminate between functional groups. The simultaneous analysis of all variables gave, therefore, an important indication of the relative influence of each variable on the discrimination and could also identify which variables were associated particularly with each group of samples. Equally good or better levels of reclassification were also possible with different sub-sets of the variables. Consequently, the analyses aimed first to understand how each variable relates to the functional groups and, secondly, to identify a suite or suites of variables that would maintain significant discrimination between functional groups while minimising the number of variables. The identification of such variables would potentially provide an effective discriminating tool as an efficient alternative to the employment of the whole range of variables initially explored.

The discriminant analyses were conducted in three stages determined by the nature of the data set. The first stage of analyses incorporated only those environmental variables which occurred or could be measured in all samples (7 variables). This included the phytolith data, in the form of the scores on the first three axes from the correspondence analysis, and the physical and chemical soil properties: the mode and inter-quartile range for particle size, pH, percentage phosphorus, percentage organic content and magnetic susceptibility.

The second stage of analysis incorporated the mollusc data and, owing to the distribution of the remains, only eleven samples could be included. The scores on the first two axes of the mollusc correspondence analysis were investigated in combination with the variables in the first stage.

The third stage of analysis investigated the discriminating potential of the density of plant, mollusc, worm and phytolith remains (as opposed to species or morphotype variation represented by the axes from the correspondence analyses) in combination with the physical and chemical soil properties. The density of mollusc and plant remains was based on the number of items produced from the bulk samples. Bulk samples were unavailable from three contexts, and these were omitted accordingly.

6.3.1 Discriminant Analyses using Scores from the Phytolith Correspondence Analysis with Physical and Chemical Soil Properties

In the first series of discriminant analyses all the samples are included with combinations of the following variables: the scores on the first three axes of the phytolith correspondence analysis, the mode and inter-quartile range for particle size, the pH, percentage phosphorus content, percentage organic content and magnetic susceptibility. The presence of six groups of samples results in a maximum of five possible discriminant functions for each analysis. In cases where fewer than five variables are included the number of functions is determined by the number of variables. A list of the variables in each analysis is given in tables 6.8, 6.13, 6.16, 6.17, 6.20 and 6.22.

6.3.1.1 All Variables

In the first analysis (analysis 1), all variables are included simultaneously which indicates the relative contribution of each to the discrimination and, moreover, which variables are associated with each group of samples. Discriminant scores for each sample are plotted on the first and second functions and the third and fourth functions (figures 6.29 and 6.30 respectively) and the results of the discrimination and the discriminant coefficients are presented (table 6.9). The analysis resulted in good discrimination with only one sample misclassifed, the kiln sample 122 which is wrongly classified with the barn samples. The majority of variation is accounted for by the first and second functions, but the discriminating potential of the variables is still significant until the third function is removed but not afterwards. Discussion will therefore concentrate on the first three functions.

Variation on the first function is dominated by pH which loads high positively, distinguishing the alkaline byre and kiln samples from the acidic stack base and vegetable plot samples with midden and barn samples intermediate. Scores on the first and second phytolith correspondence axes are the dominant discriminating variables on the second function. The first phytolith axis loads high negatively and the second axis positively, distinguishing the byre, kiln and barn samples from the midden and vegetable plot samples. This reflects the separation of midden and vegetable plot samples from the rest in the phytolith correspondence analysis (see section 6.1.3). The stack base samples occupy an intermediate position on the second function.

Organic content, particle size inter-quartile range and scores on the first phytolith correspondence axis load high positively on the third function; magnetic susceptibility, phosphorus content (and scores on phytolith axis 3) negatively, distinguishing the vegetable plot and barn samples with high organic content, from the midden samples with high magnetic susceptibility, and vice versa, with byre, kiln and stack base samples intermediate. The opposition of organic content and magnetic susceptibility reflects the strong inverse correlation between these two soil properties.

Phosphorus dominates the fourth function which separates the byre samples, high in phosphorus, from the other samples (especially the vegetable plot). The remaining variable, particle size mode, does not account for much of the variation between groups on any of the functions.

Overall, the greatest variation is demonstrated by the stack base, vegetable plot and midden samples, which are separated by the first and second functions into distinct groups situated in diametrical opposition to the kiln, byre and barn samples. The last three groups display least between group variation (being separated mainly on the third and fourth functions), and this partly accounts for the misclassification of kiln sample 122 with the barn samples.

6.3.1.2 Perfect Reclassification using the Maximum Number of Variables

The only combination of variables which resulted in the correct reclassification of all samples, whilst still incorporating the maximum number of discriminating variables possible, omitted pH (analysis 2). The discriminating information is significant after the first function is removed, but after the second function is removed the remaining information is not significant (table 6.10). The discriminant scores are plotted on the first and second functions in figure 6.31. In the absence of pH, the first and second phytolith correspondence axes dominate on the first function which distinguishes the byre, kiln and barn samples from the midden and vegetable plot samples with stack base intermediate.

Variation on the second function is dominated by phosphorus content which distinctly separates the byre samples, high in phosphorus, from the stack base and vegetable plot samples, low in phosphorus (cf. function 4 in analysis 1). Midden, barn and kiln are intermediate on this function. The kiln and barn samples display least between group variation on both functions which indicates their similarity in phytoliths and phosphorus content. Function 3 remains very much the same as in analysis 1 (not plotted). Overall, therefore, the main effect is that the function of pH in separating byre from stack base and vegetable plot samples is taken over by phosphorus, but the previous separation of alkaline kiln samples (from the stack base and vegetable plot) is forfeited.

The previous misclassification of kiln sample 122 by pH reflects the deviant nature of the sample, rather than the ineffectiveness of pH as a discriminating variable. Sample 122 is significantly more acidic than others in the kiln group and shares greater similarity with the pH range for barn samples, the group with which it is consistently reclassified. The misclassification of sample 122 therefore occurs in all analyses including pH.

6.3.1.3 The Role of the Phytolith Correspondence Axes

As the third phytolith correspondence axis is responsible for least between group variation out of the three axes, analysis 1 was repeated with the third phytolith axis omitted (analysis 3). Minimal difference is apparent between the two analyses (not shown) which suggests that, when all other variables are included, the influence of the third phytolith axis is slight.

When only the first of the phytolith axes is included with all other variables (analysis 4) the main difference is that there is no distinction between midden, stack base and vegetable plot samples (figure 6.32, table 6.11). When only the second phytolith axis is included with all other variables (analysis 5), the roles of functions 2 and 3 are reversed, relegating phytolith variation to the third function (figure 6.33, table 6.12). The success of the reclassification is unaffected by removal of some of the phytolith variation in analyses 3, 4 and 5 - sample 122 is still the only one misclassified.

The further investigation of sample variation excluded scores on the third phytolith correspondence axis, which contributed little to the analyses. On this basis, discriminant analysis was applied to different combinations of the variables in order to investigate the discriminating potential of alternative smaller suites of environmental indicators. Initially all combinations which include scores on the first and/or second phytolith correspondence axes are considered, as these axes are consistently identified as good disciminating variables in the earlier analyses. Secondly, the discriminating potential of combinations of the physical and chemical soil properties alone are considered. These are of particular interest considering the time consuming nature and specialist requirements of phytolith analysis.

6.3.1.4 Phytolith Correspondence Axes with two Soil Properties

Analyses using combinations of single soil properties with either or both the first and second phytolith axes result in large numbers of misclassified samples. When any two variables are included with either or both the phytolith axes certain combinations result in good discrimination, with only one or two samples misclassified (table 6.13). These combinations are: phosphorus with organic, phosphorus with pH, and phosphorus with magnetic susceptibility. These results establish the importance of phosphorus as a discriminating variable, as the reclassification of samples is not good with any combination from which it is excluded.

6.3.1.4.1 Phosphorus and Organic Content

Phosphorus and organic content in combination with the first phytolith axis (analysis 6) do not discriminate well between samples (three samples misclassified). In combination with the second phytolith axis (analysis 7) samples 122 and 131 are misclassified and, in combination with both phytolith axes (analysis 8), samples 122 and 123 are misclassified (table 6.13). Kiln samples 122 and 123 are wrongly classified with the barn samples, whereas barn sample 131 is wrongly classified with the stack base samples. In analyses 6 and 7 the discriminating information is no longer significant after the second function is removed, whereas in analysis 8, information is still significant after the second function is removed. The pattern of discrimination between samples is otherwise extremely similar with phosphorus dominating the first function, phytolith scores the next one or two functions and organic content the last function. Discriminant scores from analysis 8 are plotted on the first and second functions to illustrate sample variation (figure 6.34, table 6.14).

As previously, phosphorus distinguishes the byre, high in phosphorus, from the stack base and vegetable plot samples, which are low in phosphorus. Phytolith scores (especially on correspondence axis 2) distinguish the midden samples from the rest, as expected (see section 6.3.1.1). In general, the functions using organic content (functions 3 or 4) distinguish the barn, and vegetable plot samples, with high organic content, from the midden samples (cf function 3 analysis 1).

6.3.1.4.2 Phosphorus Content and pH

Phosphorus content and pH in combination with either the first or second or both phytolith axes (analyses 9, 10 and 11 respectively) are successful combinations of discriminating variables (table 6.13). All misclassify kiln sample 122 with the barn samples and, additionally, in analysis 10, the stack base sample 142 is misclassified with the vegetable plot samples. In analysis 9, the information remains significant only after the first function is removed, compared to the analyses 10 and 11, in which the information remains significant after the second function is removed. Discrimination in each analysis is very similar due to the dominance in each case of pH on the first function and phosphorus on the second function (with phytolith correspondence axes dominating the remaining function(s). The discriminant scores from analysis 11 are plotted on the first and second functions (figure 6.35, table 6.15).

On the first function pH separates the acidic stack base and vegetable plot samples from the alkaline byre and kiln samples. On the second function phosphorus distinguishes the byre samples from the stack base and vegetable plot samples as before.

6.3.1.4.3 Phosphorus Content and Magnetic Susceptibility

Both phytolith axes in combination with phosphorus and magnetic susceptibility (analysis 12) discriminate between samples successfully, with only two samples misclassified (118 and 128) although, when only one phytolith axis is included, the analyses are not successful, with four samples misclassified in each instance. The discriminating information is significant after the first function is removed, but no longer significant after the second function is removed. As in analyses 6, 7 and 8, phosphorus is dominant on the first function, the phytolith axes on the second and third function, and magnetic susceptibility on the fourth function. The misclassified samples belong to the two groups displaying least variation on both functions (barn and kiln samples), which increases the probability of classification error. The results of this analysis are important archaeologically because phosphorus and magnetic susceptibility are properties which may persist or remain stable in the soil for some time, unlike organic content and pH.

6.3.1.5 Phytolith Correspondence Axes with Three Soil Properties

When any three variables are included with either or both the phytolith axes, there are a large number of successful discriminating combinations (in which fewer than three samples are misclassified - table 6.16). The successful combinations include either phosphorus and organic content or phosphorus and pH, both identified as core combinations in the previous analyses. Which phytolith axis is most successful depends on which other variable is included with the core combination, which in turn influences which variables dominate on either function.

6.3.1.5.1 Phosphorus Content, Organic Content and pH

Not surprisingly, given the above results, phosphorus, organic content and pH in combination with either the first or second or both phytolith axes are successful combinations of discriminating variables (analyses 13, 14 and 15 respectively, table 6.16). In each analysis pH is the dominant variable on the first function; scores on phytolith correspondence axis 2 (where used) dominate the next function, followed by phosphorus content on the next, then scores on the first phytolith correspondence axis and, on the last function, organic content is dominant. This order indicates the relative contribution of the variables to the discrimination. As before, high pH distinguishes the byre and kiln samples (compared to the acidic stack base and vegetable plot samples), high phosphorus content the byre samples (especially compared to the phosphorus poor stack base and vegetable plot samples), and phytolith content (especially scores on correspondence axis 2) the midden samples (and to a lesser extent the vegetable plot).

6.3.1.5.2 The Role of Magnetic Susceptibility

In terms of the success of the discrimination, magnetic susceptibility can replace pH or organic content. In the case of pH (analyses 16, 17 and 18, table 6.16), there is a slight improvement over using organic and phosphorus content alone with the phytolith axes (analyses 6, 7 and 8) but, in analyses where magnetic susceptibility replaces organic content (analyses 19, 20 and 21, table 6.16), there is no improvement in reclassification over those analyses simply omitting organic content (analyses 9, 10 and 11). In analyses 16-18, excluding pH, phosphorus becomes the dominant variable on the first function followed by phytolith scores on correspondence axes 2 and 1; organic content and magnetic susceptibility each dominate on successive functions. In analyses 19-21, excluding organic content, pH dominates the first function and other variables follow in the same order as above. This reaffirms the lesser role played by magnetic susceptibility in the discriminations compared to the other five variables. Only the midden and vegetable plot samples are clearly distinguished, on the basis of high and low magnetic susceptibility respectively, but little discrimination is influenced between the other functional areas.

6.3.1.5.3 The Role of Soil Particle Size

In a similar way, particle size inter-quartile range (analyses 22, 23 and 24, table 6.16) can also take the place of pH to give a more successful discrimination than that using organic and phosphorus content alone with the phytolith correspondence axes (analyses 6, 7 and 8). Indeed, analysis 24 (using scores on the first two phytolith axes, organic and phosphorus content and particle size inter-quartile range) results in the correct reclassification of all samples. When replacing organic content, particle size inter-quartile range (analyses 25, 26 and 27, table 6.16) only slightly improves on results using phosphorus, pH and the phytolith correspondence axes (analyses 9-11).

In all the analyses using particle size inter-quartile range, the scores on the first phytolith axis dominate on an earlier function than scores on phytolith axis 2, suggesting that phytolith axis 1 complements the variation in particle size distribution better than phytolith axis 2 (phytolith axis 1 is primarily responsible for separating the byre from the midden, vegetable plot and stack base while phytolith axis 2 distinguishes the midden from other functional areas - see section 6.1.3 and 6.3.1.1). Particle size inter-quartile range, however, plays a lesser role in the discrimination than pH, phosphorus content and phytolith composition.

Particle size mode has very little effect on analyses using only the phytolith axes and phosphorus with either pH (analyses 28, 29 and 30, table 6.16) or organic content (analyses 31, 32 and 33, table 6.16) and again plays a lesser role than pH, phosphorus and phytolith composition in the discriminations.

The inclusion of four or more variables with either or both the first and second phytolith axes results in good reclassification as would be expected when the number of discriminating variables is increased.

6.3.1.6 Summary of Analyses including Phytolith Correspondence Axes

The analyses indicate the dominant discriminating variables to be phosphorus content, pH and both the first and second phytolith correspondence axes. Phosphorus is included in every successful discriminating combination, but does not necessarily exert the dominant influence on either the first or second function. When pH is included it always exerts the dominant influence on the first function. Magnetic susceptibility can more or less replace the combination of pH and organic content if phosphorus content and both phytolith axes are included in the analysis.

Magnetic susceptibility or particle size improve results based on the combination of phosphorus and organic content with phytolith composition but result in no improvement over the combination of pH and phosphorus with phytolith composition. The second phytolith correspondence axis and organic content are complementary as are the first phytolith axis and inter-quartile range. Particle size mode results in no obvious improvement over analyses using phosphorus or the combination of pH and organic content. Phytolith composition and phosphorus are, therefore, good discriminating variables and pH exerts a strong effect; organic content, magnetic susceptibility and particle size inter-quartile range are weaker but useful in certain combinations. Some complementary combinations of variables have been identified.

Certain consistent associations between different variables and particular sample groups are also apparent. pH causes the clustering of byre, kiln and barn samples, but all separated from the stack base and vegetable plot samples, which represents the distinction between alkaline and acidic sample groups; neutral midden samples are intermediate. The first phytolith axis and phosphorus consistently cause the separation of phosphorus-rich byre samples from stack base and vegetable plot samples, with kiln and barn samples intermediate. The midden samples have intermediate phosphorus levels but similar scores to the stack base and vegetable plot on phytolith axis 1. The separation of the midden samples is mostly achieved by the second phytolith axis, although magnetic susceptibility also distinguishes the midden samples. The consistent opposition of magnetic susceptibility and organic content results in separation of the midden samples from the organic rich vegetable plot samples. The vegetable plot samples are also distinguished by inter-quartile range. The barn and kiln samples are most similar to one another, and so it is not particularly surprising that the two samples most consistently misclassified (122 and 123) are kiln samples misclassified with the barn samples.

6.3.1.7 Analyses using Physical and Chemical Soil Properties Only

All the most successful discriminations using soil properties alone misclassify samples 122 and 130 (a kiln sample misclassified as a barn sample and a barn sample misclassified as a midden sample, respectively) (table 6.17).

In an analysis using all the chemical and physical soil properties (analysis 34 table 6.17; figure 6.36, table 6.18), the first function was dominated by pH separating the acidic stack base and vegetable plot samples from the alkaline byre and kiln samples. The second function was dominated by the opposition between organic and phosphorus content, the vegetable plot with high organic and low phosphorus content, the byre with high phosphorus and average organic content. Magnetic susceptibility and particle size were of lesser importance to the discrimination.

Removing particle size variables and organic content (analyses 35, 36, 37 and 38, table 6.17) had very little effect on the discrimination, an analysis using only phosphorus, pH and magnetic susceptibility (analysis 38) reclassifying as many samples correctly as an analysis using all six variables. In analysis 38 (figure 6.37, table 6.19), pH is dominant on the first function and phosphorus on the second function, which repeats the pattern of variation demonstrated in previous analyses, pH continuing to distinguish the acidic stack base and vegetable plot samples from the alkaline byre and kiln samples, and high levels of phosphorus distinguishing the byre from the phosphorus poor stack base and vegetable plot samples.

Magnetic susceptibility dominates the third function and results in the correct reclassification of one more sample compared to analysis 39 using pH and phosphorus alone. This demonstrates that pH and phosphorus content are powerful discriminating variables on their own and also that magnetic susceptibility can replace scores on the phytolith correspondence axes (analyses 9-11) to ensure a more successful discrimination than that with only pH and phosphorus. Surprisingly perhaps, particle size mode can replace magnetic susceptibility to give a successful discrimination based on only three variables (analysis 40).

As in the analyses including the phytolith axes, phosphorus and pH dominate over all the other soil properties. These analyses demonstrate the potential utility of soil chemical and physical characteristics without the need for phytolith data but do rely heavily on pH (and to a lesser extent on organic content) which may be of very limited use archaeologically.

6.3.2 Discriminant Analyses Using Scores from the Mollusc Correspondence Analyses

Only the kiln and the byre produced any quantity of molluscan remains and the earlier correspondence analysis demonstrated that the species of mollusc differed between the two areas. The following discriminant analyses were carried out to determine whether the differences are sufficient to discriminate between byre and kiln. Only the eleven byre and kiln samples which contained molluscan remains are included, and the scores on the first two axes of the mollusc correspondence analysis are investigated. As only two sample groups, the byre and the kiln are represented, only one discriminant function is derived. A list of the variables in each analysis is given in table 6.20.

Perfect reclassification resulted in the first analysis (analysis 41), which included only the scores on the first and second axes in the mollusc correspondence analysis. The analysis was, therefore, repeated using scores on the first correspondence axis (as this was the one which separated byre and kiln in the correspondence analysis). This resulted in perfect reclassification (analysis 42). The plot of the first analysis (analysis 41, figure 6.38, table 6.21) shows the clear separation of the two areas. Although the discrimination of byre and kiln samples is good using the mollusc data alone, it obviously does not assist with the identification of other functional areas.

6.3.3 Discriminant Analyses using the Densities of Plant Remains, Molluscs, Worm Granules and Phytoliths with the Physical and Chemical Soil Properties

The third series of discriminant analyses investigated the discriminating potential of the density of plant remains, molluscs, worm granules and phytoliths (as opposed to the species or morphotypes within each category). These densities (number of items per litre of deposit) are used in combination with the physical and chemical soil properties included in the previous analyses, i.e. particle size mode and inter-quartile range, pH, percentage phosphorus content, percentage organic content and magnetic susceptibility. The density of mollusc and plant remains is based on the number of items produced from the bulk samples. Bulk samples were unavailable for three samples and these are accordingly omitted from the analyses. All six sample groups are represented, which means a maximum of five functions can potentially be derived in the discriminant analyses. A list of the variables in each analysis is given in table 6.22.

6.3.3.1 All Variables

The first analysis included all the variables listed above (analysis 43). This combination resulted in perfect reclassification of all samples, with clear discrimination between all sample groups when plotted on the first and second functions (figure 6.39, table 6.23).

On the first function, pH is the dominant variable which, in conjunction with phytolith density, distinguishes the alkaline byre and kiln samples from the acidic stack base and vegetable plot samples (with barn and midden samples intermediate), and indicates the high frequencies of phytoliths associated with the alkaline samples compared to low frequencies with the acidic samples. On the second function, organic content loads high negatively while phosphorus content and magnetic susceptibility load high positively, distinguishing the vegetable plot samples from the byre samples. The midden and barn samples are marginally separated on the second function. The remaining variables make a greater contribution to the later functions with the exception of mollusc density which loads highest (and positively) on function 2 (along with minor contributions from seed, phytolith and worm densities), helping to characterise the byre. The separation of byre, kiln and barn on the first two functions is clearer than for the equivalent analysis using phytolith correspondence scores in place of densities (analysis 1). In analysis 1, the third axis plays a more important role (accounting for 9% of the total variance compared to only 3% in analysis 43).

6.3.3.2 Particle Size Omitted

Perfect reclassification is maintained when particle size variables are omitted (analysis 44). This combination demonstrates that the particle size variables are not necessary when a large number of variables is included.

6.3.3.3 Compositional Densities with any Three Physical and Chemical Soil Properties

When the density variables are included with any three chemical and physical soil properties, eight successful combinations of discriminating variables (misclassifying only one or two samples) are possible (table 6.22).

The best result is obtained with phosphorus, pH and particle size inter-quartile range with the four density variables (analysis 45), giving perfect reclassification of all samples. pH and phytolith density dominate the first function and phosphorus the second function, but the loss of organic content and magnetic susceptibility on the second function results in a less clear plot (not shown). All the remaining combinations, of three soil properties with compositional densities, result in at least one misclassified sample, and all combinations in which only one sample is misclassified include pH as one of the discriminating variables. In all these analyses (analyses 46 - 50), pH and phytolith density dominate the first function (cf. analyses 43 - 45). The second function is usually dominated by phosphorus and/or organic content (in opposition to one another when they are both included) and the next function is usually dominated by an opposition of seed and worm granule densities. Magnetic susceptibility, particle size inter-quartile range and mollusc density usually play a subsidiary role on later axes. Both phosphorus content and pH are necessary for the correct reclassification of sample 130.

Two analyses using phosphorus and organic content, with either magnetic susceptibility or particle size inter-quartile range, (analyses 51 and 52 respectively), misclassify only two samples. Again, the order of the variables on successive functions is the same except that organic content takes the place of pH on function 1, this time in opposition to phytolith density. Phosphorus content dominates the second function and seed versus worm density the third function in both cases.

6.3.3.4 A Suite of Variables for Fast and Effective Differentiation

A final analysis (analysis 53) was carried out by taking the most successful discrimination using only three soil properties (phosphorus content, pH and particle size inter-quartile range - analysis 45) and repeating it with only the density of molluscs (which is easier to measure than phytolith density and more reliable than the density of plant remains). This results in a successful reclassification with only sample 122 misclassified (table 6.22).

The use of compositional densities in combination with soil properties, therefore, offers the potential for a fast and effective method of discrimination between functional areas, which would remove the need for specialist involvement in the primary stages of site evaluation. The combination of soil phosphorus content, pH, particle size inter-quartile range and the frequency of molluscs represents a suite of consistently reliable discriminating variables which are also potentially durable indicators. More detailed laboratory analyses could then be applied to confirm (or otherwise) this initial test. Phytolith analyses have proved to be particularly effective in this respect.

6.3.4 Conclusions

The laboratory and statistical results in conjunction with information, regarding activities conducted on the site, and the field observations, regarding the pedogenic processes in operation, clarify the distribution and movement of materials around the farmstead.

In most functional areas, the upper levels are distinguished by higher organic and phosphorus content and a larger proportion of fine soil particles than underlying levels. Correspondingly, in the upper levels pH and magnetic susceptibility are lower than underlying levels. In general, the concentration of phytoliths and the diversity of morphotypes is greater in the organic rich upper levels, where the frequency of spiny and wavy rods, trapezoids and dumb-bells is also greater. Smooth rods predominate in the inorganic basal deposits. Similarly, in those areas where molluscan remains occur, the number of snails is larger in the upper levels and, in the case of the byre, the range of species is also greater, in the upper levels.

The byre is reliably characterised on the basis of several soil properties. The high phosphorus and organic content are consistent with the deposition of large quantities of dung and urine, and agree with other similar studies of abandoned farmsteads. The high pH with associated particle size distribution and the molluscan fauna are representative of imported machair turves, which reflects a common practice on the Outer Hebrides. The phytolith suite indicates the presence of cereals, which is consistent with their use as fodder and bedding material.

The barn floor is characterised by low organic and phosphorus content, high magnetic susceptibility and a mixture of very fine and coarse soil particles. In contrast, the fallen roof material overlying the floor is characterised by very high organic and phosphorus content, low magnetic susceptibility and a large proportion of very fine soil particles with a dearth of coarse particles. The phytolith morphotypes indicate the presence of cereals, which is consistent with the storage of cereals in the barn and the presence of straw in the roofing material.

The kiln is distinguished by high pH, due to the use of lime in its construction, and by shade loving and rupestral mollusc species, reflecting the sheltered, rocky and alkaline environment. The kiln floor is characterised by low organic content and a mixture of very fine and coarse soil particles. Moderately high organic content, with fine and medium sand particles, characterises the fallen roof material contained in the kiln bowl. The phytolith suite, from the upper levels of both kiln bowl and flue, indicates the presence of cereals.

The stack base is characterised by a moderately organic soil with low phosphorus content and low pH, which may reflect dominant pedogenic processes. A large proportion of sand particles in the sub-surface sample is consistent with the deposition of sand prior to stack construction, whilst a phytolith suite indicative of cereals from the uppermost samples is in accord with the storage of cereal crops.

The vegetable plot is characterised by very high organic content and very low pH, phosphorus content and magnetic susceptibility, which is consistent with post abandonment acidification and water retention. A large proportion of sand particles is present in the upper level, which is consistent with the use of dung (mixed with turves) from the byre, and coarse particles are dominant in the lower level. The phytolith suite may indicate peat contamination, possibly from the adjacent area, or contamination by the dung from grazing sheep.

The midden is characterised by a distinctive phytolith suite, in which the dominant morphotypes are consistent with ancient midden deposits and modern peat and dung samples. The midden is also distinguished by moderate phosphorus content and slightly acid pH. In the uppermost level, organic content is higher, and the proportion of fine soil particles larger, than in underlying levels.

The majority of the plant remains were recovered from the byre (see section 6.1.1), as opposed to the barn or kiln, for example, where crop processing operations occurred, including the parching of grain which brings cereals into close contact with fire. The plant remains in the byre are likely to represent cereal cleaning waste (from parching operations) which was sometimes used in the byre as bedding material for the calves. Similarly, the absence of charred material in the kiln or barn is accounted for by the cleaning of the kiln bowl and flue and the sweeping of the barn floor after all parching operations. The characterisation of the byre on the basis of the presence of charred plant remains is not overly reliable, because such waste material is also deposited randomly outside and some waste may remain accidentally in the barn.

Similarly, the abundance and distribution of molluscan remains, which is clearly dependent on neutral and alkaline soils (see section 6.1.2), means that density of remains is not necessarily representative of function. The assemblage composition is a more reliable indication of function. For example, the synanthropic species, such as the rupestral species, indicate structures, but differentiation between buildings is limited on this basis alone. In a non-machair environment, however, a distinctive machair fauna is suggestive of imported turves, and more reliable characterisation is possible.

In general, the midden has lower densities of material than might be expected if animal bedding from the byre was cleaned onto the midden (section 6.1.2; 6.1.3). This may be partly due to the periodic removal of the midden to the fields, leaving only the chemical traces to identify it.

CHAPTER SEVEN

CONCLUSIONS

7.1 Resource Management

Investigation of the contemporary but traditional agricultural practices on the Outer Hebrides has provided information regarding the limitations on agricultural productivity in this area, which are variously associated with the availability of land, labour and fertiliser and the tolerance range of crops. Particular attention was paid to the strategies employed for the management of scarce resources.

The nature of the agricultural regime is strongly conditioned by two principal natural constraints: the infertility of the soils and the brevity of the effective growing season. As a result, the growing of crops is heavily dependent on regular fertilising. One principal source of fertiliser is byre manure, but the keeping of livestock poses serious problems of overwintering and this in turn has, in the recent past, placed further pressure on arable farming because of the need to produce fodder grain and hay.

Three main types of land available for cultivation are the machair, blackland and peatland. The machair is relatively easy to work and reasonably fertile, but cannot support successive cropping without regular fertilisation due to the risk of destabilisation and due to deficiencies in certain trace elements. The blackland is fertile and can tolerate successive years of cropping but is harder to cultivate where the ground is rocky, wet and the covering soil is thin. The peatland is the least fertile and most difficult to reclaim for cultivation. The main grain crop, barley, is suited to the blackland and areas of the machair. Oats are suited to moist ground and grow well on the blackland, peatland and wet areas of the machair, whilst rye is suited to the dry areas of machair.

Dung (rich in phosphorus), from the midden, and seaweed (rich in nitrogen and potassium) are the two predominant fertilisers used for cultivation. Dung is used mainly on the blackland, whilst seaweed, predominantly tangle, is used mainly on the machair (which is deficient in potassium and manganese). Dung and seaweed are both used on the peatland, particularly bladderwrack which grows on the rocky shores of the east coast. This pattern of utilisation partly reflects the proximity of the respective land types to the different sources of fertiliser, where a short distance represented a huge advantage in the transport of bulky materials. The quantity available is also an important limiting factor on the use of dung and seaweed as fertilisers: for example, if sufficient dung is available it will be used on the machair. Land type is also important, however, as demonstrated at Iochdar, where the machair was too weak to benefit from dung. Here dung was dumped on the shore and the extra labour required to gather seaweed was preferred to using the readily available dung. In contrast, the use of seaweed was more dependent on the labour costs of collection than on the quantity available. Although seaweed is considered a valuable fertiliser suited to all land types, it is preferred for the machair, because it provides essential nutrients and improves the stability and water holding capacity of the soil.

Cultivation regimes vary according to land type. Barley, the staple grain crop, was preferentially sown on the relatively fertile blackland, receiving most of the manure in the first year of the rotation sequence. After the barley crop, oats were sown for two years with less or no manure, sometimes followed by hay crops. On the machair, rye tended to be sown on the driest parts, oats on the wettest and barley in intermediate locations. The machair required heavier fertilisation than the blackland, particularly where barley was sown for grain. Cultivation regimes on the peatland were similar to those on the blackland, but less intensive because the ground was less fertile and more difficult to work.

While a good loamy blackland is generally better than the machair, requiring less fertiliser, blackland can be more difficult to work, requiring spade cultivation where the ground is too rocky, wet or thin to take the plough. In this case, labour-intensive lazybeds may be prepared, to increase the depth of soil and improve drainage. Similarly, if peatland is too wet for the plough to provide adequate drainage, lazybeds may also be prepared.

Before the increase in imported flour, collecting sufficient fertiliser was vital. Seaweed was collected all winter in order to supplement the limited quantity of dung and in places where seaweed was not readily available, such as inland Lewis, importance was placed on thatch for fertiliser. When imported flour became more readily available, less barley was grown in favour of oats and rye, which demanded less fertiliser. In turn, the machair was worked in preference to the blackland because, although requiring more fertiliser, it is more easily cultivated.

7.2 Disposal Routes of Material Resources

Ethnographic information provides the basis for modelling the movement of resources within the agricultural system, as represented by the utilisation of materials and the disposal of associated by-products (figure 7.1). The analysis of material types and soil properties from a range of recent deposits, representative of specific activities within a traditional farmstead, in conjunction with ethnographic information regarding the utilisation of resources, provides the means to investigate the disposal routes of materials, the nature of post depositional processes and, in turn, to establish a reliable and distinct signature for the different functional areas.

The storage of cereals on the stack base is characterised most reliably by a high density of phytoliths and a suite of morphotypes that represent cereal components. The presence of similar phytolith morphotypes in samples from above the barn and kiln floors is consistent with the storage and processing of cereals in these locations but, in this instance, such phytoliths may also represent straw incorporated within the fallen roof material. Any charred cereal grains resulting from accidents in the kiln would most likely be removed by sweeping of the barn floor and kiln after use and this is supported by the absence of charred plant remains in these areas. It would be much more difficult to sweep away all traces of chaff and straw from regularly stored cereals, and these may well have contributed to the phytolith suite in the barn and kiln.

The physical composition of the stack base, barn and kiln deposits provides information to supplement the evidence of plant remains thereby increasing the reliability of the differentiation between these functional areas. A high proportion of medium sized sand particles together with the architectural features of stack base construction - a circular platform composed of large stones overlain by turf - provide additional means for the identification of outdoor crop storage. In contrast, the cobbled, clay packed construction of the barn floor, required for many of the crop processing activities, can be distinguished by the extremely inorganic character of the deposits, the particle size distribution and the high magnetic susceptibility, whilst the kiln is recognisable by unique structural characteristics and by predictably high magnetic susceptibility values due to the presence of fires on the floor of the kiln flue (although not particularly apparent in this study, due to absence of the end of the flue).

The byre, as a place for stalling cattle, can be distinguished by high phosphorus and organic content, indicating the accumulation of dung and bedding material. The use of machair turves for animal bedding is reliably characterised by a dominance of sand particles, by high pH and by the presence of a distinct mollusc assemblage. Furthermore, the presence of worm granules and slug plates, indicates the creation of an alkaline miocroenvironment, through the importation of machair turves, which is conducive, first, to the presence of worms and slugs and, secondly, to the preservation of their calcareous remains. If machair turves had not been used for animal bedding, the direct indictors of machair would be absent, although worms and slugs would still be anticipated if the soil conditions were not too acidic. The presence of different indicators would depend on whether peat, turf, ash or other materials were used for bedding. The presence of a drainage ditch in the byre provides a reliable means for differentiating between the byre and the midden, which are likely to be similar in other respects (see below). A drain can be identified by deposits rich in phosphorus and with indicators for the water inhibition of organic decay (i.e., high organic content, lower pH and magnetic susceptibility values), in conjunction with physical features resembling a drain.

By definition, the farmyard midden is composed predominantly of byre waste and, therefore, the midden deposits are most likely to resemble those of the byre. The overall composition of the midden may vary according to possible, but uncommon, additions of ash, thatch or floor cleanings. Food waste was consumed by chickens and dogs. The bulk of the midden material is regularly removed to the fields, and many of the material types that represent the byre and domestic by-products will also be removed, leaving only chemical traces to reflect the former composition and location of the midden. Depending on the dominant pedogenic factors, the chemical signature of the midden may also vary as, for example, in this instance, where the phosphorus content and pH of the midden are lower than in the byre deposits. If the chemical signature is unaltered by post depositional processes, the midden site would be represented by high phosphorus and organic content, and if the midden is not removed, other material types and soil properties that represent animal bedding material and domestic by-products may also be anticipated. On the basis of ancient and modern samples, a high density of phytoliths (and particularly a large proportion of trapezoids) tends to indicate midden deposits though the exact source of the phytolith suite is unknown

Vegetable plot deposits are likely to contain similar material types and soil properties to the midden deposits, owing to the use of midden material as fertiliser. Phosphorus is removed during plant growth, however, and remnant levels will depend on the intensity of the last cropping. Depending on how well they survive, material remains (such as seeds, molluscs and phytoliths) from the midden may be more reliable indicators of middening, particularly in conjunction with indications of cultivation, such as relatively homogenised soil horizons or plough marks.

The investigation of disposal routes and post depositional processes, through the characterisation of deposits, provides the information necessary for modelling site formation processes and, therefore, for the identification of a range of activities. In particular, a useful suite of characteristics for rapid field evaluation has been identified. This comprises phosphorus content, pH, particle size distribution and the density of molluscs. Initial characterisations would then need to be backed up by further laboratory analyses, particularly of phytoliths.

7.3 Historical Limitations

While this thesis has principally emphasised the natural constraints on agriculture in the twentieth century Outer Hebrides, in particular the limitations of poor soils and a short growing season, other cultural constraints must also be considered. For example, since the early twentieth century, imported grain has become more accessible and many islanders have either emigrated or abandoned full-time farming. As a result, farmers have widely given up growing grain crops on the blackland and have concentrated on fodder crops grown on the more vulnerable but more easily worked machair. Increased use of the machair has also been facilitated by the decreased demand for fertiliser on the blackland and by the fact that fodder oats and rye need less fertiliser than barley grown for grain. Latterly, many part-time farmers have taken up sheep rearing rather than the more labour-intensive cattle husbandry. Prior to these changes, farming in the early twentieth century was under considerable pressure from scarcity of land and fertiliser.

These pressures can be traced back to radical social and economic changes which took place during the seventeenth to nineteenth centuries. Early historical accounts (fourteenth to-seventeenth centuries) indicate the importance of stock rearing in the Outer Hebrides and describe the use of seasonal shielings (Fenton, 1980). Pressure on land is thought to have been low, partly because the population was small and partly because the clan system placed few limitations on access to land, with 'rents' being paid in kind and in services (e.g. Barber, 1985). From the seventeenth century, both rents and some services were increasingly paid in cash, encouraging more stock rearing and greater exploitation of the shieling grazing areas to supply cattle to mainland Scotland and ultimately England (cf. Fenton, 1980 pp. 103-5). During the eighteenth century, the dissolution of clan society led to the introduction as 'tacksmen' of outsiders, who were free from social constraints on exploiting the population. In the mid-eighteenth century, the introduction of the potato as an additional staple must have eased somewhat the position of small-scale farmers and may have enabled a growing population to farm marginal moorland areas with intensively hand-cultivated plots (Dodgshon, 1992). In the early nineteenth century, the population was forcibly concentrated near the coast in order to collect kelp (i.e. seaweed) for the landowners and, in place of the traditional communal ownership, the land was divided between individual crofts to encourage more intensive and so more productive use of the land. In the mid-nineteenth century, the shieling areas were closed off for 'estate' sheep grazing and a large farming population was crowded into a restricted area of land which, with the loss of the summer pastures, now had to serve both as arable and also as pasture for the whole year round (Caird, 1979). Together with the collapse of the kelp trade during the nineteenth century, which reduced competition for seaweed as fertiliser, these transformations gave rise to the intensive system of mixed farming which existed in the early twentieth century.

This brief historical sketch emphasises the importance of a high population density and of unequal access to land in shaping the recent intensive agriculture of the Outer Hebrides. As Dodgshon (1992) has observed, a cultivation regime associated with intensive recycling of nutrients may already have developed in the eighteenth century under the pressure of a growing population, but the social and economic upheavals at the end of the eighteenth century must at least have greatly accentuated this tendency.

For later prehistory, our knowledge of such parameters is inevitably imperfect, but the modest number and size of known settlement sites is at least consistent with a smaller and more egalitarian population than in recent centuries (Barber, 1985; Armit, 1992). If these speculations are broadly accurate, good arable land will have been relatively abundant and will have needed relatively low levels of manuring. Pasture will likewise have been both abundant and of good quality, by recent standards, and so the number of livestock available to manure each acre of arable land may potentially have been more favourable than in recent times. Oats and rye may not have been available as crops (e.g. Jones, 1981), but this may have been insignificant if abundant pasture made livestock less dependent on stall feeding.

For the Neolithic, a wealth of monuments has led Barber (1985) to suggest a period of relatively high population density. The climatic optimum would have afforded a longer growing season, however, and the existence of fertile forest brown earths in place of the later peat (Bennett *et al.*, 1990) and encroaching machair (Ritchie, 1979) would have ensured access to arable and pasture land of a quality far superior to that available in later periods. The implication of these speculations is that the intensive recycling of nutrients characteristic of the recent past should have been less essential in later prehistory.

7.4 Archaeological Interpretations and Expectations

This thesis has explored both the way in which resources have been recycled in the recent past and possible analytical methods of characterising such recycling with a view to improving understanding of the archaeological record. The previous section (7.2) has summarised the potential of different analytical methods for identifying past pathways of resource use. Ultimately, it is intended that these techniques should be applied to the archaeological record, but such an application is beyond the scope of this study. Environmental archaeology is in its infancy in the Outer Hebrides and relevant bio-archaeological studies of prehistoric sites are still in progress or awaiting publication. As a result, this final section is confined to a somewhat impressionistic comparison of the results of analysing a twentieth century farmstead with reported or personal observations from recent excavations of prehistoric settlement sites.

Results from sites such as Baleshare, Hornish Point, Kildonan, Kilpheder and the Udal (Barber, 1985; Armit, 1992; personal observation) show that these 'middens' in fact consist of interleaved occupation levels (both rubbish deposits and structures including wheel-houses) and cultivation levels (probably including both deliberately fertilised cultivation horizons and opportunistically cultivated, *in situ* rubbish deposits). The alternation of occupation and cultivation on the same spot at first sight contrasts with the separation of these areas today, but this may simply reflect the longer time scale represented by the archaeological sites. The machair was plainly unstable, as these Iron Age sites were periodically covered with blown sand. Cultivation episodes, therefore, may represent opportunistic re-use of abandoned occupation sites. Alternatively, inhabitants may have relocated buildings from time to time within a continuously occupied settlement, creating the appearance of periodic abandonment.

A second striking feature of these Iron Age 'midden' sites, in comparison with the twentieth century farmstead, is the highly mixed composition of the refuse: both deep organic deposits within the settlement and thinner deposits in cultivation horizons appear to have included a wide range of household rubbish (animal bone and shell, charred plant remains, pottery and slag) and also traces of dung (Barber, 1985). This contrasts with the recent practice of accumulating just dung and other byre materials (and sometimes ash) on the midden, ultimately to be spread on the fields, while food waste (bones, scraps etc.) was mostly consumed by dogs and hens. In part, this may reflect the keeping of relatively few livestock, consumption of relatively little meat and discarding of relatively modest quantities of bone in the twentieth century, which would be consistent with the tentative suggestion that stock rearing may have been more important in later prehistory. On the other hand, the recent inhabitants of the Outer Hebrides may also have been constrained by different attitudes to rubbish than their Iron Age predecessors, as bone (when not consumed by dogs) and shell were deliberately disposed of separately from the dung midden. It was also suggested above (section 7.3) that available pasture will have been both more abundant and of better quality in prehistory, raising the possibility that Iron Age livestock were not stalled in the byre consuming stored fodder for the entire winter, but spent much of the winter grazing outdoors or around the farmyard. If livestock spent less time indoors, farmers may not have had such a concentrated accumulation of byre manure and may instead have collected up dung mixed with domestic refuse from around the settlement.

A third and perhaps most interesting contrast between the twentieth century farmstead and the Iron Age sites is the almost complete lack of dung and other refuse on the former and the deep accumulation of mixed organic deposits on the latter. Barber (1985) has interpreted some deep organic deposits as resulting from the artificial creation of 'plaggen' soils, but it has been argued above that these may represent opportunistic cultivation of *in situ* rubbish deposits. Either way, the apparent use of midden material in the construction of a corbelled-roof wheel-house (Armit, 1992 p.68) and the accumulation of a large organic-rich midden at the Dun Vulan broch site suggest a far less intensive recycling of resources than on the twentieth century farmstead. The existence of 'surplus' manure is again consistent with the tentative suggestion of a relatively high ratio of livestock to arable fields in the prehistoric Outer Hebrides.

It must also be recalled, however, that most of the known Iron Age 'midden' sites are located on the machair, where seaweed is in many respects a more beneficial fertiliser than dung. Some empirical support for this suggestion is provided by the discovery at Hornish Point and Baleshare of marine prosobranchs consistent with the introduction of seaweed (Thew, in press). The association between machair and the discarding of dung is reinforced by recent work in Orkney, where large manure heaps of Norse date have been found only on the wind-blown calcareous sands of Sanday and North Ronaldsay (Davidson et al., 1986); documentary evidence of more recent date records the deliberate discarding of dung and the preferential use of seaweed as fertiliser on these two islands (Fenton, 1978).

If future analytical work confirms the use of seaweed as fertiliser in Iron Age cultivation horizons in the Outer Hebrides, it should be recalled that the availability of seaweed is subject to considerable year-to-year variation, depending on the strength and direction of winter storms. In recent times, farmers have used seaweed to make up shortages of dung and *vice versa* and a similar practice in the Iron Age could account for the apparently contradictory evidence of mixed organic refuse being spread on cultivation horizons in some contexts and being accumulated in large middens in others.

A broader issue is the reason for the apparent concentration of these Iron Age sites on the machair, rather than the more fertile and more stable, but more labour-demanding, blackland. It must be emphasised that both the machair and the blackland are very variable, and good quality blackland is today very restricted in extent. It is possible that the good blackland was also under cultivation: many of the known Iron Age sites have been found recently because the instability of the machair has exposed previously buried sites, and future survey may also locate Iron Age sites on the blackland. Alternatively, if the apparent association between Iron Age sites and machair is not an artefact of archaeological exploration, this may be a hint that the inhabitants were more concerned with ease of cultivation than with reliability of yields. This in turn would be consistent with the tentative suggestion that stock rearing played a major role in Iron Age subsistence, making it possible to take risks with arable production.

The purpose of conducting an ethnoarchaeological study of disposal routes on a recent farmstead was not to find a direct analogue for archaeological sites, but rather to gain insights which would help their investigation and interpretation. Appropriately, this study has concluded by drawing attention to the contrasts between the modern analogue and its prehistoric counterparts and by suggesting that Iron Age 'midden' sites in the Outer Hebrides may be evidence as much for the wasting as for the recycling of resources.

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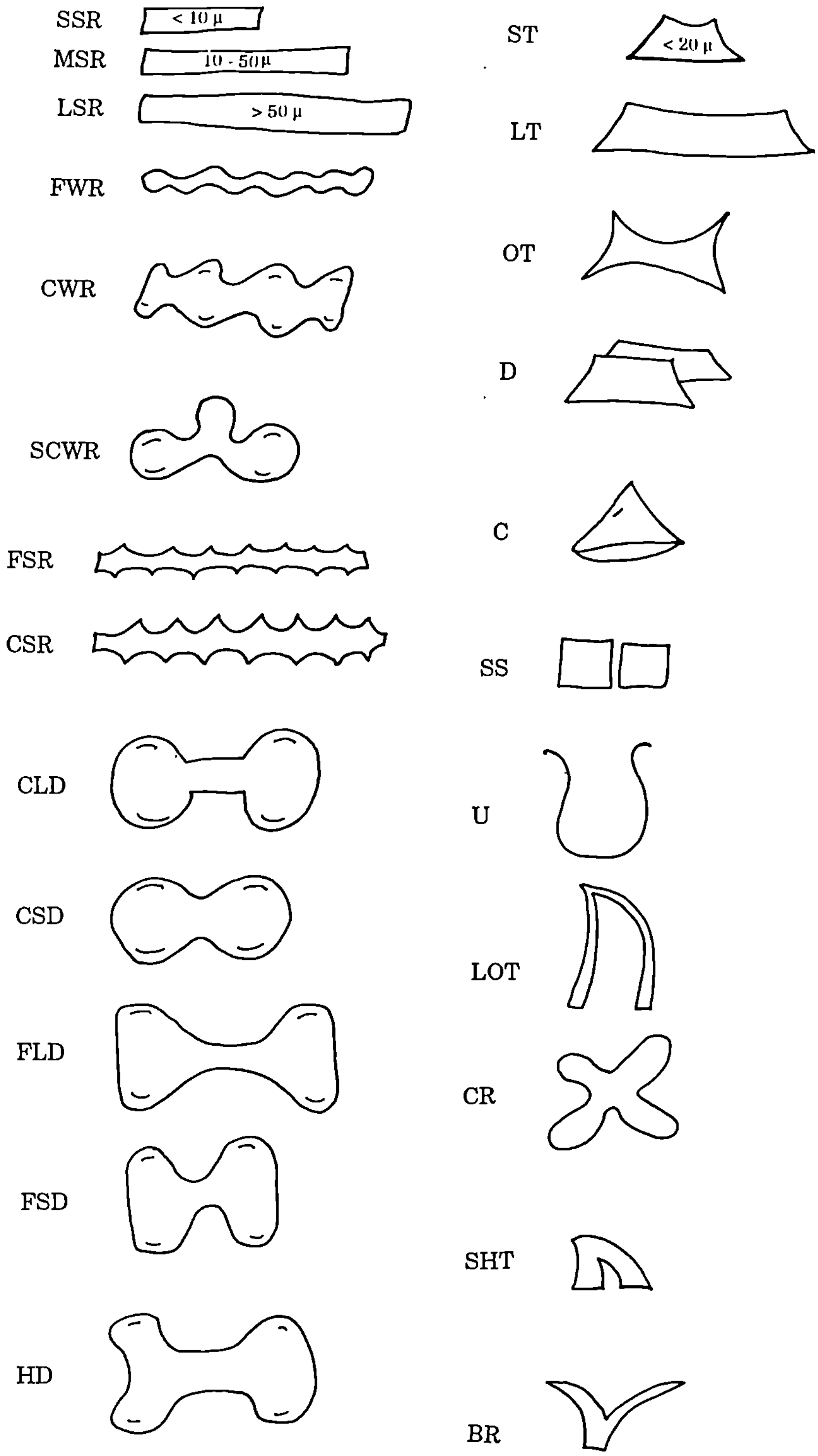
Tables

Figures

ENVIRONMENTAL SAMPLE NUMBER	SAMPLE CONTEXT Functional Area	Context Number	SAMPLE TYPE	No. litres taken for bulk ('B') sample
101	Byre	201	A,B,C	46
102	Byre	202	A,B	40
103	Byre	203	A,B	14
104	Byre	204	A,B,C	28
118	Barn	218	A,B,C	10
120	Barn	220	A,B,C	7.5
130	Barn	230	A,B	10
131	Barn	231	A	-
122	Kiln Bowl	222	A,B,C	10
123	Kiln Bowl	223	A,B,C	10
124	Kiln Bowl	224	A,B	2.5
162	Kiln Bowl	262	A,B	4
128	Kiln Flue	228	A,B,C	20
129	Kiln Flue	229	A,B	1
161	Kiln Flue	261	A,B	5
137	Stach Base	237	A,B,C	10
138	Stack Base	238	A,B,C	6
141	Stack Base	241	A,B,C	10
142	Stack Base	242	A	-
146	Veg. Plot	246	A,B,C	10
147	Veg. Plot	247	A,B,C	5
156	Midden	256	A,B,C	10
157	Midden	257	A,B,C	7.5
158	Midden	258	A,B,C	10
159	Midden	259	A,B	10
160	Midden	260	A	-

Table 3.1: Type and volume of samples in relation to context.



SSR	Short smooth rod	CSD	Convex short dumb-bell	D	Duo
MSR	Medium smooth rod	CLD	Convex long dumb-bell	C	Cones
LSR	Long smooth rod	FSD	Flat lshort dumb-bell	SS	Sub-squares
FWR	Fine wavy rod	FLD	Flat long dumb-bell	U	Urns
CWR	Coarse wavy rod	HD	Hybrid dumb-bell	SHT	Short trichomes
SCWR	Short coarse wavy rod	ST	Short trapezoids	LOT	Long trichomes
FSR	Fine spiny rod	LT	Long trapezoids	CR	Crosses
CSR	Coarse spiny rod	OT	Ornamented trapezoids	BR	Branched

Table 4.1: Classification of phytolith morphotypes.

GRAVEL		> 1.7 mm
SAND	Coarse	1.7 - 0.5 mm
	Medium	0.5 - 0.25 mm
	Fine	0.25 - 0.106 mm
	Very Fine	0.106 - 0.06 mm
SILT		0.06 -0.002 mm
CLAY		< 0.002 mm

Table 4.2: Boundaries of Soil Textural classes.

	CATEGORY	pH
ACIDITY		< pH 3.5 the extreme pH for acid peat soils
	Very Strongly acid	3.0 - 3.9
	Strongly acid	4.0 - 4.9
	Moderately acid	5.0 - 5.9
	Slightly acid	6.0 - 6.9
NEUTRALITY	Neutral	7.0
ALKALINITY	Slightly alkaline	7.0 - 7.9
	Moderately alkaline	8.0 - 8.9
	Strongly alkaline	9.0 - 9.9
	Very srongly alkaline	10.0 -11.0 > pH 10.5 attained only by alkali mineral soils.

Table 4.3: The scheme for the verbal classification of pH (after Brady 1984).

LAND MANAGEMENT		FARMSTEAD MANAGEMENT
Seaweeding	**January**	Cattle stalled
		Crops processed
Seaweeding	**February**	Cattle stalled
		Crops processed
Midden spread	**March**	Grain Parched
	to	Midden removed
Ploughing/	**April**	Grain to mill/meal sieved
Lazybeds dug		Animals returned to land/
Crops sown	**May**	Byre cleaned out
Animals restricted to	**June**	
areas of common grazing		
		animals traditionally
		off croft and at shieling
Hay cut	**July**	
Cereal Harvest	**August**	
	September	Stack Construction
Animals permitted on	**October**	
arable land	**November**	Byre preparation
Seaweeding	**December**	Animals stalled

Table 5.1: Annual timetable of agricultural activities.

Taxon	Common name	BYRE				BARN				KILN						
		101	**102**	**103**	**104**	**118**	**120**	**130**	**131**	**122**	**123**	**124**	**162**	**128**	**129**	**161**
Hordeum	Barley	2	4	2	3									1		
Hordeum / Secale	Barley/Rye	1			1											
Hordeum / Avena	Barley/Oat	1														
Avena	Oat	16	10	4	17											
Secale	Rye	1	1		5											
Triticum / Secale	Wheat/Rye	1														
Cereal indet		4	5		5	1										
Cruciferae capsule		1		1	4											
Root/twig																
Vitis vinifera (mineralised)	Grape seed	1			1											
Unidentified seed (mineralised)			2													
Total		28	22	7	36	1	0	0	-	0	0	0	0	1	0	0
No. litres		46	40	14	28	10	7.5	7.5	-	10	10	2.5	4	20	1	5
Seeds/litre		.6	.55	.5	1.2	.1	0	0	-	0	0	0	0	·05	0	0

Table 6.1: Plant remains: raw counts.

Taxon	Common name	STACK BASE				VEG. PLOT		MIDDEN				
		137	138	141	142	146	147	156	157	158	159	160
Hordeum	Barley		1									
Hordeum / Secale	Barley/Rye											
Hordeum / Avena	Barley/Oat											
Avena	Oat											
Secale	Rye											
Triticum / Secale	Wheat/Rye											
Cereal indet												
Cruciferae capsule												
Root/twig				1		5						
Vitis vinifera (mineralised)	Grape seed											
Unidentified seed (mineralised)												
Total		0	1	1	-	5	0	0	0	0	0	-
No. litres		10	6	10	-	10	5	10	7.5	10	10	-
Seeds/litre		0	.16	.1	-	.5	0	0	0	0	0	-

Table 6.1 continued: Plant remains: raw counts.

Taxon	BYRE				BARN				KILN						
	101	102	103	104	118	120	130	131	122	123	124	162	128	129	161
Oxychillus cellarius	4	3							12		11		22	4	
Oxychillus alliarius													4		
Lauria cylindracea	22	1			1				1		3	2	8	3	
Balea perversa	5	5													
Vitrina pellucida		2													
Cochliocopa lubrica	8												1		
Cochliocopa sp.	10	2	4												
Cochlicella acuta	7	4	5										2		
Marine gastropod											1				
Slug plate: *Milax/ Limax/Deroceras*	1		2								1			1	
Total	57	17	11	0	1	0	0	0	13	0	16	2	37	8	0
No. litres	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
molls/litre	28.5	8.5	5.5	0	0.5	0	0	0	6.5	0	8	1	18.5	4	0

Table 6.2a : Molluscan remains in two-litre samples: raw counts.

	BYRE				BARN				KILN						
	101	102	103	104	118	120	130	131	122	123	124	162	128	129	161
Earthworm granules/litre	116	46	38	310	6	10	0	0	48	5	33	2	8	1	0

Table 6.2b: Density of earthworm granules in two-litre samples.

Taxon	STACK BASE				VEG. PLOT		MIDDEN				
	137	138	141	142	146	147	156	157	158	159	160
Oxychillus cellarius											
Oxychillus alliarius											
Lauria cylindracea											
Balea perversa											
Vitrina pellucida											
Cochliocopa lubrica											
Cochliocopa sp.											
Cochlicella acuta											
Marine gastropod											
Slug plate: *Milax/ Limax/Deroceras*											
Total	0	0	0	0	0	0	0	0	0	0	0
No. litres	2	2	2	2	2	2	2	2	2	2	2
molls/litre	0	0	0	0	0	0	0	0	0	0	0

Table 6.2a continued: Molluscan remains in two-litre samples: raw counts.

	STACK BASE				VEG. PLOT		MIDDEN				
	137	138	141	142	146	147	156	157	158	159	160
Earthworm granules/litre	0	0	0	0	0	0	0	0	0	0	0

Table 6.2b continued: Density of earthworm granules in two-litre samples.

Taxon	BYRE				BARN				KILN						
	101	102	103	104	118	120	130	131	122	123	124	162	128	129	161
Oxychillus cellarius	64	10	3	6			1		39	11	2	2	327	1	3
Oxychillus alliarius	3														
Nesovitrea hammonis	3	1											2		
Lauria cylindracea	191	10	2	10					8	6	2		139		4
Balea perversa	26	2													
Punctum pygmaeum	2												8		
Vitrina pellucida		3													
Cochliocopa lubrica	82		3						1				20	1	
Cochliocopa lubricella	35			6					1				7		
Cochliocopa sp.	64			4									9		
Vertigo cf sp. pygmaea	2														
Pupilla muscorum	2														
Vallonia costata	4														
Vallonia excentrica															1
Helicella italia	2		1								1				
Cochlicella acuta	91	66	104	8											
Hydrobia							1						2		
Marine gastropod	2	2													
Slug plate: *Milax / Limax / Deroceras*			1												
Total	573	94	114	34	0	0	2	-	49	17	5	2	514	2	8
No. litres	46	40	14	28	10	7.5	7.5	-	10	10	2.5	4	20	1	5
molls/litre: excluding *Hydrobia* and slug plates	12.4	2.4	8.07	1.2	0	0	0	-	4.9	1.7	2	0.5	25.6	2	1.6

Table 6.3a: Molluscan remains from flots of bulk samples: raw counts.

N.B. The density of molluscs in the bulk samples excludes material retrieved from the residues due to the possible inaccuracy introduced when multiplying fractions up to a whole.

	STACK BASE				VEG. PLOT		MIDDEN				
Taxon	137	138	141	142	146	147	156	157	158	159	160
Oxychillus cellarius											
Oxychillus alliarius											
Nesovitrea hammonis											
Lauria cylindracea											
Balea perversa											
Punctum pygmaeum											
Vitrina pellucida											
Cochliocopa lubrica											
Cochliocopa lubricella											
Cochliocopa sp.											
Vertigo cf sp. pygmaea											
Pupilla muscorum											
Vallonia costata											
Vallonia excentrica											
Helicella italia											
Cochlicella acuta											
Hydrobia			1		1			1	2	1	
Marine gastropod											
Slug plate: *Milax/Limax/Deroceras*											
Total	0	0	1	-	1	0	0	1	2	1	-
No. litres	10	6	10	-	10	5	10	7.5	10	10	-
molls/ litre: excluding *Hydrobia* and slug plates	0	0	0	-	0	0	0	0	0	0	-

Table 6.3a continued: Molluscan remains from bulk samples: raw counts.

Taxon	BYRE				BARN				KILN						
	101	102	103	104	118	120	130	131	122	123	124	162	128	129	161
Oxychillus cellarius													56		
Lauria cylindracea									8						
Marine gastropod				16											
Slug plate: *Milax / Limax / Deroceras*	24			64	16										
Fraction sorted	1/8	1/32	1/16	1/8	1/16	1/16	1/16	-	1/4	1/8	1/2	1/4	1/8	1/1	1/8
No. litres	46	40	14	28	10	7.5	7.5	-	10	10	2.5	4	20	1	5

Table 6.3b: Molluscan remains from residues of bulk samples: raw counts.
(N.B. The number of items are multiplied by the fraction of residue sorted from each sample).

Taxon	STACK BASE				VEG. PLOT		MIDDEN				
	137	138	141	142	146	147	156	157	158	159	160
Fraction sorted	-	1/8	1/16	-	-	-	-	1/8	1/16	1/16	-
No. litres	10	6	10	-	10	5	10	7.5	10	10	-

Table 6.3b continued: Molluscan remains from residues of bulk samples: raw counts.

Morphotype	BYRE				BARN				KILN						
	101	102	103	104	118	120	130	131	122	123	124	162	128	129	161
Short smooth rod	2	7	15	9	1	3		8	9	9	9	13	10	13	45
Medium smooth rod	65	45	80	41	24	26	12	51	33	69	68	62	27	55	57
Long smooth rod		2	2	5	1		1				4		3	3	1
Fine wavy rod	26	9	14	27	27	36		3	31	14	14	9	20	17	6
Coarse wavy rod	14	8	9	19	24	32			15	6	7		21	16	
Fine spiny rod	5	3	5	11	11	7	1		6	10	8		5	5	
Coarse spiny rod	1	6		8	3	10			8	8	8	4	8	7	
Short coarse wavy rod															
Convex short dumb-bell	3		1	3	4	2		1	6	1	3		1	2	2
Convex long dumb-bell	9	7	9	8	31	22			21	11	21	4	40	23	
Flat short dumb-bell	5	1	2	3	5	10			5	3	3	1	6	1	2
Flat long dumb-bell	8	5	6	8	17	18	1	1	14	6	13	1	12	10	
Hybrid dumb-bell			1			1									74
Short trapezoid	43	39	45	54	52	51	3	21	57	55	37	74	40	48	20
Long trapezoid	20	62	19	11	16	7		1	13	13	5	27	7	6	5
Ornamented trapezoid	7	11	4	4	10	8		1	8	2	8	8	13	4	
Duo		4		1	2	1			3						
Cones	28	28	25	24	16	7	1	35	15	30	24	42	21	16	29
Sub-squares	4	4	2	4	3	4	4	3	3	13	12	4	11	20	8
Urns	7	5	5	9	3	3	1		2		3		5	4	
Short trichome			2			1					2				
Long trichome	1	2	4	1								1			1
Cross	2	1				1									
Branched		1							1		1				
Total	250	250	250	250	250	250	24	125	250	250	250	250	250	250	250
No./Lycopodium spore	0.66	0.51	3.09	0.23	1.67	0.73	1.41	5.43	8.93	1.04	1.24	1.85	1.55	0.99	1.30

Table 6.4 :Phytolith morphotypes: raw counts.

Morphotype	STACK BASE				VEG. PLOT		MIDDEN				
	137	138	141	142	146	147	156	157	158	159	160
Short smooth rods	10	1	1	15	3		1	3	4	5	
Medium smooth rods	41	27	46	61	34	6	18	35	32	26	3
Long smooth rods		1	2						2		
Fine wavy rods	67	77	49	9	37	9	30	18	20	10	
Coarse wavy rods	24	27	12	10	17	2	5	3	11	4	
Fine spiny rods	4	4	8		7	1	2		2	2	
Coarse spiny rods	5	11	11	3	10	2	2	2	4	3	1
Short coarse wavy rods									2	1	
Convex short dumb-bell	2	1	3		4		10	3	4	6	
Convex long dumb-bell	9	10	16	3	31	10	34	36	25	18	1
Flat short dumb-bell	1	1	2	2	1	1	4	1	2	4	
Flat long dumb-bell	5	2	6	3	22	2	21	16	15	10	2
Hybrid dumb-bell					7				7	4	
Short trapezoids	40	47	63	50	58	16	99	102	97	119	11
Long trapezoids	6	7	9	10	10	2	14	11	10	17	
Ornamented trapezoids	6	3	5	2	1	1	2				
Duo										1	
Cones	23	23	13	26	6	3	8	19	9	19	
Sub-squares	1	5	1	5				1	4		
Urns	3	3	3		1					1	
Short trichomes	2			1							
Long trichomes	1				1						
Cross											
Branched											
Total	250	250	250	200	250	55	250	250	250	250	18
No./Lycopodium spore	2.66	3.97	0.56	0.55	0.18	0.07	6.76	0.57	0.72	0.83	0.07

Table 6.4 continued: Phytolith morphotypes: raw counts.

		BYRE				BARN				KILN						
		101	102	103	104	118	120	130	131	122	123	124	162	128	129	161
Starting Weight		30	30	30	25	25	25	30	30	30	30	25	30	20	30	30
Sieve	Size															
Phi	Microns															
-0.75	1700	2.79	6.47	7.81	1.17	1.65	5.84	8.46	5.46	1.92	10.03	4.58	5.91	3.07	6.01	5.59
-0.25	1180	0.95	2.17	2.45	0.62	1.31	1.40	2.14	2.40	0.92	2.16	2.19	2.32	1.38	2.84	1.97
0.25	850	1.31	2.44	2.14	1.22	1.59	1.52	2.25	2.31	1.16	2.06	2.18	2.20	1.40	2.62	2.09
0.75	600	1.85	2.01	2.12	1.87	1.85	1.37	2.69	2.48	2.10	1.96	1.75	2.45	1.49	2.36	2.16
1	500	1.13	1.02	1.08	1.61	1.40	0.83	1.04	0.97	1.22	0.87	1.10	1.30	0.91	0.93	1.07
1.25	425	1.81	1.36	1.45	1.89	1.14	0.85	1.06	1.26	1.79	1.04	1.01	1.26	0.94	1.32	1.36
1.5	355	1.75	0.95	0.72	1.33	0.91	0.69	0.77	0.86	1.15	0.66	0.99	1.08	0.41	0.77	1.11
2	250	4.96	3.19	3.04	4.26	2.25	1.80	2.38	2.24	3.70	1.89	1.97	2.74	1.68	2.44	3.18
2.5	180	4.69	2.41	2.42	3.39	2.16	1.64	1.63	1.60	3.30	1.66	1.81	1.61	1.45	2.00	2.62
3	125	3.76	2.61	2.19	3.56	2.72	2.33	1.50	1.47	4.22	1.67	1.80	2.04	1.72	1.98	1.95
3.25	106	1.11	0.86	0.69	0.90	0.98	0.90	0.68	0.73	1.76	0.66	0.67	0.74	0.65	0.71	0.92
	Tray	3.75	4.16	3.33	2.81	6.86	5.52	5.01	7.88	6.28	5.04	4.52	5.90	4.54	5.67	5.68
End Weight		29.86	29.65	29.44	24.63	24.82	24.69	29.61	29.66	29.52	29.70	24.57	29.55	19.64	29.65	29.70

Table 6.5: Particle Size Distribution: weight (g).

		STACK BASE				VEG. PLOT		MIDDEN				
		137	138	141	142	146	147	156	157	158	159	160
Starting Weight		20	30	30	30	30	25	20	30	30	30	30
Sieve	Size											
Phi	Microns											
-0.75	1700	0.22	6.66	7.09	7.58	2.40	6.16	5.02	8.62	7.73	8.25	4.90
-0.25	1180	0.38	2.26	2.67	2.89	1.54	2,78	1.20	2.53	2.52	2.70	2.18
0.25	850	0.96	3.21	2.33	2.38	2.59	2.69	1.19	2.37	2.04	2.68	2.60
0.75	600	1.97	2.32	1.80	1.76	2.58	2.55	1.25	2.04	2.12	2.28	3.26
1	500	0.96	1.53	0.89	0.79	1.14	0.95	0.76	0.74	1.00	1.02	1.70
1.25	425	1.30	1.01	0.99	1.04	1.68	0.96	0.78	0.85	1.24	1.14	2.38
1.5	355	1.04	0.73	0.79	0.80	1.16	0.60	0.52	0.68	0.85	0.81	1.58
2	250	3.08	2.68	2.60	2.70	3.37	1.89	1.47	2.22	2.49	2.39	4.74
2.5	180	2.83	2.08	2.05	2.18	3.29	1.26	1.44	1.84	1.65	2.02	2.75
3	125	2.26	2.05	2.09	1.80	3.81	1.60	1.53	1.83	1.85	1.98	2.04
3.25	106	0.77	0.77	0.83	0.67	1.15	0.61	0.54	0.72	0.65	0.73	0.60
	Tray	4.11	4.50	5.64	5.01	4.93	2.83	4.02	5.08	5.29	3.93	1.19
End Weight		19.88	29.83	29.77	29.60	29.64	24.88	19.72	29.52	29.43	29.93	29.92

Table 6.5 continued: Particle Size Distribution: weight (g).

	Sample No.	% <0.106mm	% fine sand (<0.106 - 0.25)mm	% medium sand (0.25 - 0.5)mm	% coarse sand (0.5 - 1.7)mm	%Gravel >1.7mm
BYRE	101	12.6	32.0	28.6	17.5	9.3
	102	14.0	19.8	18.5	25.9	21.8
	103	11.3	18.0	17.7	26.5	26.5
	104	11.4	31.8	30.4	21.6	4.8
BARN	118	27.6	23.7	17.3	24.8	6.6
	120	22.4	19.7	13.6	20.7	23.6
	130	16.9	12.9	14.2	27.4	28.6
	131	26.6	12.8	14.7	27.5	18.4
KILN	122	21.3	31.4	22.5	18.3	6.5
	123	17.0	13.4	12.1	23.7	33.8
	124	18.4	17.4	16.2	29.4	18.6
	162	20.0	14.8	17.2	28.0	20.0
	128	23.1	19.5	15.4	26.4	15.6
	129	19.1	15.8	15.3	29.5	20.3
	161	19.1	18.5	19.0	24.6	18.8
STACK BASE	137	20.7	29.5	27.2	21.5	1.1
	138	15.1	16.4	14.8	31.4	22.3
	141	18.9	16.7	14.7	25.9	23.8
	142	17.0	15.7	15.4	26.4	25.6
VEGETABLE PLOT	146	16.6	27.8	21.0	26.5	8.1
	147	11.4	13.9	13.9	36.1	24.7
MIDDEN	156	20.4	17.8	14.0	22.3	25.5
	157	17.2	14.9	12.7	26.0	29.2
	158	18.0	14.1	15.5	26.1	26.3
	159	13.1	15.8	14.5	29.0	27.6
	160	4.0	18.0	29.1	32.5	16.4

Table 6.6: Percentage of material in each textural soil class.

CONTEXT	Sample No.	Particle size mode	Particle size I Q R	Average pH value	Phosphorus rapid test (1-5)	Total available Phosphorus (%)	Organic content (%)	Magnetic suscept. ($10^{-8}m^3kg^{-1}$)
	101	0.25	0.375	7.19	5	0.170	10.39	0.085
BYRE	102	0.25	1.005	7.24	4.5	0.169	6.58	0.098
	103	0.25	1.52	7.32	4	0.159	4.13	0.143
	104	0.25	0.375	7.02	5	0.145	17.46	0.109
	118	0.125	0.494	6.45	3.5	0.126	29.50	0.093
BARN	120	0.125	1.074	6.37	4	0.129	25.82	0.097
	130	0.6	1.52	6.19	5	0.051	1.93	0.246
	131	0.6	1.074	6.53	3.5	0.041	2.97	0.268
	122	0.125	0.319	6.32	5	0.075	17.59	0.089
KILN BOWL	123	0.85	1.52	7.01	3.5	0.082	5.91	0.125
	124	0.85	1.055	7.31	4	0.091	6.03	0.112
	162	0.25	1.055	7.20	2.5	0.105	4.90	0.089
	128	0.125	0.744	7.28	4	0.092	12.69	0.078
KILN FLUE	129	0.25	1.055	7.36	3	0.106	6.44	0.116
	161	0.25	1.055	7.08	3	0.045	2.09	0.177
	137	0.25	0.3	4.46	1.5	0.020	12.61	0.136
STACK BASE	138	0.85	1.0	4.52	1	0.015	7.53	0.133
	141	1.18	1.055	4.68	1	0.011	6.16	0.135
	142	1.18	1.575	4.86	1	0.013	3.51	0.178
VEGETABLE	146	0.125	0.475	4.94	0.5	0.007	22.54	0.018
PLOT	147	0.6	1.0	5.12	0.5	0.013	13.57	0.012
	156	0.125	1.575	5.93	2	0.093	23.89	0.531
	157	1.18	1.575	5.87	3.5	0.086	8.41	0.243
MIDDEN	158	0.25	1.575	6.06	4	0.084	4.62	0.152
	159	0.85	1.52	6.11	4	0.088	7.23	0.118
	160	0.25	0.6	6.09	3	0.042	1.11	0.063

Table 6.7: Results of physical and chemical soil analyses.

Analysis No.	Fig. No.	Tab. No.	Discriminating Variables															Misclassified Samples
			Moll. axis 1	Moll. axis 2	Phyto. axis 1	Phyto. axis 2	Phyto. axis 3	P.S. mode	P.S. IQR	pH	Phos.	Org.	Mag sus.	Seed den.	Moll. den.	Worm den.	Phyto. den.	
1	6.29 6.30	6.9			*	*	*	*	*	*	*	*	*					122
2	6.31	6.10			*	*	*	*	*	-	*	*	*					-
3					*	*	-	*	*	*	*	*	*					122
4	6.32	6.11			*	-	-	*	*	*	*	*	*					122
5	6.33	6.12			-	*	-	*	*	*	*	*	*					122

Table 6.8: Discriminant analyses using the scores on the phytolith correspondence axes and the physical and chemical soil properties (an asterisk marks those variables included in the analyses) .

FCN.	EIGEN VALUE	%. OF VARIANCE	CUM. %	CANON. CORR.	AFTER FCN.	WILKS' LAMBDA	CHI SQU.	DF	SIG
					0	0.0001	163.167	45	0.0000
1	41.7896	67.28	67.28	0.9882	1	0.0038	97.432	32	0.0000
2	13.3429	21.48	88.76	0.9645	2	0.0548	50.825	21	0.0003
3	5.5927	9.00	97.77	0.9210	3	0.3612	17.821	12	0.1212
4	1.0070	1.62	99.39	0.7083	4	0.7249	5.629	5	0.3440
5	0.3794	0.61	100.00	0.5245					

Table 6.9a: The canonical discriminant functions for analysis 1.

	FUNCTION 1	FUNCTION 2	FUNCTION 3	FUNCTION 4	FUNCTION 5
pH	**1.238**	-0.185	0.418	-0.265	-0.009
Phyto. axis 1	0.133	**-1.476**	**1.481**	**0.898**	-0.138
Phyto. axis 2	-0.174	**1.283**	-0.363	0.137	-0.073
Organic	0.210	-0.235	**3.184**	-0.258	0.077
Mag. Sus	0.228	0.463	**-1.758**	0.311	0.709
P.S. IQR	-0.424	0.585	**1.307**	-0.593	0.069
Phyto. axis 3	0.278	0.347	**-0.811**	-0.405	-0.579
Phosphorus	-0.333	-0.147	**-1.054**	**1.695**	0.084
P.S. Mode	-0.039	-0.012	-0.257	-0.059	0.411

Table 6.9b: The rotated standarized discriminant function coefficients for analysis 1.

FCN.	EIGEN VALUE	% OF VARIANCE	CUM %	CANON. CORR	AFTER FCN	WILKS' LAMBDA	CHI SQU	DF	SIG
					0	0.0007	130.093	40	0.0000
1	20.3861	56.75	56.75	0.9763	1	0.0155	74.964	28	0.0000
2	13.2069	36.77	93.52	0.9642	2	0.2207	27.196	18	0.0754
3	1.7024	4.74	98.26	0.7937	3	0.5964	9.302	10	0.5037
4	0.5242	1.46	99.72	0.5864	4	0.9091	1.716	4	0.7879
5	0.1000	0.28	100.00	0.3015					

Table 6.10 a: The canonical discriminant functions for analysis 2.

	FUNCTION 1	FUNCTION 2	FUNCTION 3	FUNCTION 4	FUNCTION 5
Phyto. axis 1	**2.112**	0.316	1.058	-0.277	-0.021
Phyto. axis 2	-0.692	0.091	-0.161	**1.055**	-0.005
Phosphorus	0.502	**1.478**	-0.888	0.073	0.114
Organic	0.528	-0.222	**2.893**	-0.068	0.071
Mag. Sus	-0.611	0.433	**-1.631**	0.205	0.710
P.S. IQR	-0.218	-0.679	**1.392**	0.434	0.093
Phyto. axis 3	-0.394	-0.336	**-0.828**	0.315	-0.557
P.S. Mode	-0.527	0.241	-0.138	-0.481	0.310

Table 6.10 b: The rotated standarized discriminant function coefficients for analysis 2.

FCN.	EIGEN VALUE	% OF VARIANCE	CUM %	CANON. CORR	AFTER FCN.	WILKS' LAMBDA	CHI SQU	DF	SIG
					0	0.0006	135.799	35	0.0000
1	33.2098	76.90	76.90	0.9853	1	0.0222	70.448	24	0.0000
2	7.2431	16.77	93.67	0.9374	2	0.1829	31.424	15	0.0077
3	2.0522	4.75	98.42	0.8200	3	0.5584	10.781	8	0.2144
4	0.4356	1.01	99.43	0.5509	4	0.8016	4.091	3	0.2518
5	0.2475	0.57	100.00	0.4454					

Table 6.11 a: The canonical discriminant functions for analysis 4.

	FUNCTION 1	FUNCTION 2	FUNCTION 3	FUNCTION 4	FUNCTION 5
pH	**1.18294**	-0.01990	0.40728	0.04848	0.01866
Phyto. axis 1	-0.04827	**1.73761**	**0.80401**	0.10302	0.05711
Organic	0.30726	0.36411	**2.69283**	0.01409	-0.05711
Phosphorus	-0.33828	**0.87177**	**-1.49318**	**0.89984**	0.24164
Mag. Sus.	0.07290	-0.07511	**-1.27110**	0.06492	**1.097735**
P.S. IQR	-0.24841	**-1.06442**	**1.23027**	0.27788	-0.19348
P.S. Mode	-0.02152	0.23641	-0.19472	-0.47935	0.36375

Table 6.11 b: The rotated standardized discriminant function coefficients for analysis 4.

FCN.	EIGEN VALUE	% OF VARIANCE	CUM %	CANON. CORR	AFTER FCN.	WILKS' LAMBDA	CHI SQU	DF	SIG
					0	0.0004	143.215	35	0.0000
1	30.5361	71.74	71.74	0.9840	1	0.0137	79.369	24	0.0000
2	7.4913	17.60	89.34	0.9393	2	0.1163	39.797	15	0.0005
3	3.8829	9.12	98.46	0.8917	3	0.5681	10.461	8	0.2342
4	0.3918	0.92	99.38	0.5306	4	0.7907	4.344	3	0.2266
5	0.2647	0.62	100.00	0.4575					

Table 6.12 a: The canonical discriminant functions for analysis 5.

	FUNCTION 1	FUNCTION 2	FUNCTION 3	FUNCTION 4	FUNCTION 5
pH	**1.23210**	0.39661	-0.26134	-0.05954	0.01438
Organic	0.32091	**2.34478**	0.11059	0.12495	-0.17178
Phosphorus	-0.35503	**-1.72225**	0.40539	**0.89953**	0.28975
P.S. IQR	-0.27010	**1.44888**	0.18154	-0.00998	-0.22290
Mag. Sus.	0.04657	**-1.08378**	0.06825	0.13518	**1.10068**
Phyto axis 2	-0.17433	0.01369	**1.17823**	0.05070	0.01545
P.S. Mode	-0.03684	-0.16371	-0.08073	-0.16825	0.35848

Table 6.12 b: The rotated standardized discriminant function coefficients for analysis 5.

Analysis No.	Fig. No.	Tab. No.	Discriminating Variables															Misclassified Samples
			Moll. axis 1	Moll. axis 2	Phyto. axis 1	Phyto. axis 2	Phyto. axis 3	P.S. mode	P.S. IQR	pH	Phos.	Org.	Mag sus.	Seed den.	Moll. den.	Worm den.	Phyto. den.	
6					*	-	-	-	-	-	*	*	-					122, 128, 156
7					-	*	-	-	-	-	*	*	-					122, 131
8	6.34	6.14			*	*	-	-	-	-	*	*	-					122, 123
9					*	-	-	-	-	*	*	-	-					122
10					-	*	-	-	-	*	*	-	-					122, 142
11	6.35	6.15			*	*	-	-	-	*	*	-	-					122
12					*	*	-	-	-	-	*	-	*					118, 128

Table 6.13: Discriminant analyses using the scores on the first or second phytolith correspondence axes and any two of the physical and chemical soil properties.

FCN.	EIGEN VALUE	% OF VARIANCE	CUM %	CANON. CORR	AFTER FCN.	WILKS' LAMBDA	CHI SQU	DF	SIG
					0	0.0077	97.392	20	0.0000
1	9.9560	62.08	62.08	0.9533	1	0.0841	49.515	12	0.0000
2	5.2379	32.66	94.74	0.9163	2	0.5246	12.902	6	0.0446
3	0.7617	4.75	99.49	0.6575	3	0.9242	1.576	2	0.4547
4	0.0820	0.51	100.00	0.2753					

Figure 6.14 a: The canonical discriminant functions for analysis 8.

	FUNCTION 1	FUNCTION 2	FUNCTION 3	FUNCTION 4
Phosphorus	**1.26727**	0.08585	0.18859	-0.20307
Phyto. axis 2	0.05767	**1.17859**	-0.14415	0.06595
Phyto. axis 1	0.29086	-0.31816	**1.46712**	0.54184
Organic	-0.30296	0.15051	0.52033	**1.44407**

Figure 6.14 b: The rotated standardized discriminant function coefficients for analysis 8.

FCN.	EIGEN VALUE	% OF VARIANCE	CUM %	CANON. CORR	AFTER FCN.	WILKS' LAMBDA	CHI SQU	DF	SIG
					0	0.0020	123.995	20	0.0000
1	25.4680	78.24	78.24	0.9809	1	0.0537	58.476	12	0.0000
2	5.0960	15.66	93.90	0.9143	2	0.3275	22.324	6	0.0011
3	1.9533	6.00	99.90	0.8133	3	0.9673	0.665	2	0.7172
4	0.0338	0.10	100.00	0.1808					

Figure 6.15 a: The canonical discriminant functions for analysis 11.

	FUNCTION 1	FUNCTION 2	FUNCTION 3	FUNCTION 4
pH	**1.12141**	-0.14381	-0.14580	-0.10605
Phosphorus	-0.29809	**1.24599**	0.17832	0.37894
Phyto. axis 2	-0.23647	0.12684	**1.20016**	-0.19533
Phyto. axis 1	-0.23456	0.41000	-0.29569	**1.28382**

Figure 6.15 b: The rotated standardized discriminant function coefficients for analysis 11.

Analysis No.	Fig. No.	Tab. No.	Discriminating Variables															Misclassified Samples
			Moll. axis 1	Moll. axis 2	Phyto axis 1	Phyto axis 2	Phyto axis 3	P.S. mode	P.S. IQR	pH	Phos.	Org.	Mag sus.	Seed den.	Moll den.	Worm den.	Phyto den.	
13					*	-	-	-	-	*	*	*	-					122, 156
14					-	*	-	-	-	*	*	*	-					122
15					*	*	-	-	-	*	*	*	-					122
16					*	-	-	-	-	-	*	*	*					122
17					-	*	-	-	-	-	*	*	*					122
18					*	*	-	-	-	-	*	*	*					122, 123
19					*	-	-	-	-	*	*	-	*					122, 159
20					-	*	-	-	-	*	*	-	*					122, 142
21					*	*	-	-	-	*	*	-	*					122
22					*	-	-	-	*	-	*	*	-					122
23					-	*	-	-	*	-	*	*	-					122, 130
24					*	*	-	-	*	-	*	*	-					-
25					*	-	-	-	*	*	*	-	-					122
26					-	*	-	-	*	*	*	-	-					122
27					*	*	-	-	*	*	*	-	-					122
28					*	-	-	*	-	*	*	-	-					122
29					-	*	-	*	-	*	*	-	-					122
30					*	*	-	*	-	*	*	-	-					122
31					*	-	-	*	-	-	*	*	-					122, 137
32					-	*	-	*	-	-	*	*	-					122, 130
33					*	*	-	*	-	-	*	*	-					122, 123

Table 6.16: Discriminant analyses using the scores on the first or second phytolith correspondence axes and any three of the physical and chemical soil properties.

Analysis No.	Fig. No.	Tab. No.	Discriminating Variables															Misclassified Samples
			Moll. axis 1	Moll. axis 2	Phyto. axis 1	Phyto. axis 2	Phyto. axis 3	P.S. mode	P.S. IQR	pH	Phos.	Org.	Mag. sus.	Seed den.	Moll. den.	Worm den.	Phyto. den.	
34	6.36	6.18						*	*	*	*	*	*					122, 130
35								-	*	*	*	*	*					122, 130
36								*	-	*	*	*	*					122, 130
37								-	-	*	*	*	*					122, 130
38	6.37	6.19						-	-	*	*	-	*					122, 130
39								-	-	*	*	-	-					122, 130, 142
40								*	-	*	*	-	-					122, 130

Table 6.17: Discriminant analyses using physical and chemical soil properties only.

FCN.	EIGEN VALUE	% OF VARIANCE	CUM %	CANON. CORR	AFTER FCN.	WILKS' LAMBDA	CHI SQU	DF	SIG
					0	0.0019	119.077	30	0.0000
1	29.2930	79.03	79.03	0.9834	1	0.0575	54.270	20	0.0001
2	6.8265	18.42	97.45	0.9339	2	0.4499	15.177	12	0.2319
3	0.4546	1.23	98.68	0.5590	3	0.6544	8.057	6	0.2339
4	0.3899	1.05	99.73	0.5296	4	0.9095	1.802	2	0.4062
5	0.0995	0.27	100.00	0.3008					

Table 6.18 a: The canonical discriminant functions for analysis 34.

	FUNCTION 1	FUNCTION 2	FUNCTION 3	FUNCTION 4	FUNCTION 5
pH	**1.18893**	0.40990	-0.05789	0.00794	0.07387
Organic	0.37596	**2.36123**	0.00080	-0.20067	-0.20950
Phosphorus	-0.31298	**-1.64311**	**0.98022**	0.32656	0.25222
Mag. Sus.	0.04116	**0.97584**	0.19774	**1.08591**	0.52640
P.S. IQR	-0.23862	**1.12740**	0.24980	-0.13632	**-1.44719**
P.S. Mode	-0.03517	0.08894	-0.04113	0.26788	**1.07315**

Table 6.18 b: The rotated standardized discriminant function coefficients for analysis 34.

FCN.	EIGEN VALUE	% OF VARIANCE	CUM %	CANON. CORR	AFTER FCN.	WILKS' LAMBDA	CHI SQU	DF	SIG
					0	0.0132	88.643	15	0.0000
1	23.4903	93.56	93.56	0.9794	1	0.3244	23.078	8	0.0033
2	1.2400	4.94	98.50	0.7440	2	0.7267	6.545	3	0.0879
3	0.3761	1.5	100.00	0.5228					

Table 6.19 a: The canonical discriminant functions for analysis 38.

	FUNCTION 1	FUNCTION 2	FUNCTION 3
pH	**1.00913**	-0.02605	0.01715
Phosphorus	-0.0880	**1.01522**	0.10755
Mag. Sus.	0.04699	0.08340	**1.01588**

Table 6.19b: The rotated standardized discriminant function coefficients for analysis 38.

Analysis No.	Fig. No.	Tab. No.	Discriminating Variables															Misclassified Samples
			Moll. axis 1	Moll. axis 2	Phyto. axis 1	Phyto. axis 2	Phyto. axis 3	P.S. mode	P.S. IQR	pH	Phos.	Org.	Mag. sus.	Seed den.	Moll. den.	Worm den.	Phyto. den.	
41	6.38	6.21	*	*														-
42			*															-

Table 6.20: Discriminant analyses using the scores on the mollusc correspondence axes.

FCN.	EIGEN VALUE	% OF VARIANCE	CUM %	CANON. CORR	AFTER FCN.	WILKS' LAMBDA	CHI SQU	DF	SIG
					0	0.1900852	13.282	2	
1	4.26080	100.00	100.00	0.8999527					

Table 6.21a: The canonical discriminant functions for analysis 41.

	FUNCTION 1
Moll axis 1	**1.15257**
Moll axis 2	0.17136

Table 6.21 b: The rotated standardized discriminant function coefficients for analysis 41.

FCN.	EIGEN VALUE	% OF VARIANCE	CUM %	CANON. CORR	AFTER FCN.	WILKS' LAMBDA	CHI SQU	DF	SIG
					0	0.0000	146.323	50	0.0000
1	79.3852	71.29	71.29	0.9983	1	0.0023	84.907	36	0.0000
2	26.4485	23.75	95.04	0.9816	2	0.0638	38.535	24	0.0305
3	3.2677	2.93	97.97	0.8750	3	0.2721	18.220	14	0.1969
4	2.0531	184	99.82	0.8200	4	0.8309	2.594	6	0.8578
5	0.2035	0.18	100.00	0.4112					

Table 6.23a: The canonical discriminant functions for analysis 43.

	FUNCTION 1	FUNCTION 2	FUNCTION 3	FUNCTION 4	FUNCTION 5
pH	**2.13175**	-0.67932	0.05117	-0.03618	-0.25798
Phyto. Den.	**1.74709**	0.54344	-0.28238	0.16689	-0.23400
Organic	-0.09143	**-2.94976**	0.20845	-0.21720	0.30931
Phosphorus	**-0.84068**	**2.04044**	**0.87618**	0.06562	0.23508
Mag. Sus.	-0.57527	**1.26460**	0.21315	-0.46471	0.07043
Moll. Den.	-0.31561	0.58222	-0.16101	0.6755	0.20571
Seed Den.	0.11735	0.73213	-0.00238	**1.50021**	0.15773
Worm Den.	0.20860	0.51954	0.17775	-0.85789	0.46314
P.S. IQR	-0.56335	-0.73180	0.04834	0.07492	**1.64680**
P.S. Mode	0.35577	0.09074	-0.11491	-0.15879	-0.52620

Table 6.23 b: The rotated standardized discriminant function coefficients for analysis 43.

Analysis No.	Fig. No.	Tab. No.	Discriminating Variables															Misclassified Samples
			Moll. axis 1	Moll. axis 2	Phyto. axis 1	Phyto. axis 2	Phyto. axis 3	P.S. mode	P.S IQR	pH	Phos.	Org.	Mag. sus.	Seed den.	Moll. den.	Worm den.	Phyto. den.	
43	6.38	6.23						*	*	*	*	*	*	*	*	*	*	-
44								-	-	*	*	*	*	*	*	*	*	-
45								-	*	*	*	-	-	*	*	*	*	-
46								-	-	*	*	*	-	*	*	*	*	156
47								-	-	*	*	-	*	*	*	*	*	159
48								-	*	*	-	-	*	*	*	*	*	130
49								-	-	*	-	*	*	*	*	*	*	130
50								-	*	*	-	*	-	*	*	*	*	130
51								-	-	-	*	*	*	*	*	*	*	130, 159
52								-	*	-	*	*	-	*	*	*	*	123, 130
53								-	*	*	*	-	-	-	*	-	-	122

Table 6.22: Discriminant analyses using the densities of plant remains, molluscs, worm granules and phytoliths with the physical and chemical soil properties.

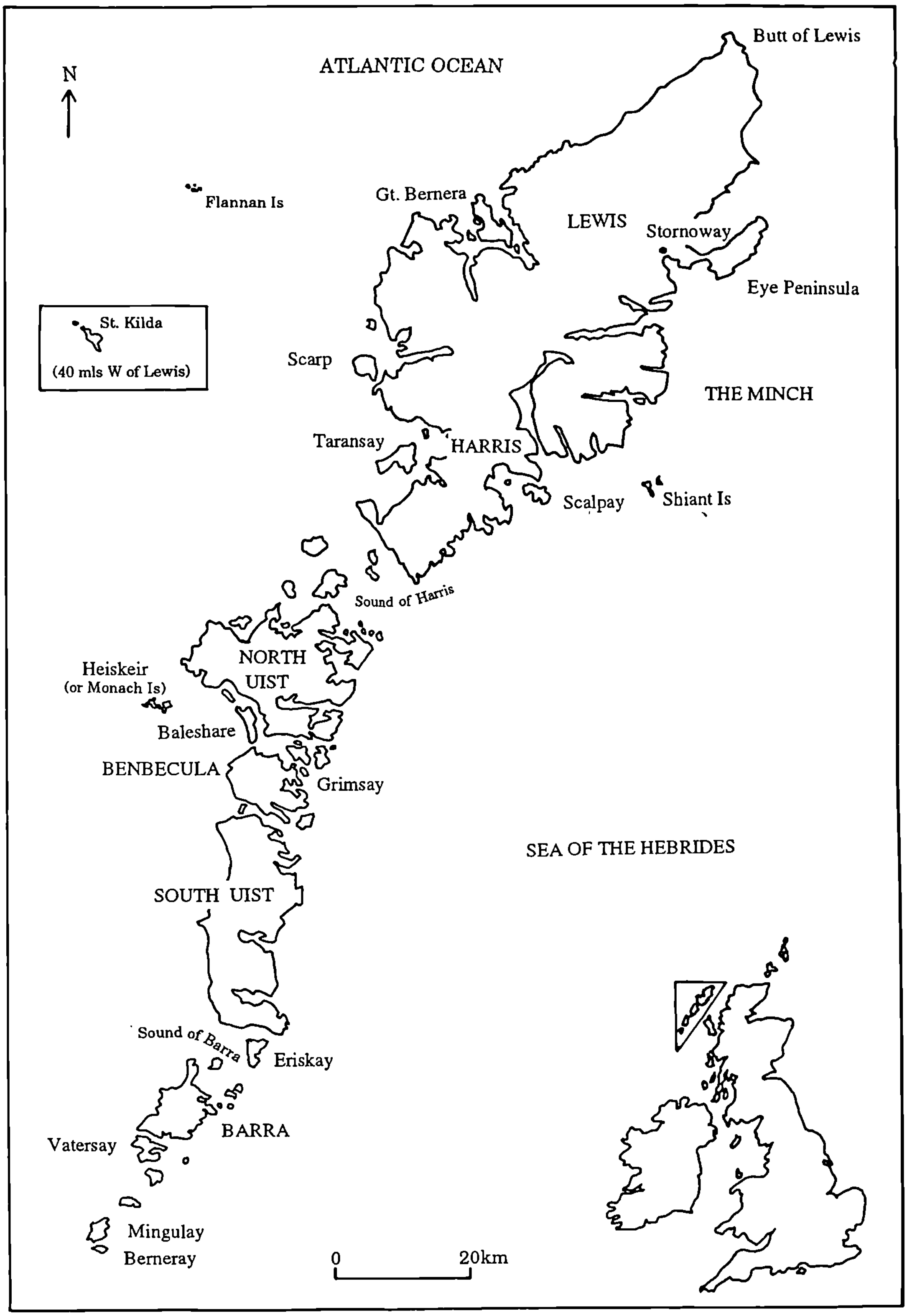


Figure 2.1: Location map for the Outer Hebrides.

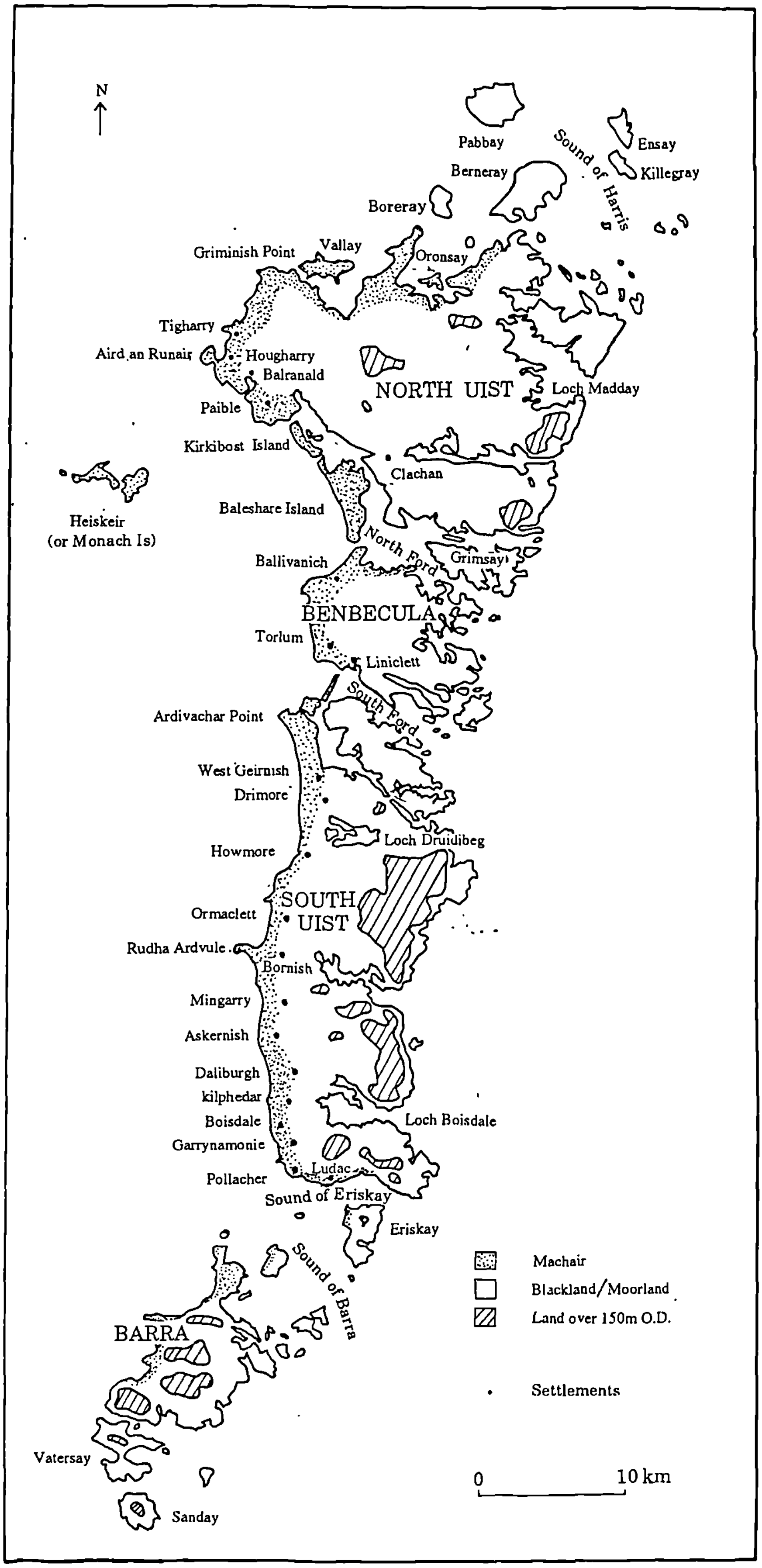


Figure 2.2: Map showing the three broad zones of soil type in the southern isles of the Outer Hebrides.

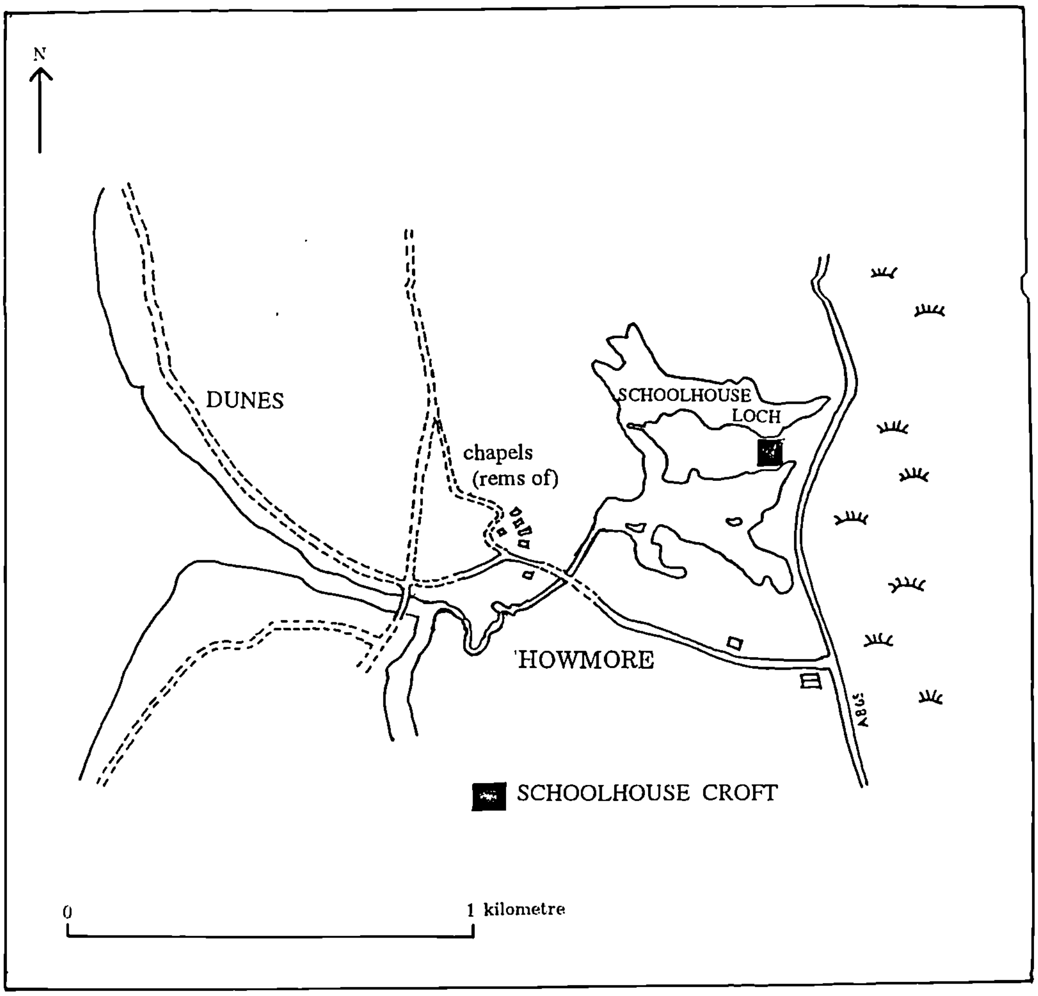


Figure 3.1: Location map of Schoolhouse Croft, Howmore, South Uist.

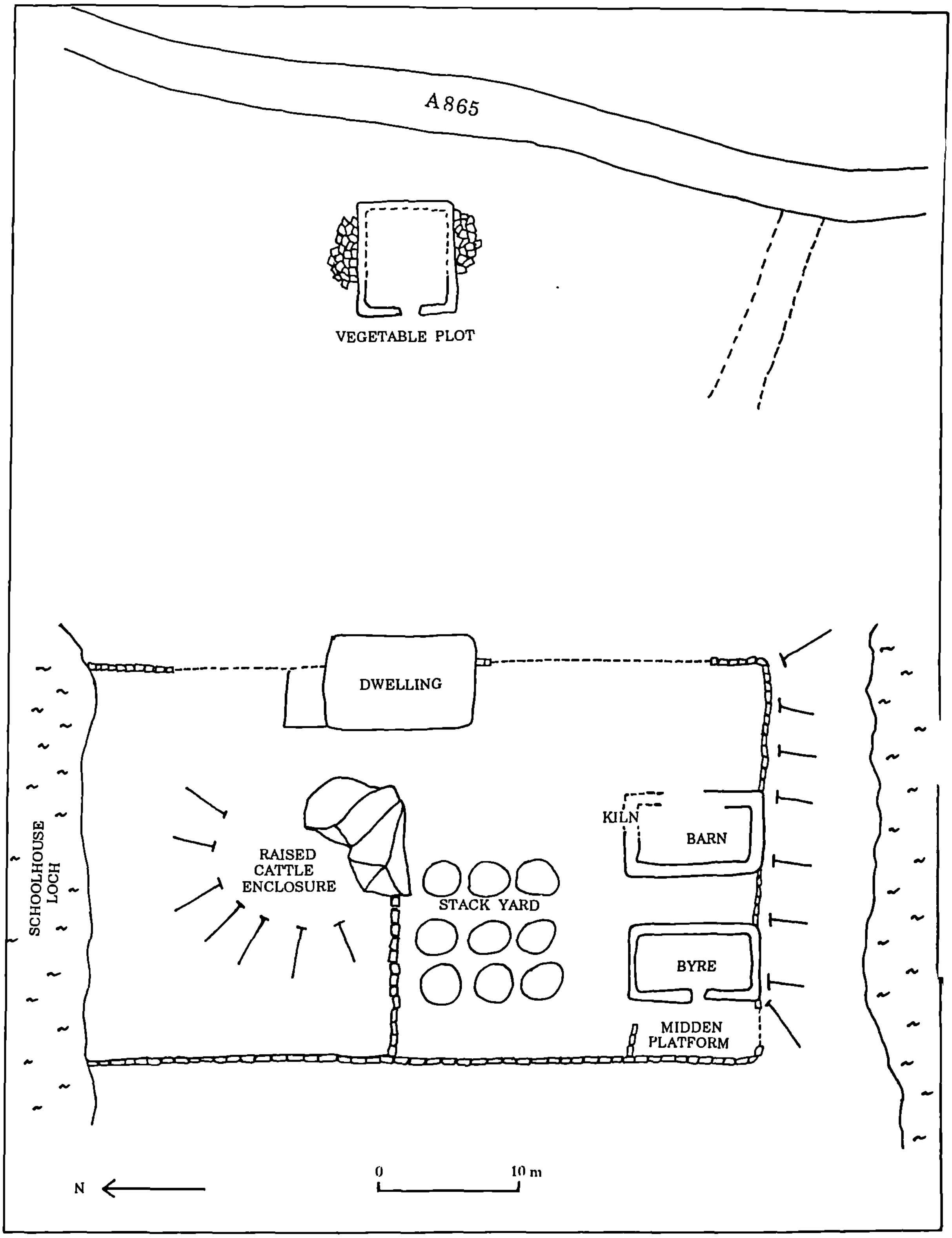


Figure 3.2: Plan of Schoolhouse Croft.

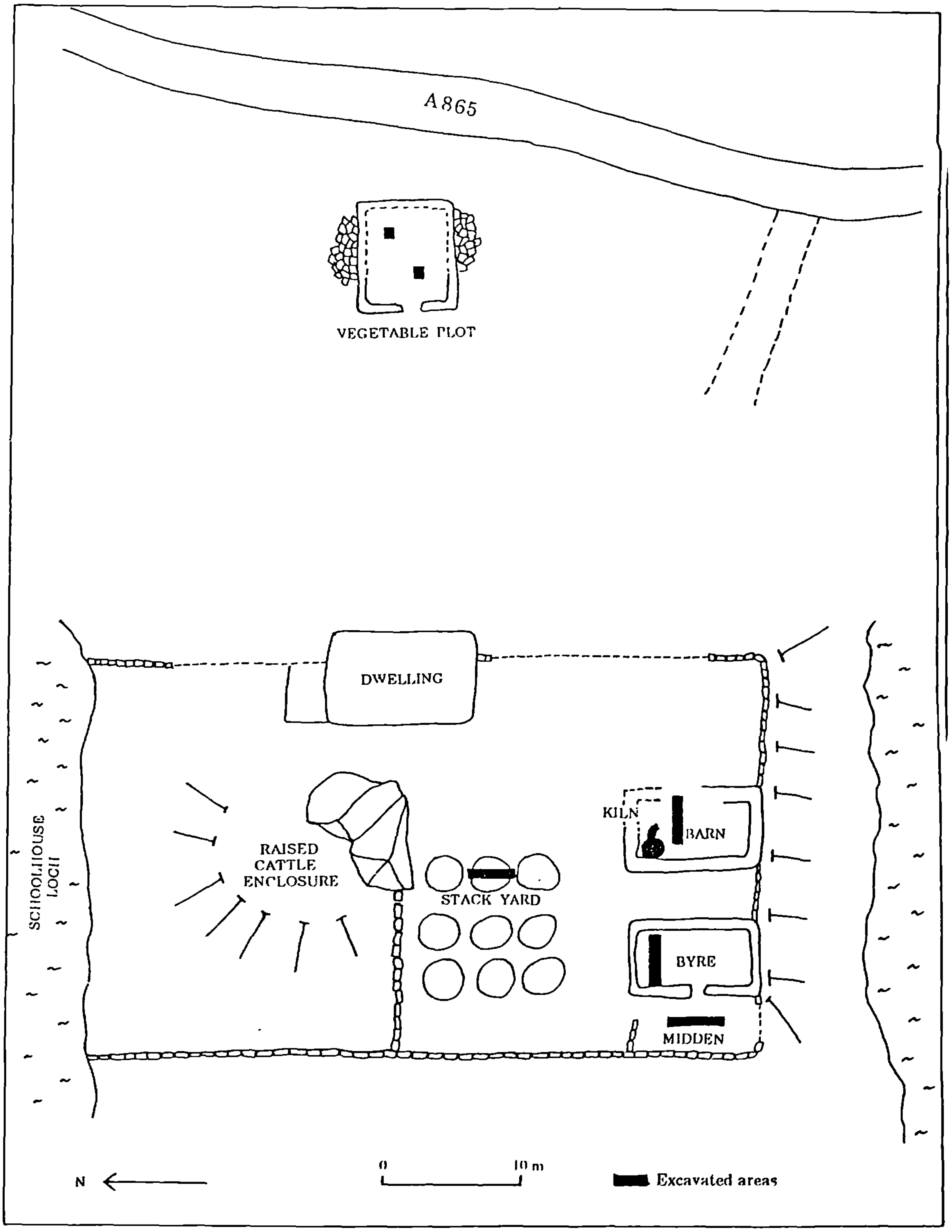
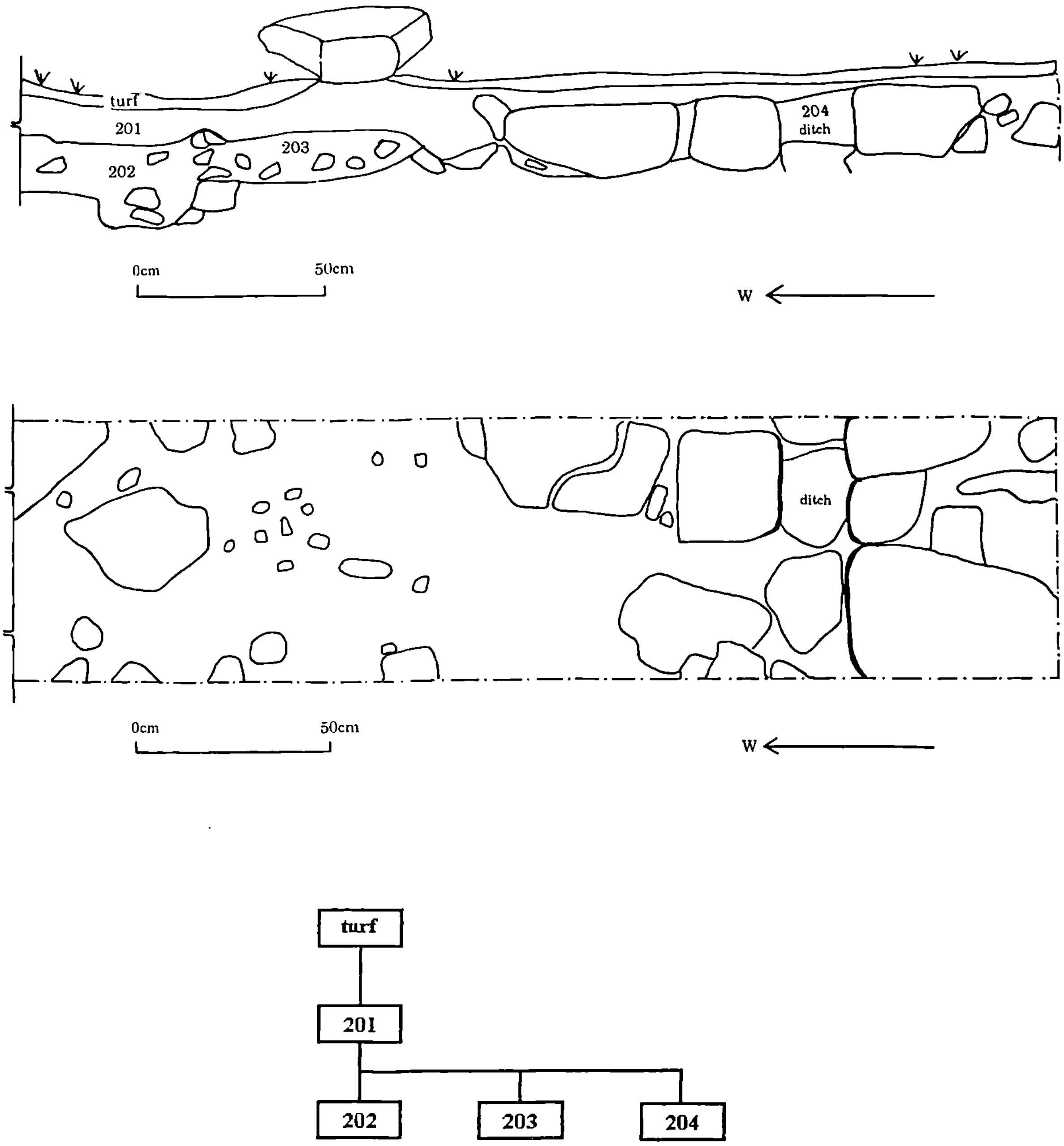
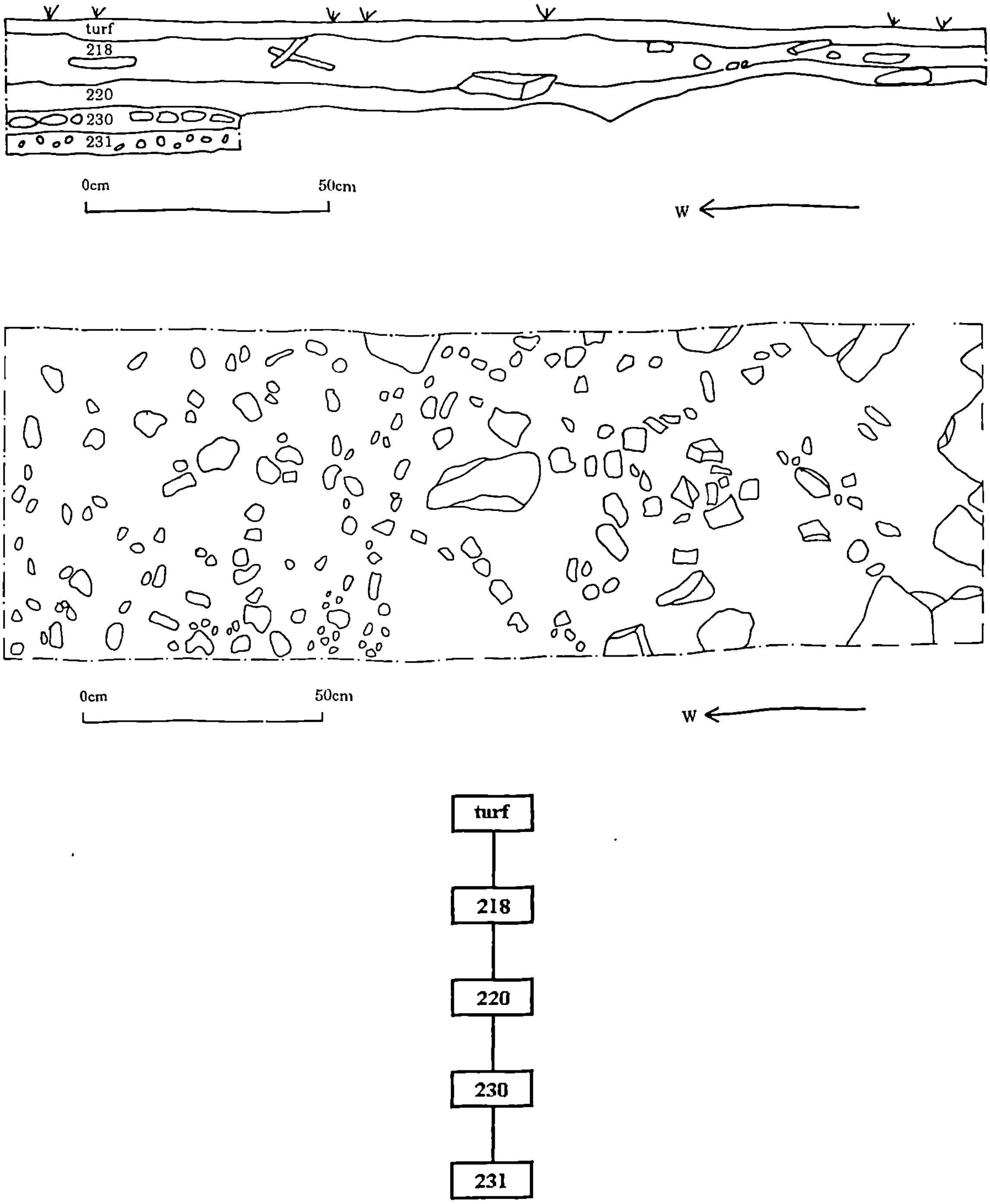


Figure 3.3: Location of excavation trenches at Schoolhouse Croft



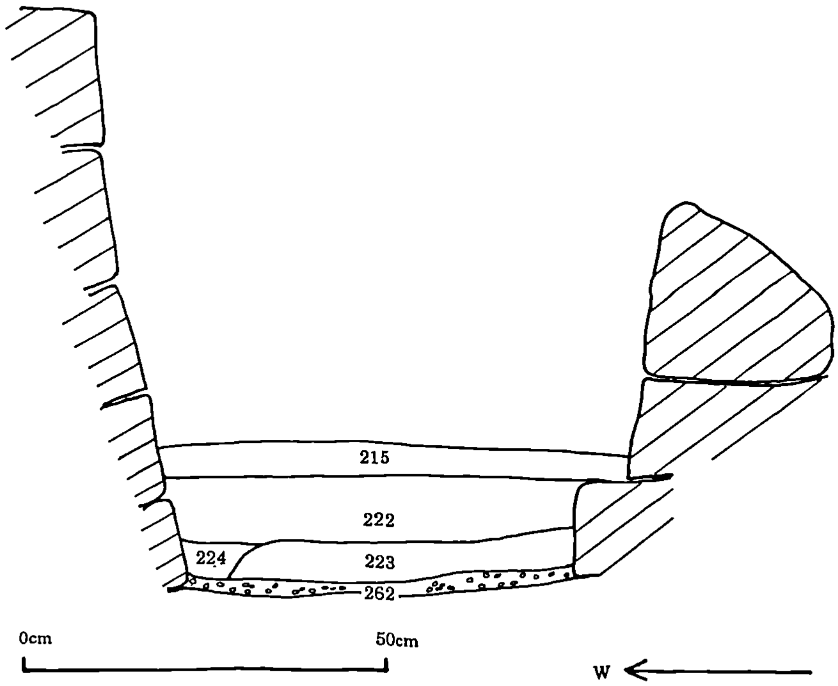
Turf horizon
201 sandy loamy, humic layer
202 stoney and gravelly clay layer
203 stoney and more gravelly reddish clay layer
204 dark brown loamy layer, high humic content

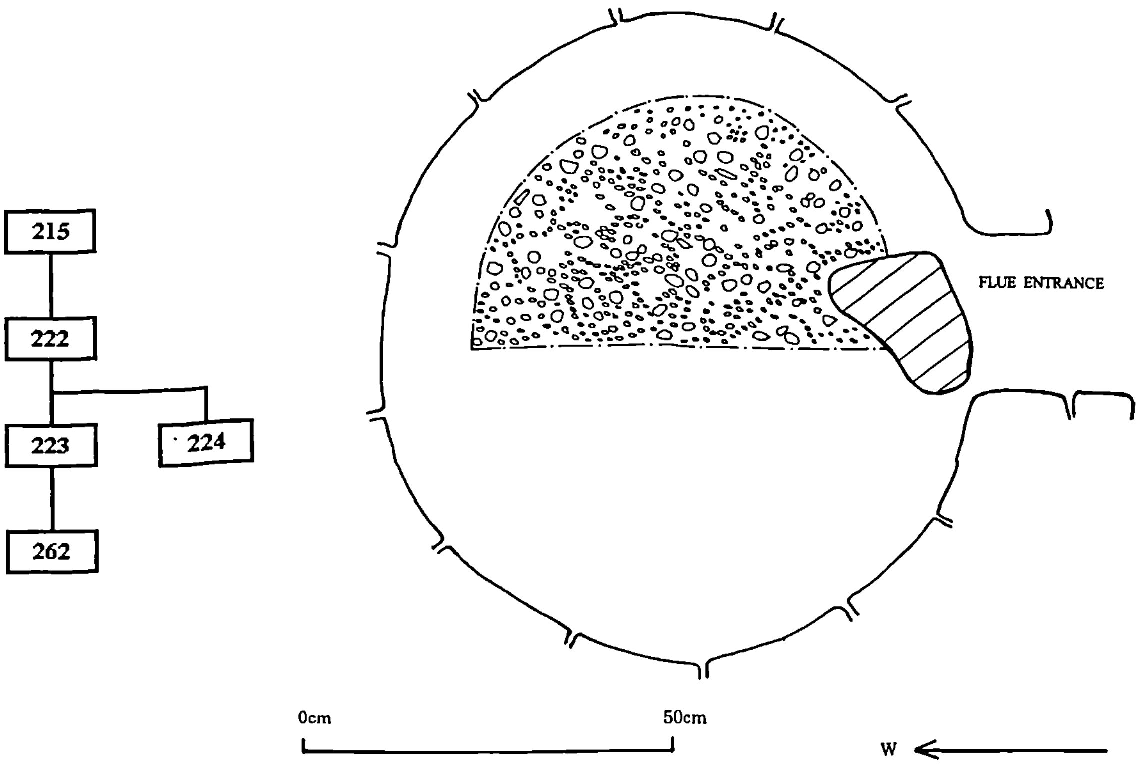
Figure 3.4: The section, plan and context details within the byre.



Turf horizon
218 very dark brown humic layer, contained rotten wood and visible plant material
220 humic layer, with some sandy clay
230 cobbled floor set within compacted sandy, clay matrix
231 orange sandy, clay and gravel compacted matrix, contained medium and large stones

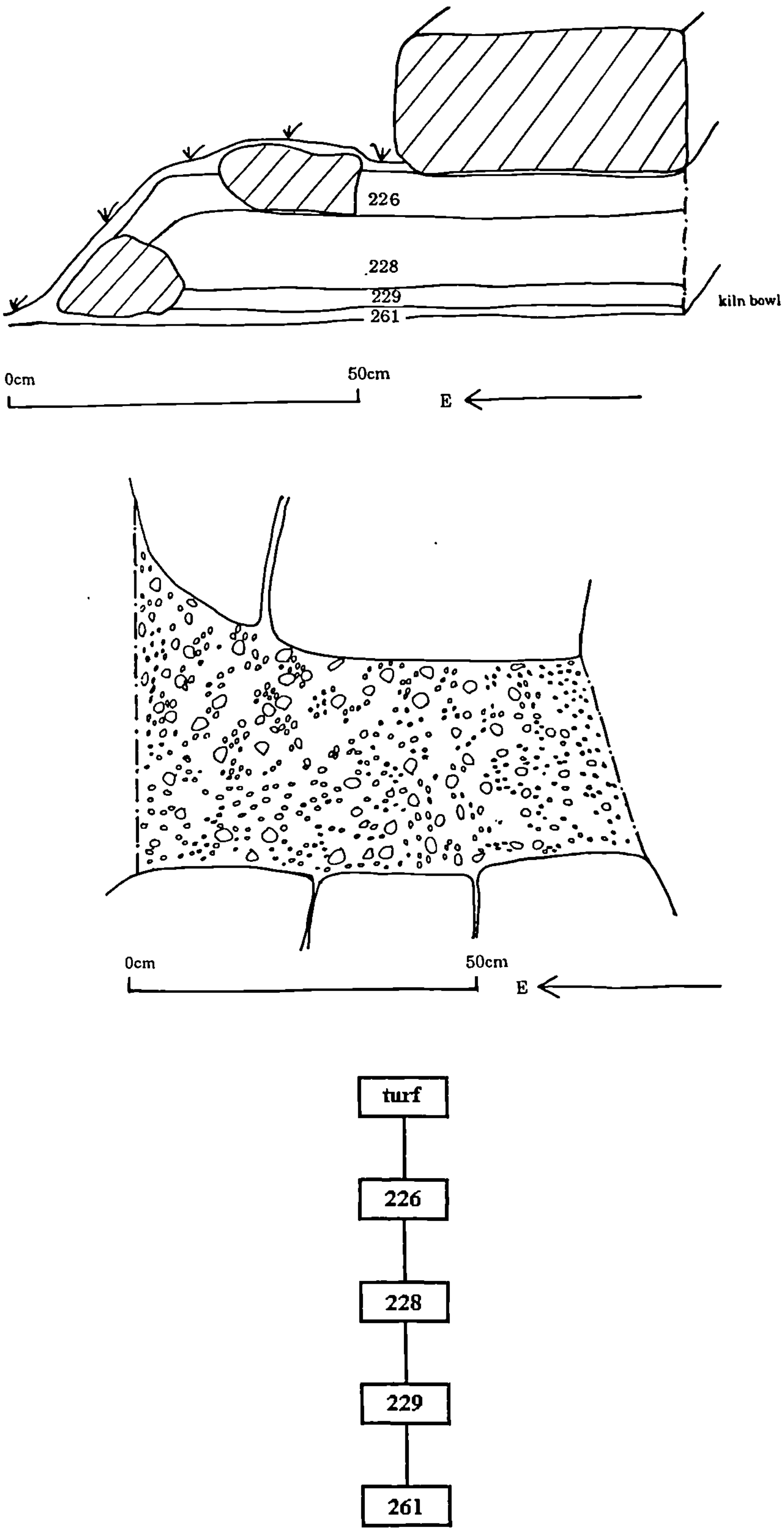
Figure 3.5: The section, plan and context details within the barn.





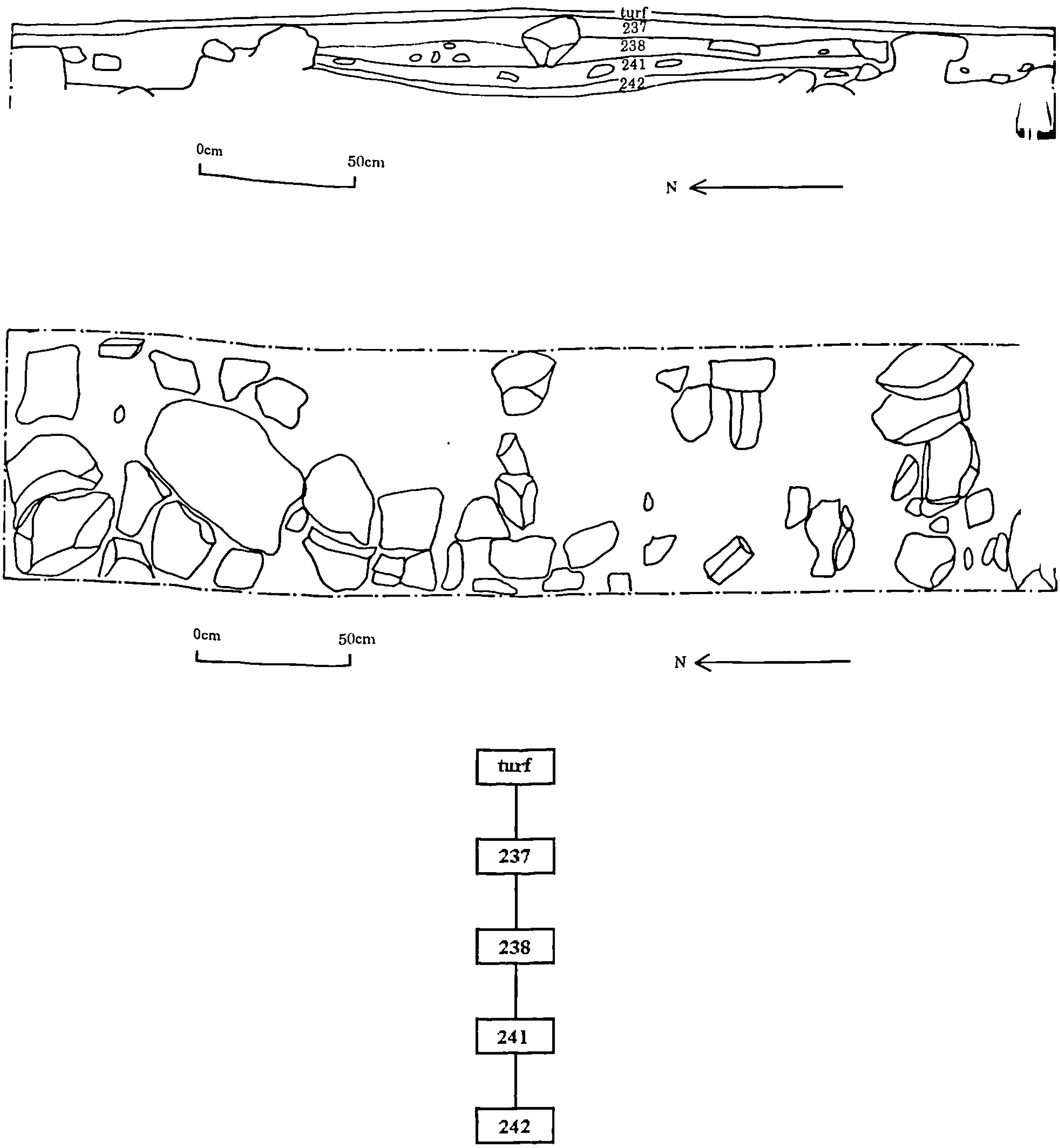
215 surface horizon contained large proportion of intrusive rubbish
222 dark humic soil, contained rotten wood
223 coarse gravel in pale brown sandy clay matrix
224 dark humic sandy soil, packing junction of wall and floor, abutting and surrounding 223
262 small stones/cobbles set within compacted sandy clay matrix

Figure 3.6: The section, plan and context details within the kiln bowl.



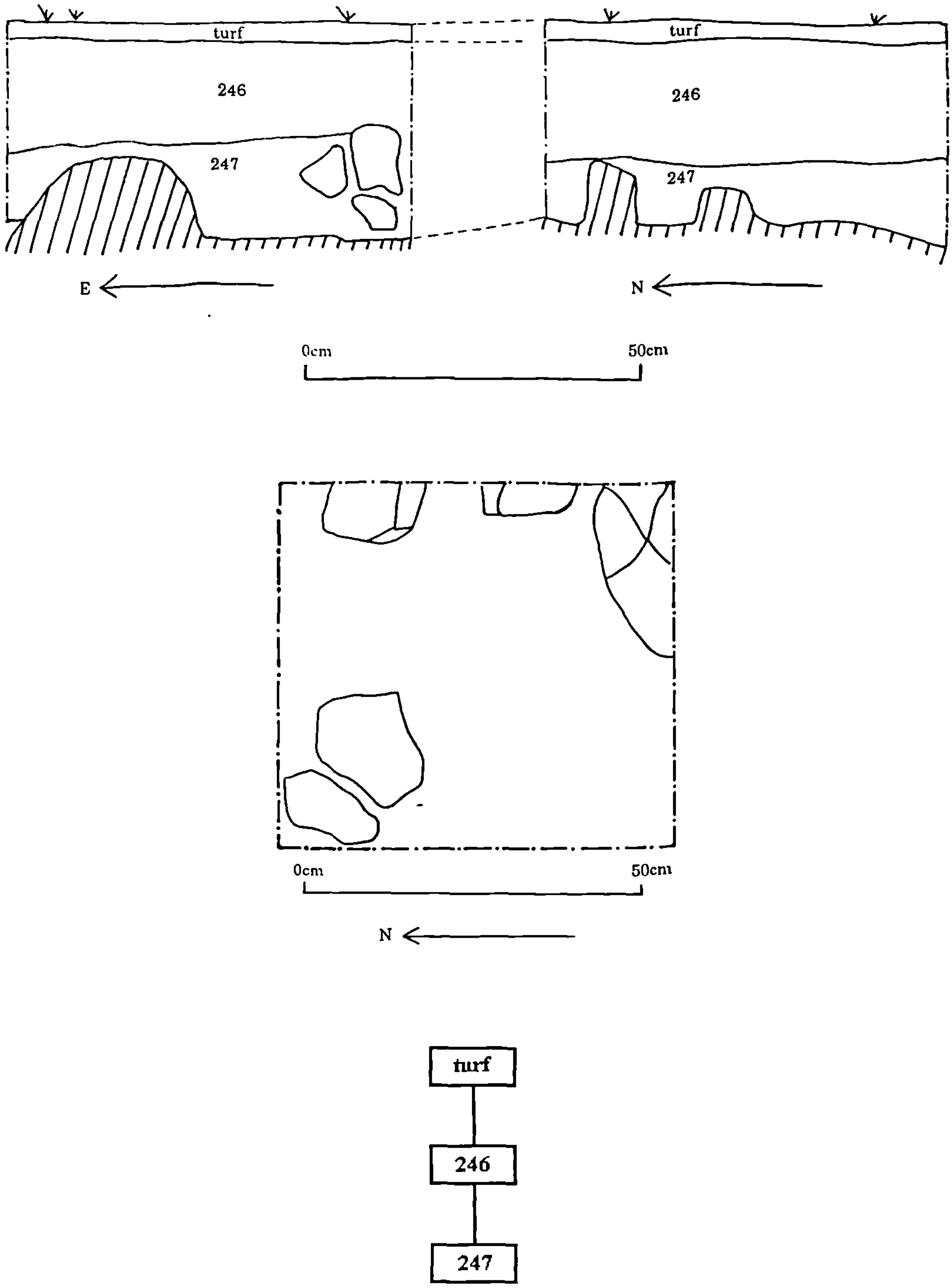
Turf horizon
226 dark humic soil, contained intrusive rubbish
228 dark humic soil, contained rotten wood and plant material
229 orange coarse gravel layer, in sandy clay matrix, like 223
261 small stones/cobbles set within orange sandy gravel and clay matrix

Figure 3.7: The section, plan and context details within the kiln flue.



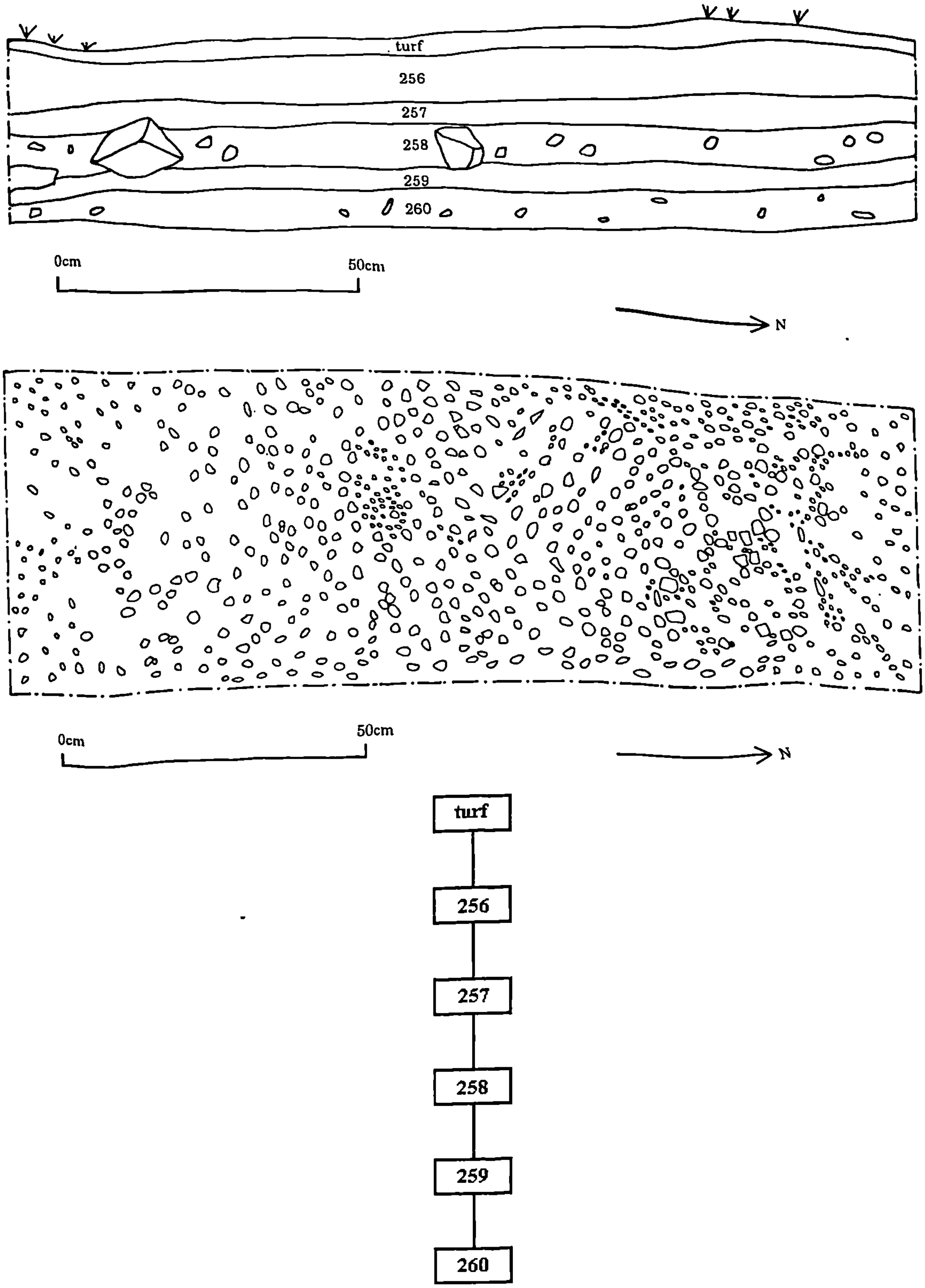
Turf horizon
237 dark brown humic sandy soil, contained straw/rooty material
238 humic sandy gravelly soil, contained medium and large stones
241 sandy gravelly layer contained larger stones
242 orange sandy clay and gravelly layer

Figure 3.8: The section, plan and context details within the stack base.



Turf horizon
246 dark, sandy, loamy and humic soil
247 dark, humic soil, contained large stones.
Forms packing around irregular bedrock boulders

Figure 3.9: The section, plan and context details within the vegetable plot.



Turf Horizon
256 dark humic soil
257 dark humic soil, contained clinker
258 dark humic gravelly layer, contained some orange clay and large stones
259 dark humic soil
260 orange, fine gravelly layer, contained some stones

Figure 3.10: The section, plan and context details within the midden.

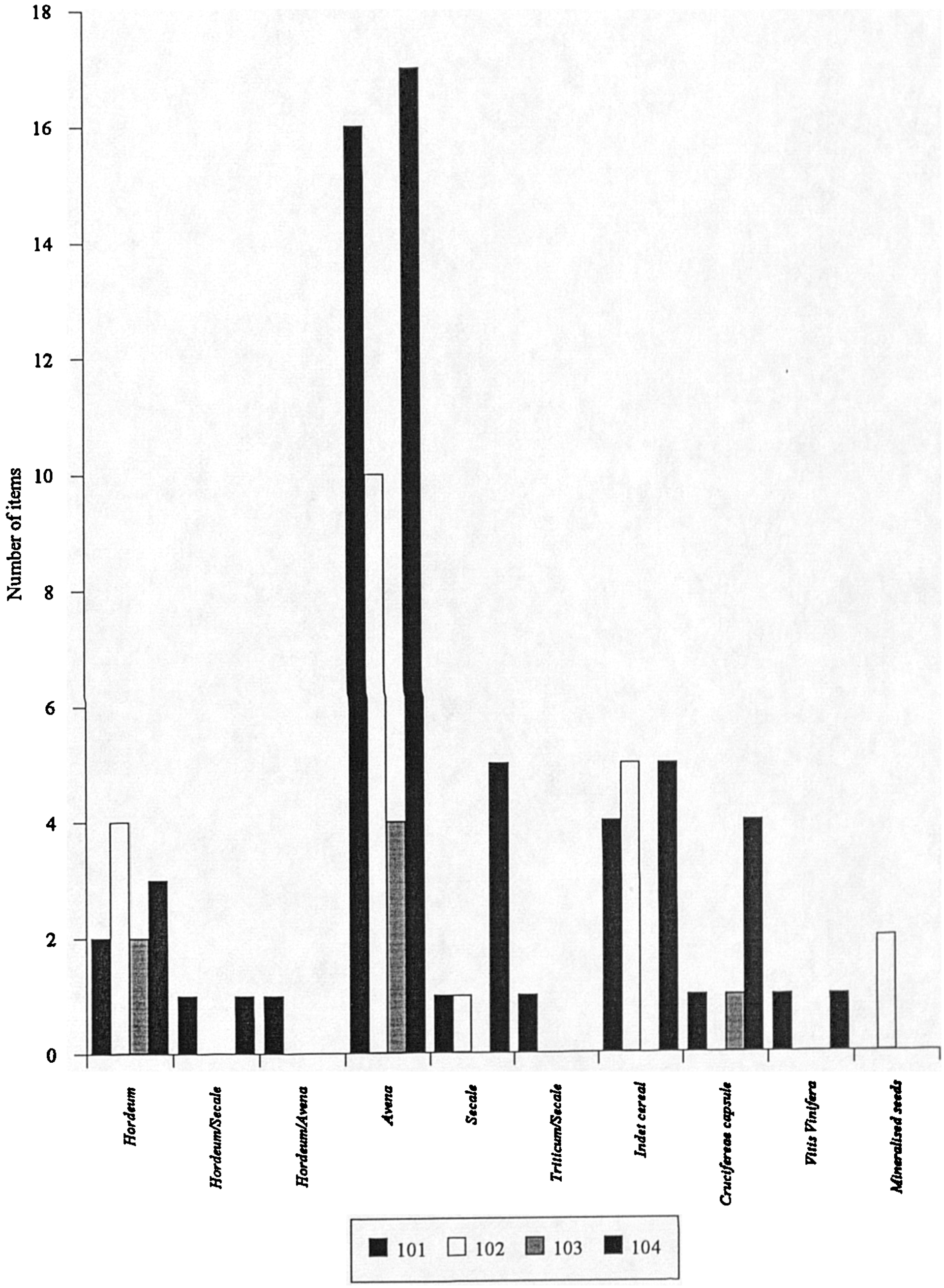
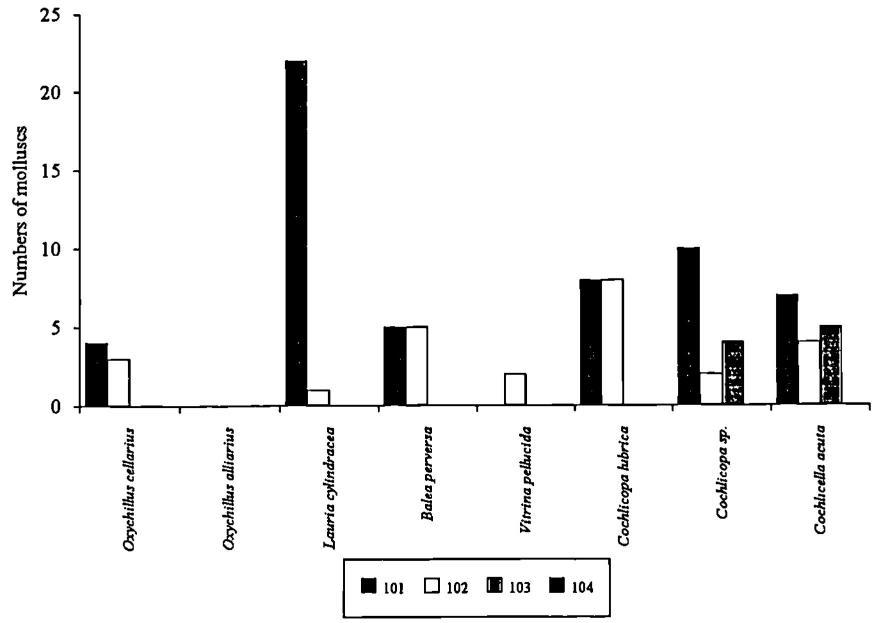


Figure 6.1: Absolute frequency of plant remains from the byre.

The Byre



The Kiln

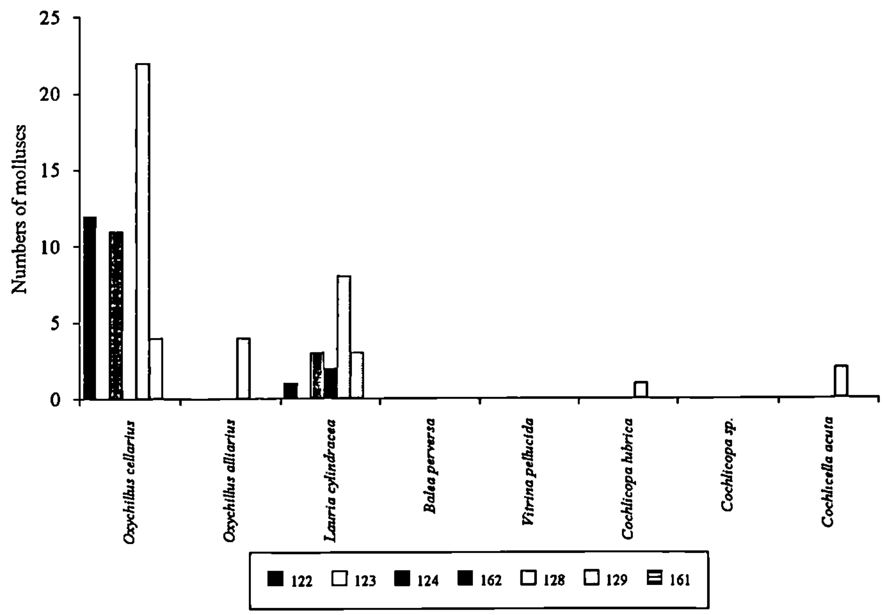
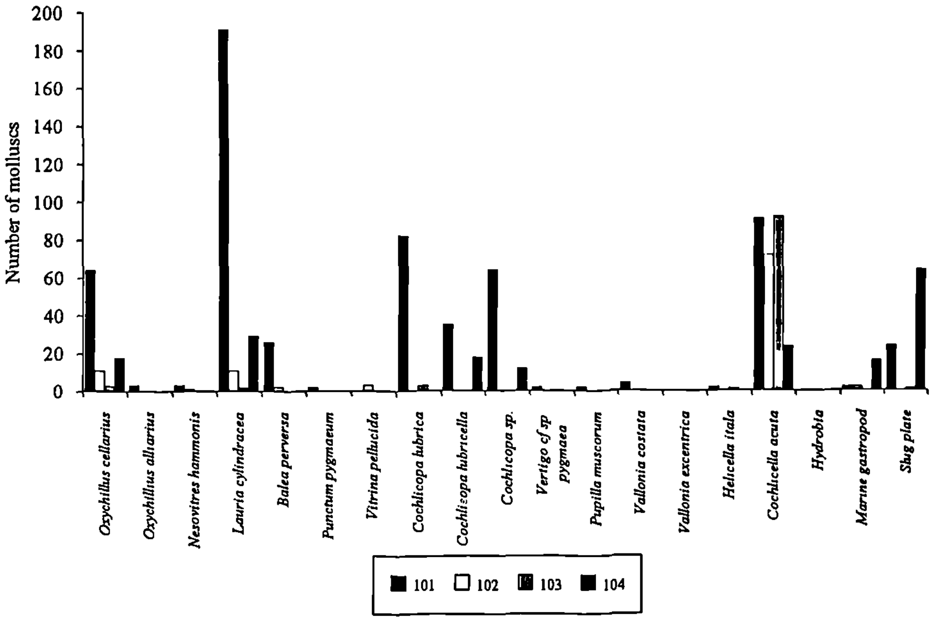


Figure 6.2: Absolute frequency of mollscan remains from the two litre samples.

The Byre



The Kiln

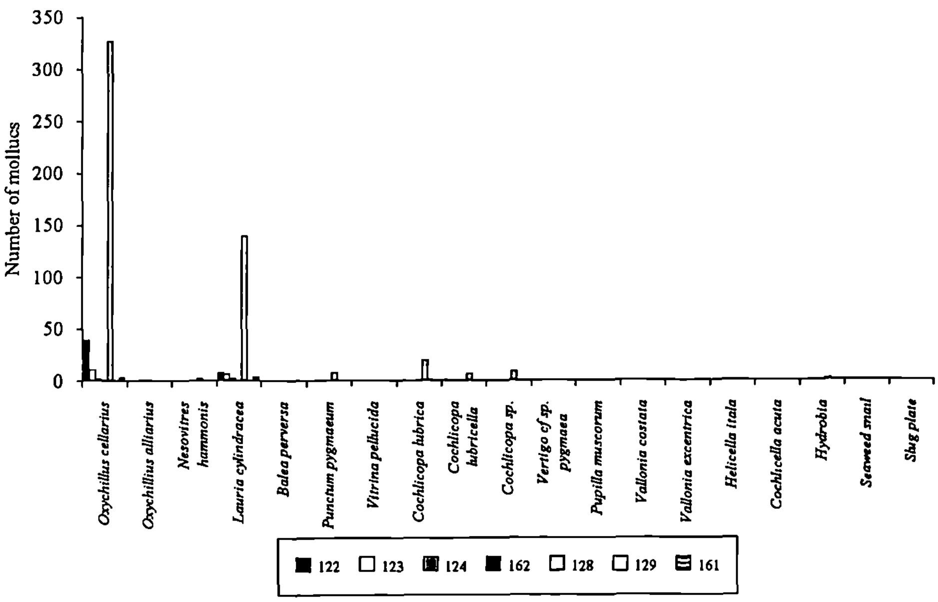


Figure 6.3: Absolute frequency of molluscan remains from the bulk samples.

CL	*Cochlicopa lubrica*
CLA	*Cochlicopa lubricella*
CSP	*Cochlicopa sp.*
CA	*Cochlicella acuta*
LC	*Lauria cylindracea*
OA	*Oxychilus alliarius*
OC	*Oxychilus cellarius*
VE	*Vallonia excentrica*
VC	*Vallonia costata*
BP	*Balea perversa*
MG	*marine gastropod*
HI	*Hellicella italia*
NH	*Nesovitrea hammonis*
V	*Vertigo cf pygmaea*
PM	*Pupilla muscorum*
PP	*Punctum pygmaea*
VP	*Vitrina pellucida*
SP	slug plate

List of abbreviations used for molluscs.

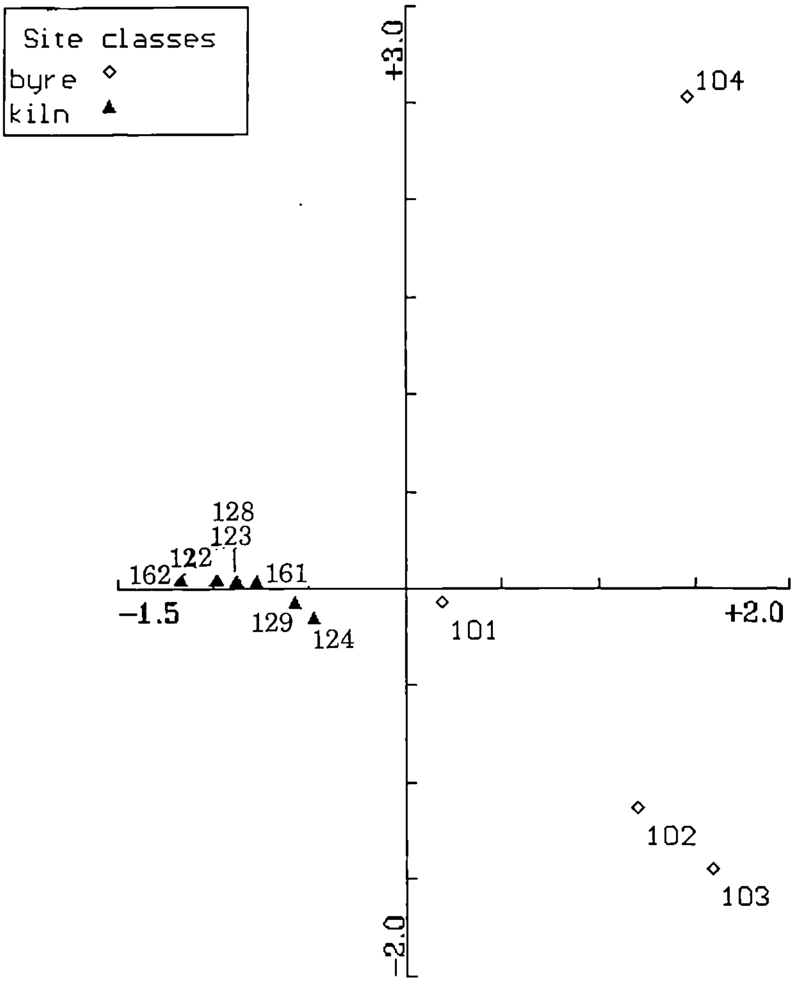


Figure 6.4a: Correspondence analysis using the molluscan remains from bulk samples (sites plotted on axes 1 and 2).

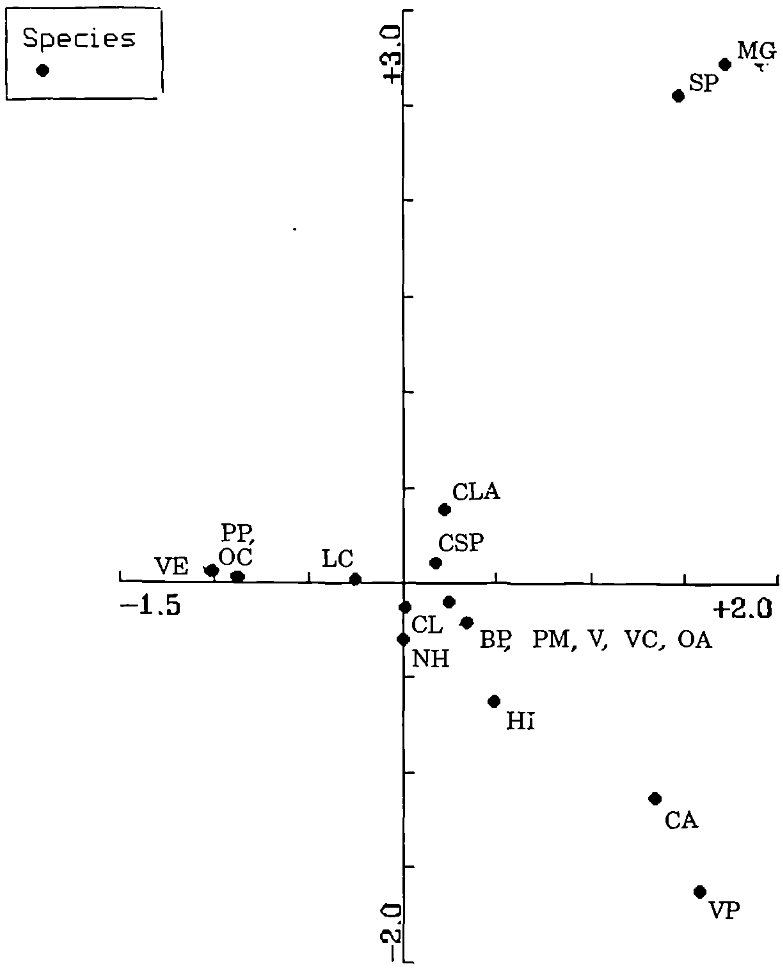


Figure 6.4b: Correspondence analysis using the molluscan remains from bulk samples (species plotted on axes 1 and 2).

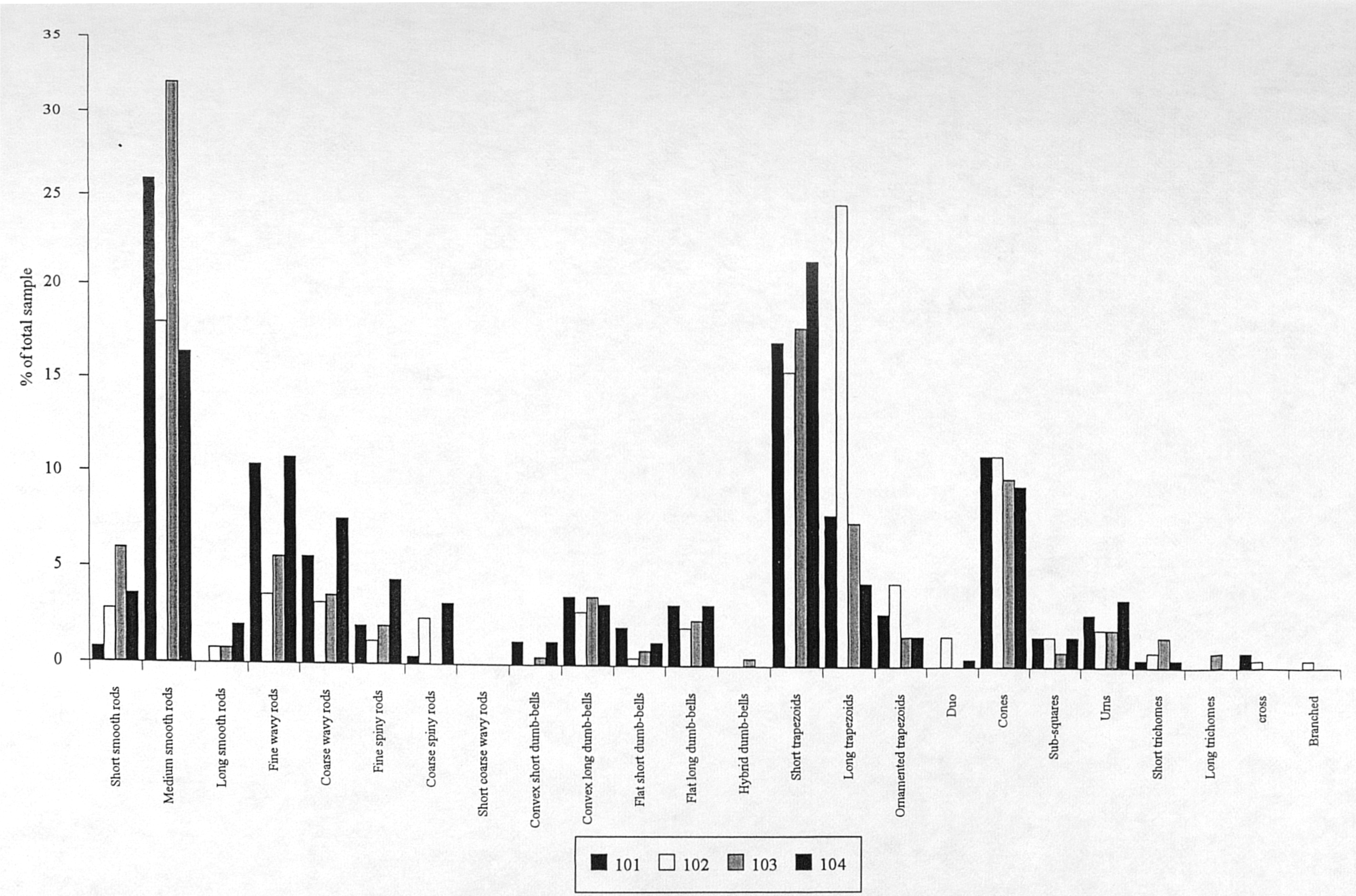


Figure 6.5: The relative distribution of phytolith morphotypes in the byre.

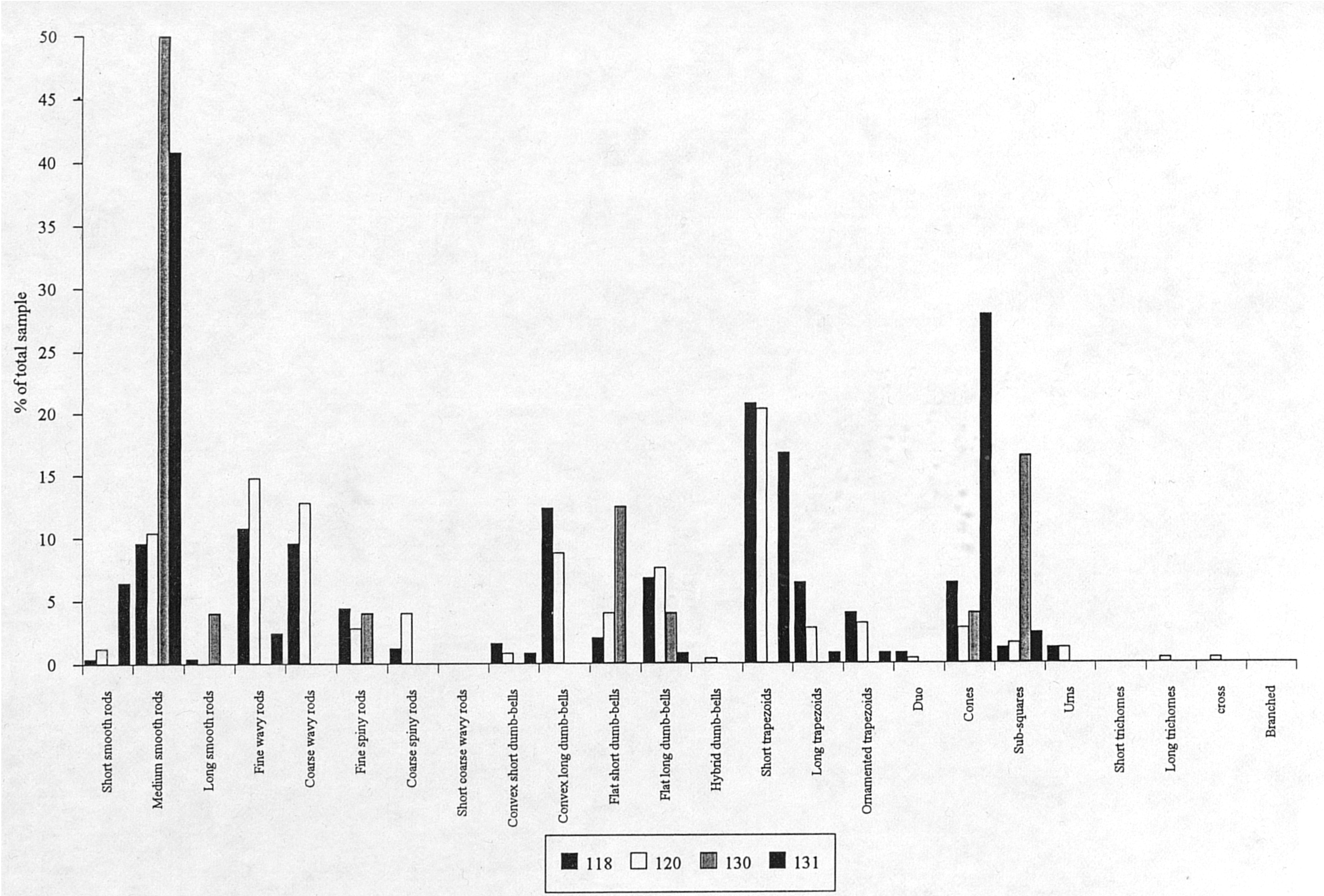


Figure 6.6: The relative distribution of phytolith morphotypes in the barn.

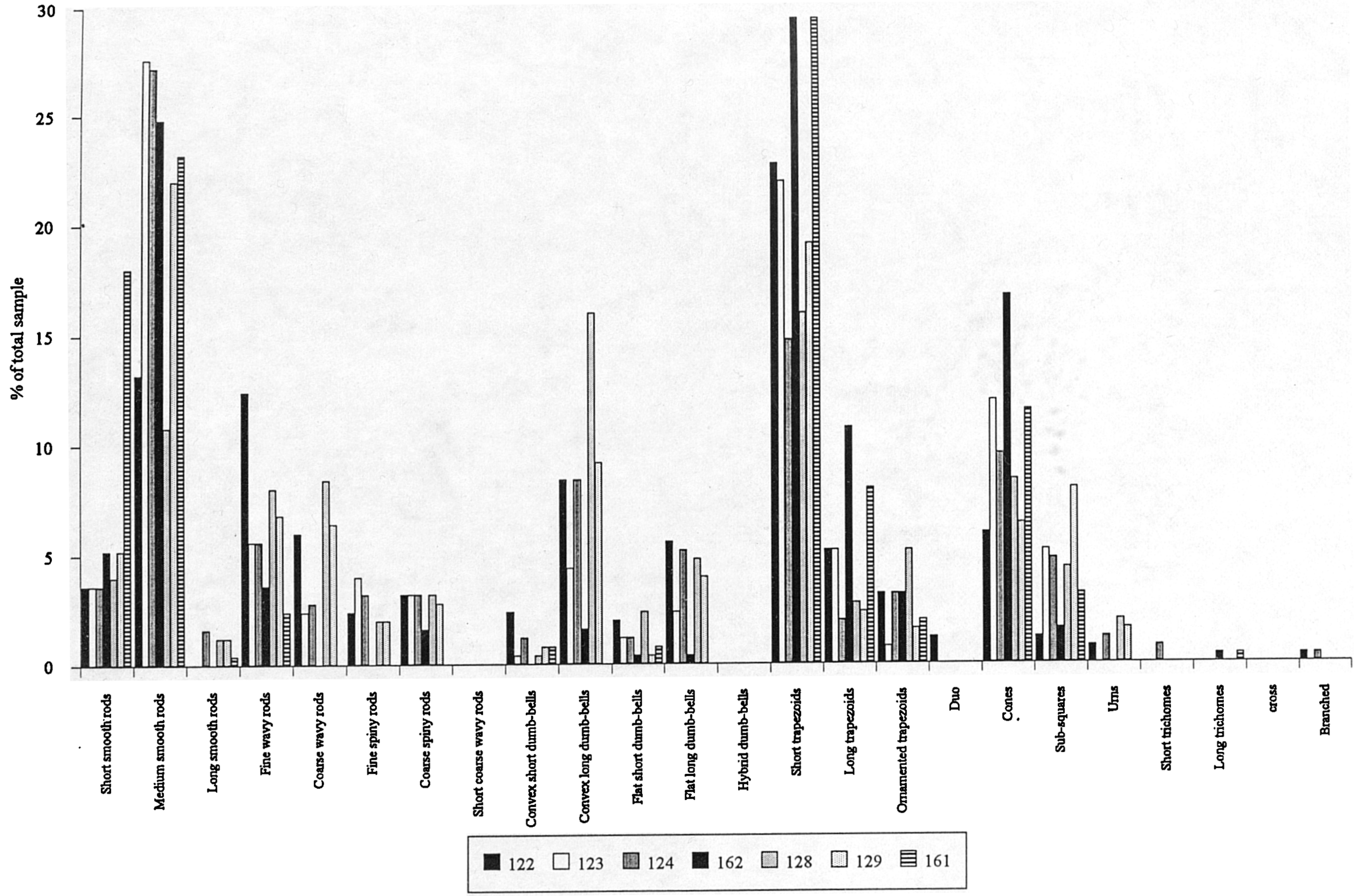


Figure 6.7: The relative distribution of phytolith morphotypes in the kiln.

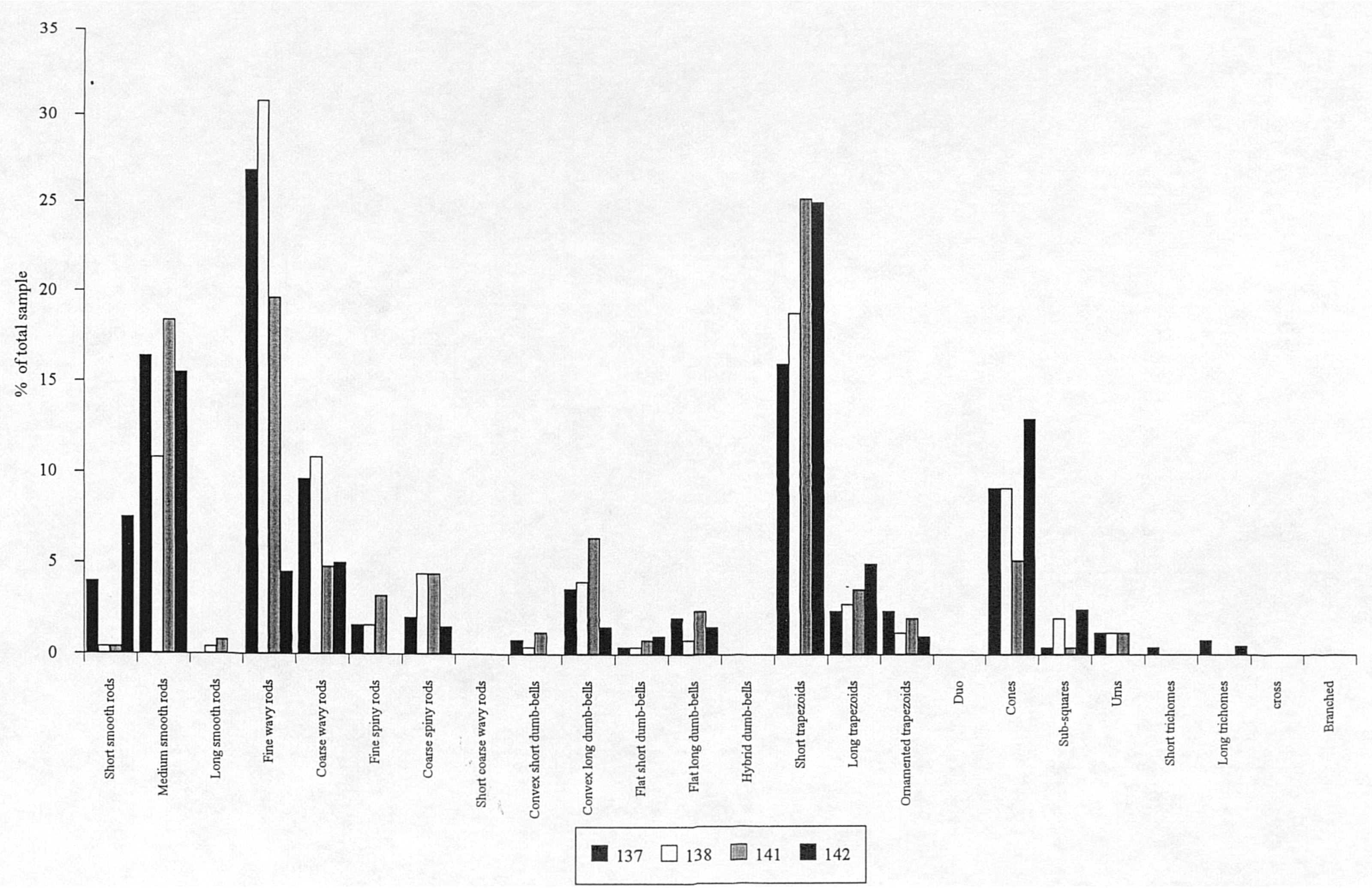


Figure 6.8: The relative distribution of phytolith morphotypes in the stack base.

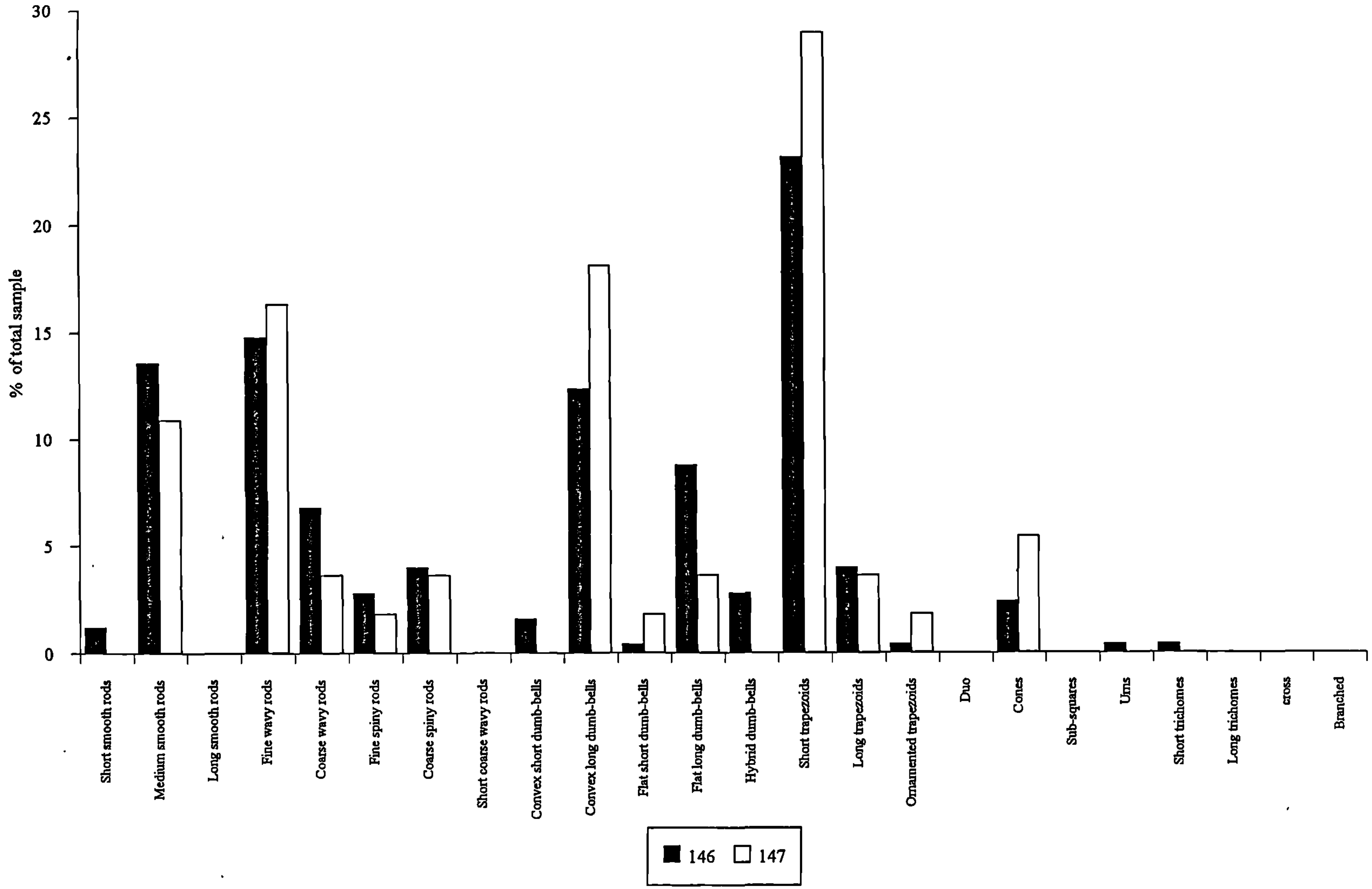


Figure 6.9: The relative distribution of phytolith morphotypes in the vegetable plot.

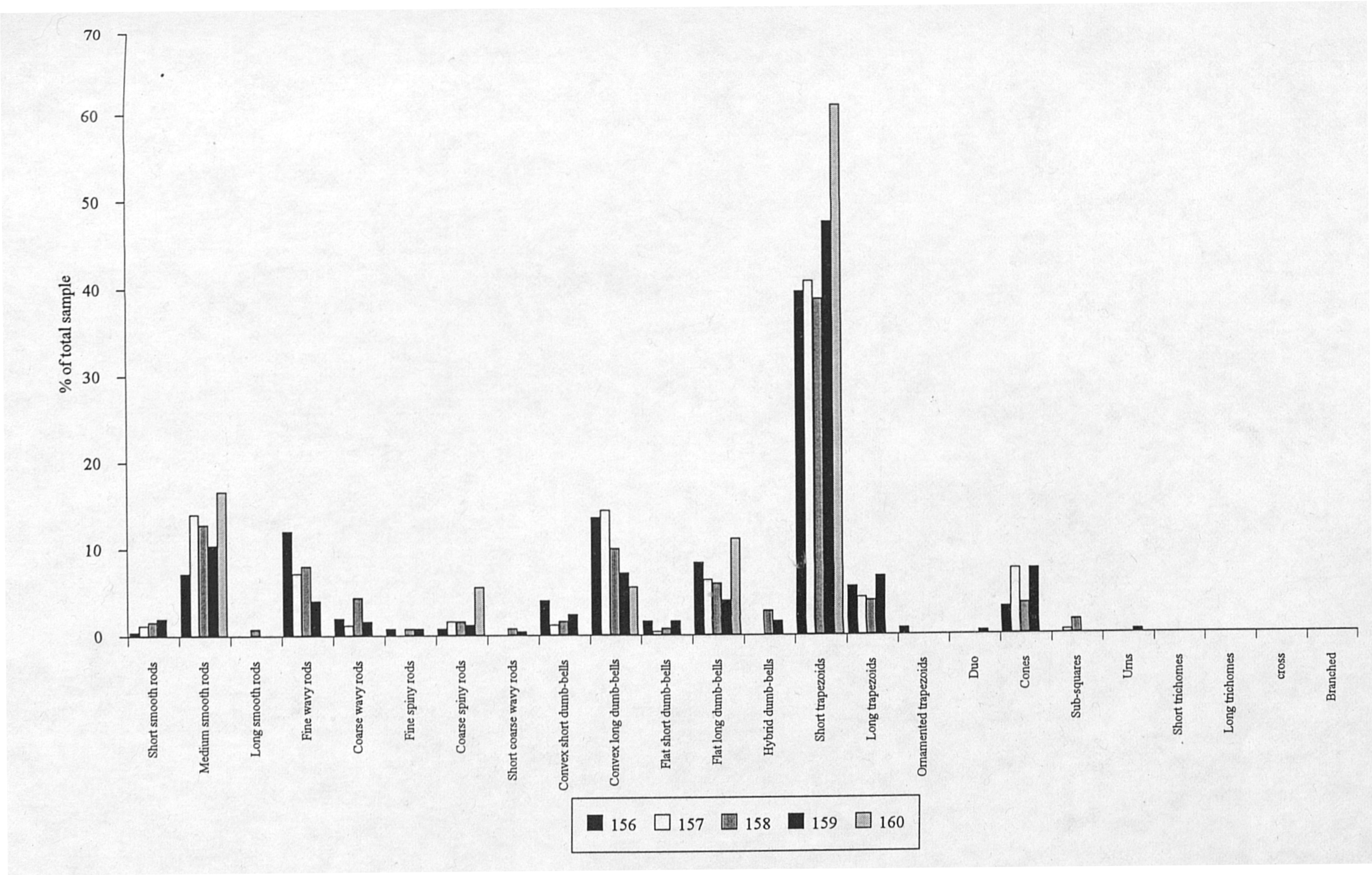


Figure 6.10: The relative distribution of phytolith morphotypes in the midden.

SSR	Short smooth rod
MSR	Medium smooth rod
LSR	Long smooth rod
FWR	Fine wavy rod
CWR	Coarse wavy rod
SCWR	Short coarse wavy rod
FSR	Fine spiny rod
CSR	Coarse spiny rod
CSD	Convex short dumb-bell
CLD	Convex long dumb-bell
FSD	Flat short dumb-bell
FLD	Flat long dumb-bell
HD	Hybrid dumb-bell
ST	Short trapezoids
LT	Long trapezoids
OT	Ornamented trapezoids
D	Duo
C	Cones
SS	Sub-squares
U	Urns
SHT	Short trichomes
LOT	Long trichomes
CR	Cross
BR	Branched

List of abbreviations used for the phytolith morphotypes.

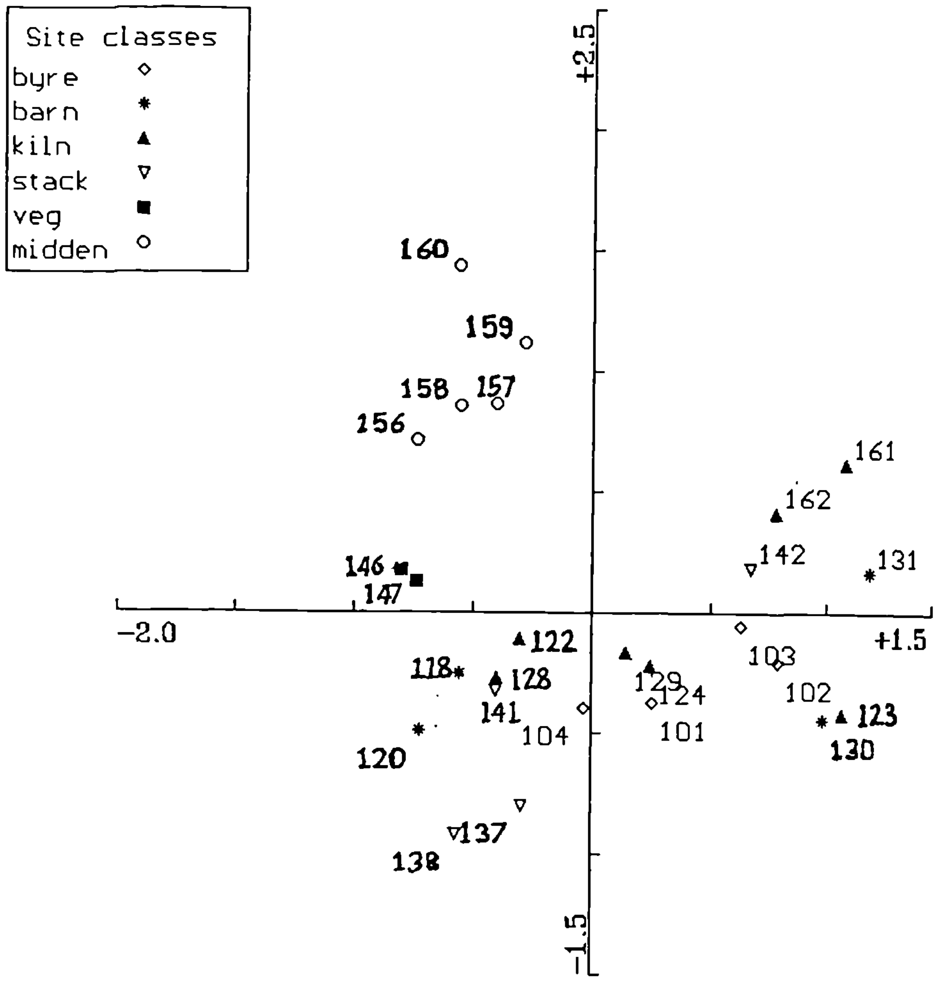


Figure 6.11a: Correspondence analysis using the complete phytolith data set - 26 samples and 26 morphotypes (sites plotted on axes 1 and 2).

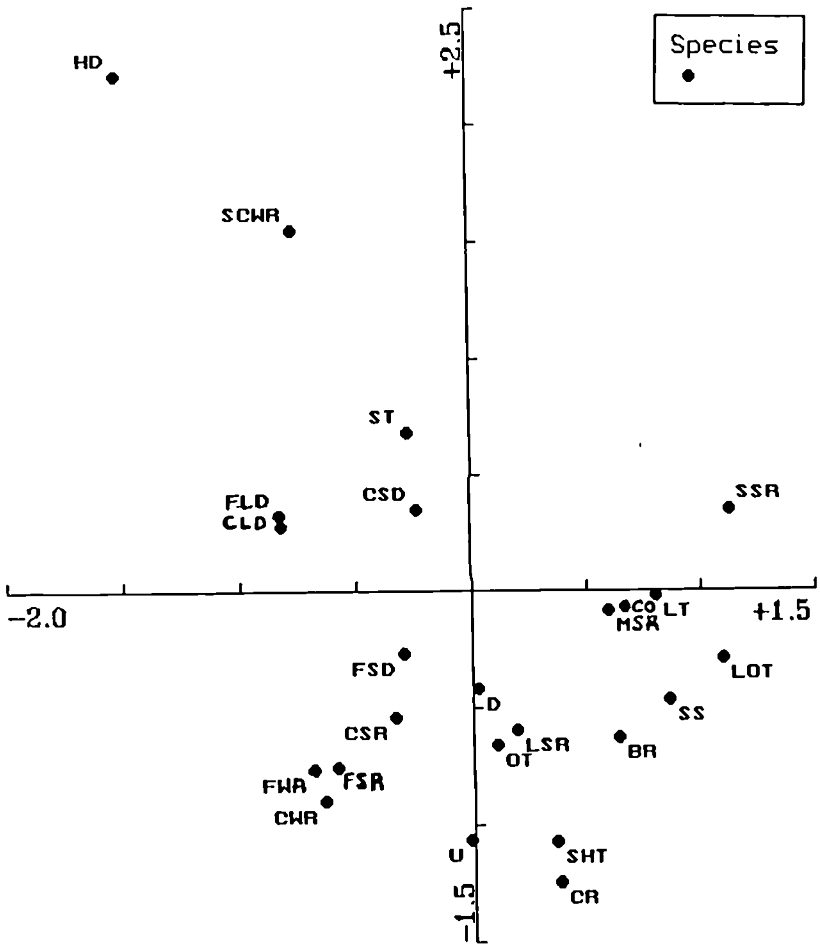


Figure 6.11b: Correspondence analysis using the complete phytolith data set - 26 samples and 26 morphotypes. (morphotypes plotted on axes 1 and 2).

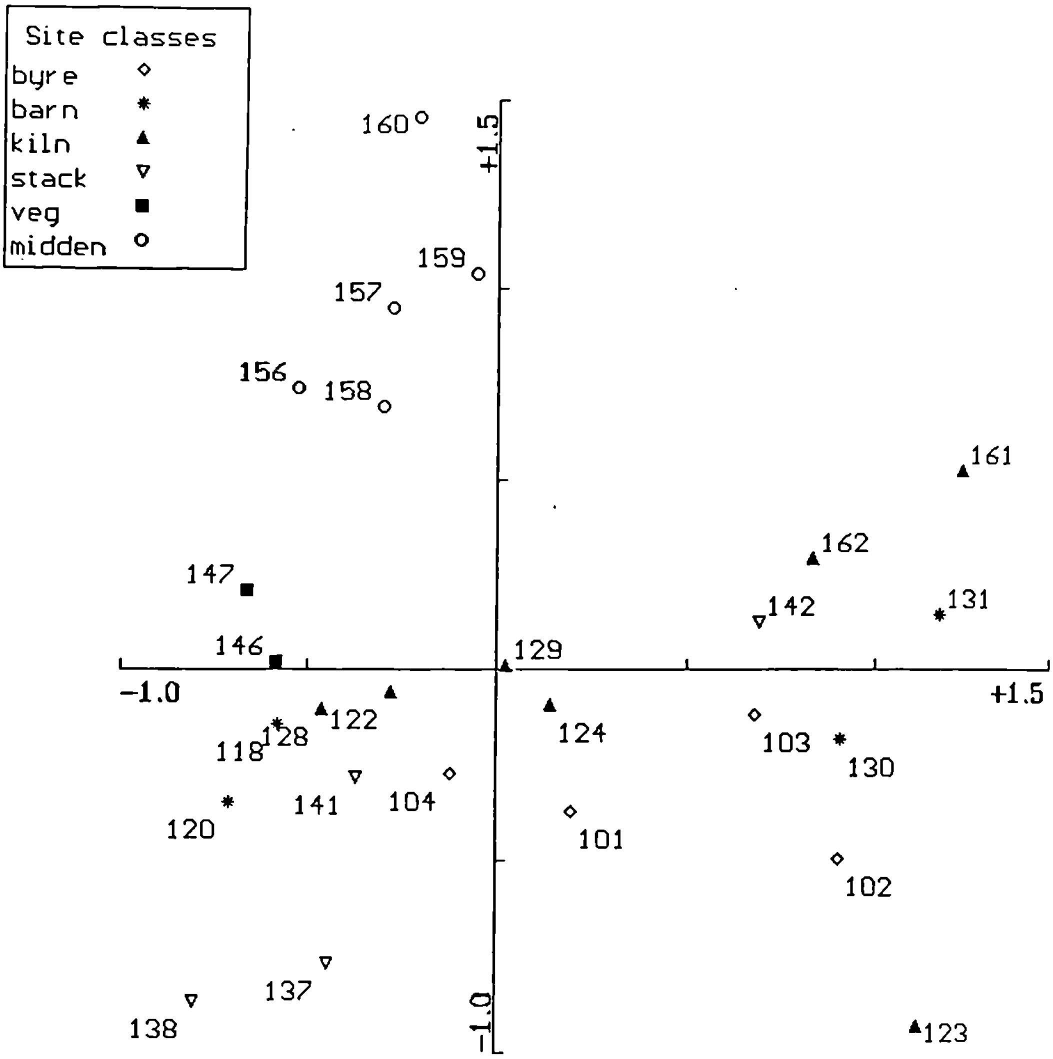


Figure 6.12a: Correspondence analysis using 26 samples and 14 morphotypes (sites plotted on axes 1 and 2).

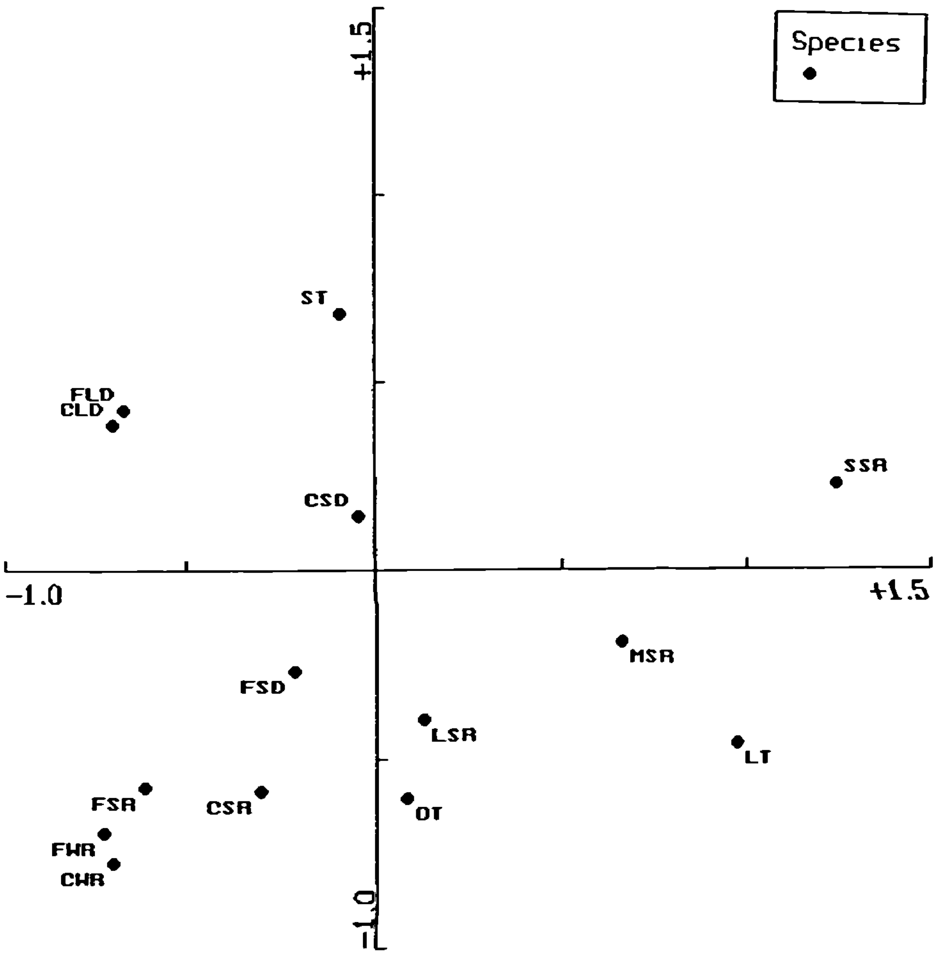


Figure 6.12b: Correspondence analysis using 26 samples and 14 morphotypes (morphotypes plotted on axes 1 and 2).

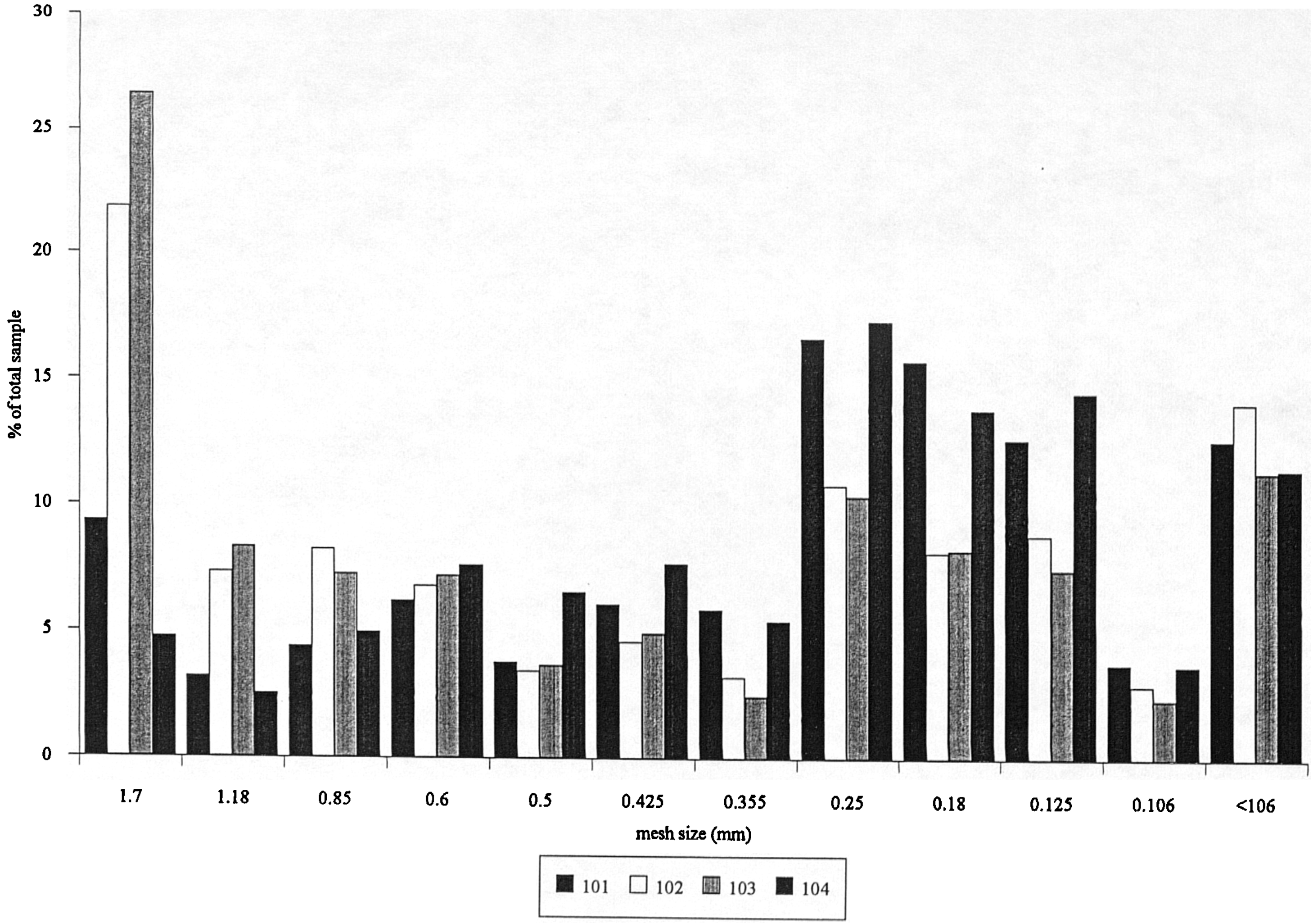


Figure 6.13: Particle size distribution in the byre.

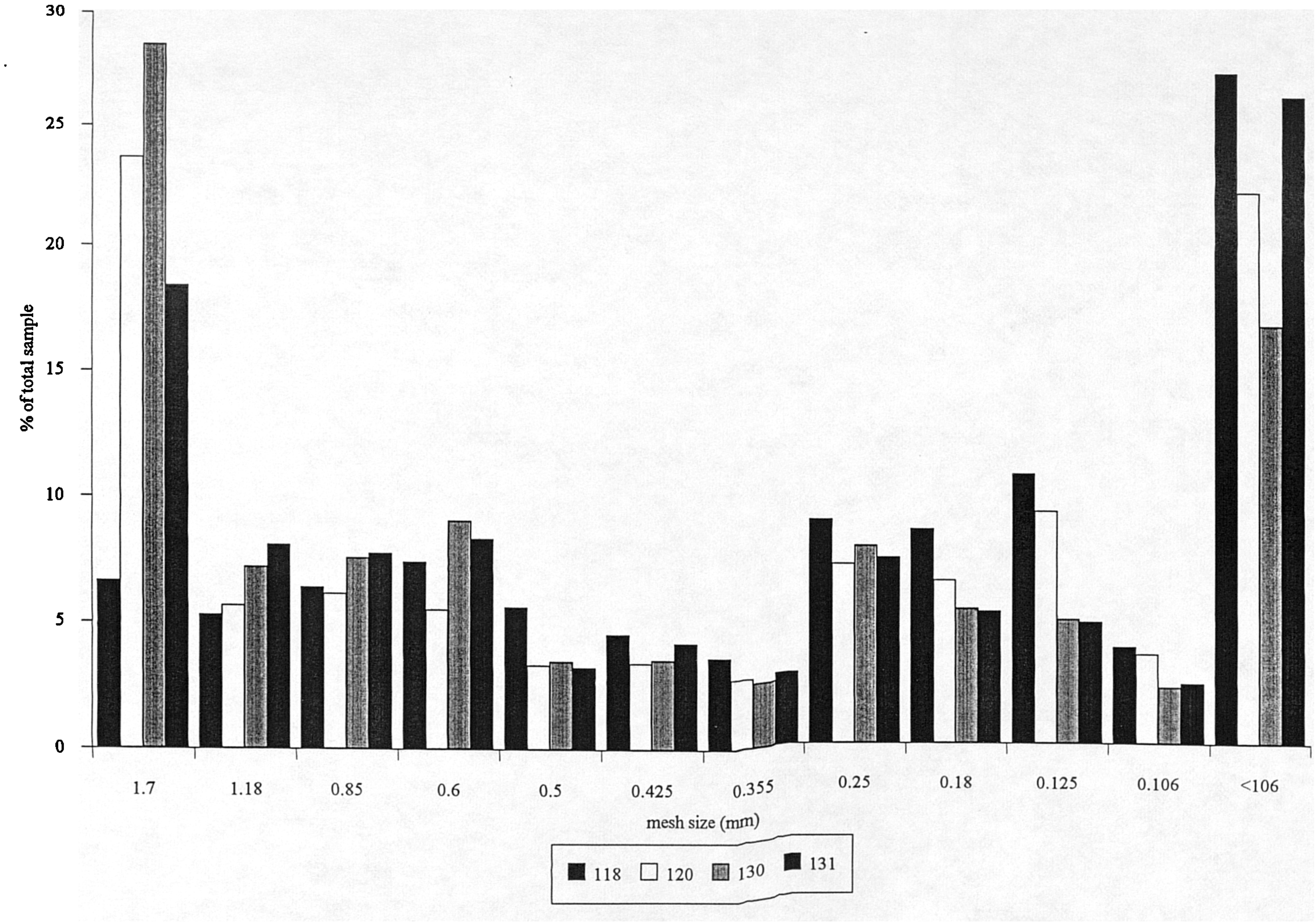


Figure 6.14: Particle size distribution in the barn.

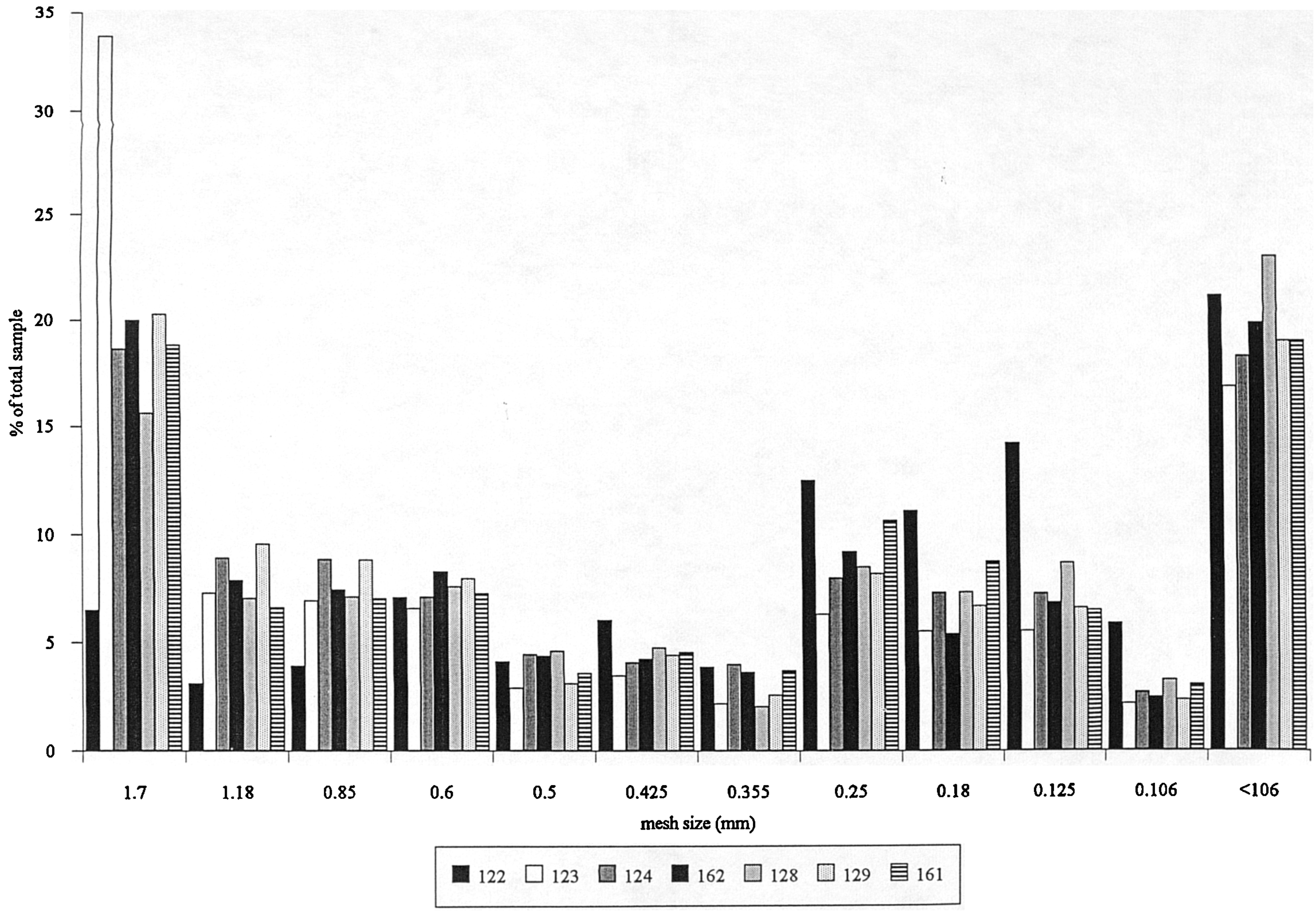


Figure 6.15: Particle size distribution in the kiln.

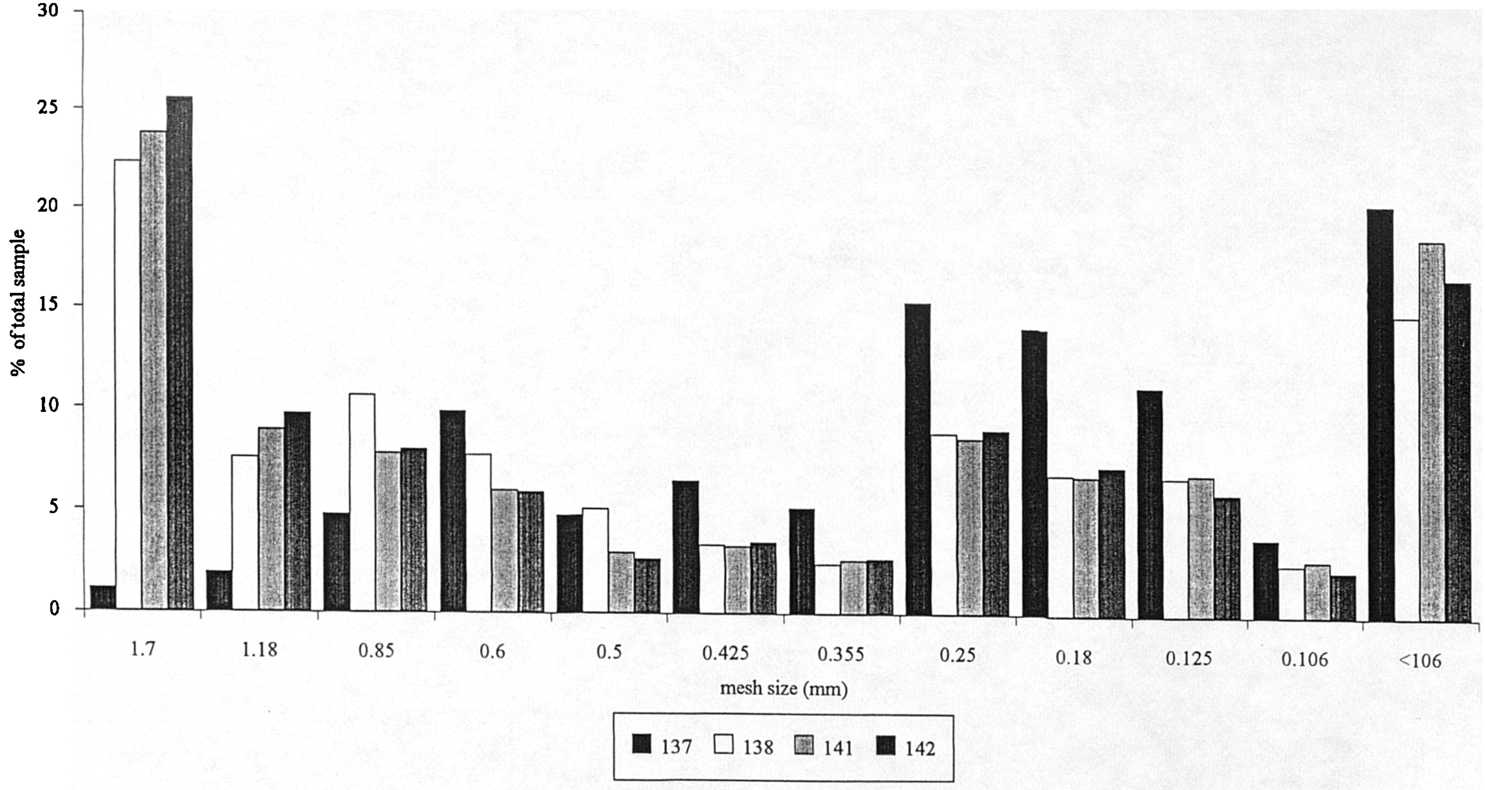


Figure 6.16: Particle size distribution in the stack base.

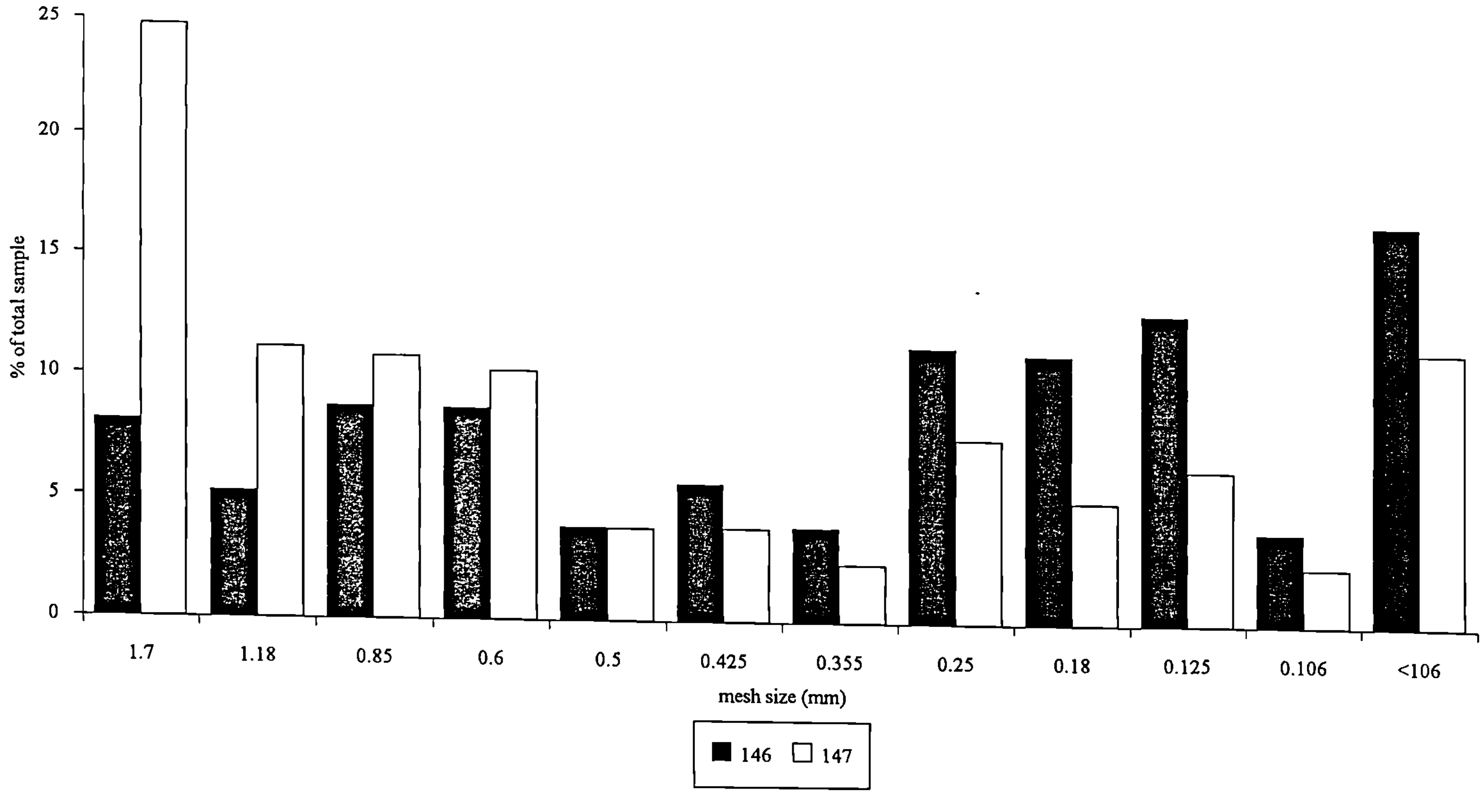


Figure 6.17: Particle size distribution in the vegetable plot.

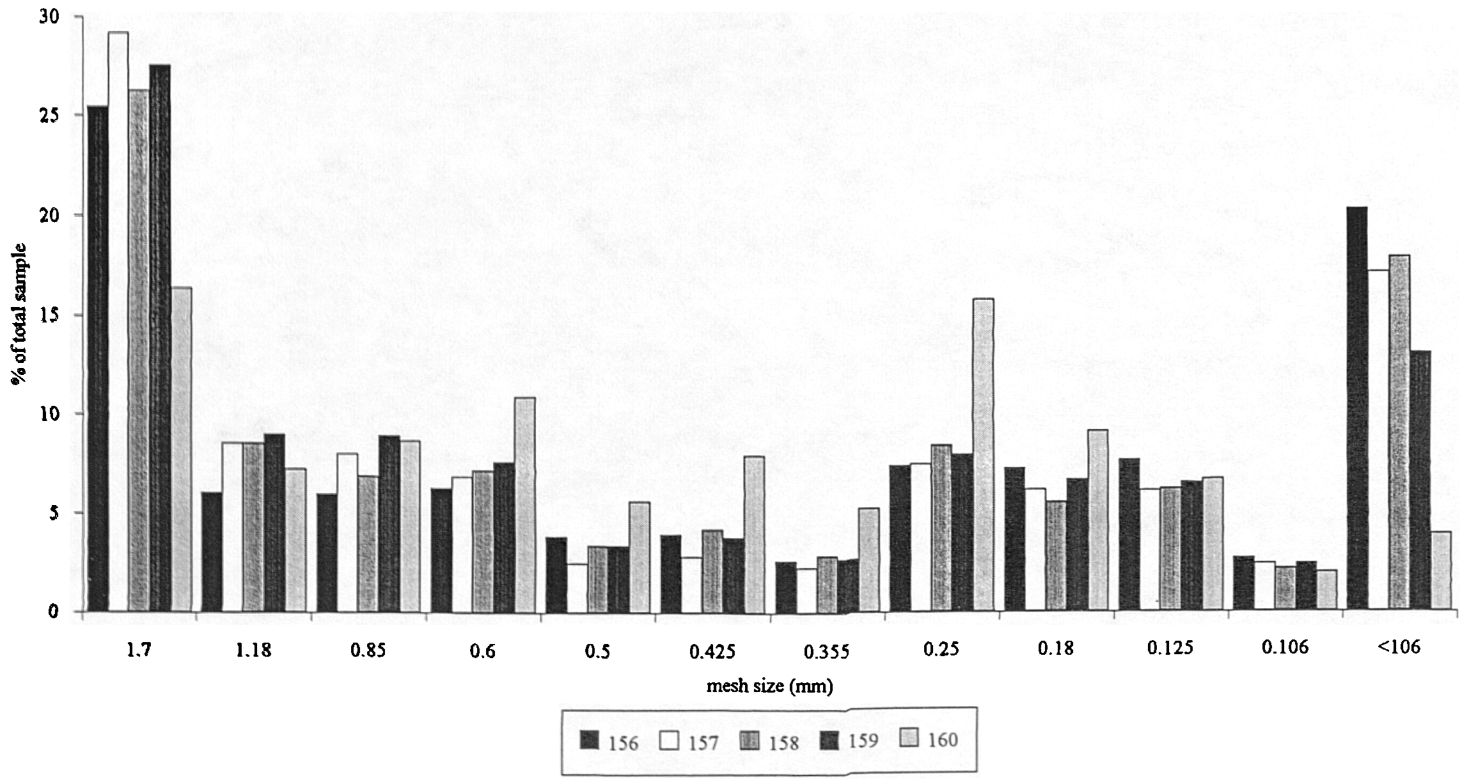


Figure 6.18: Particle size distribution in the midden.

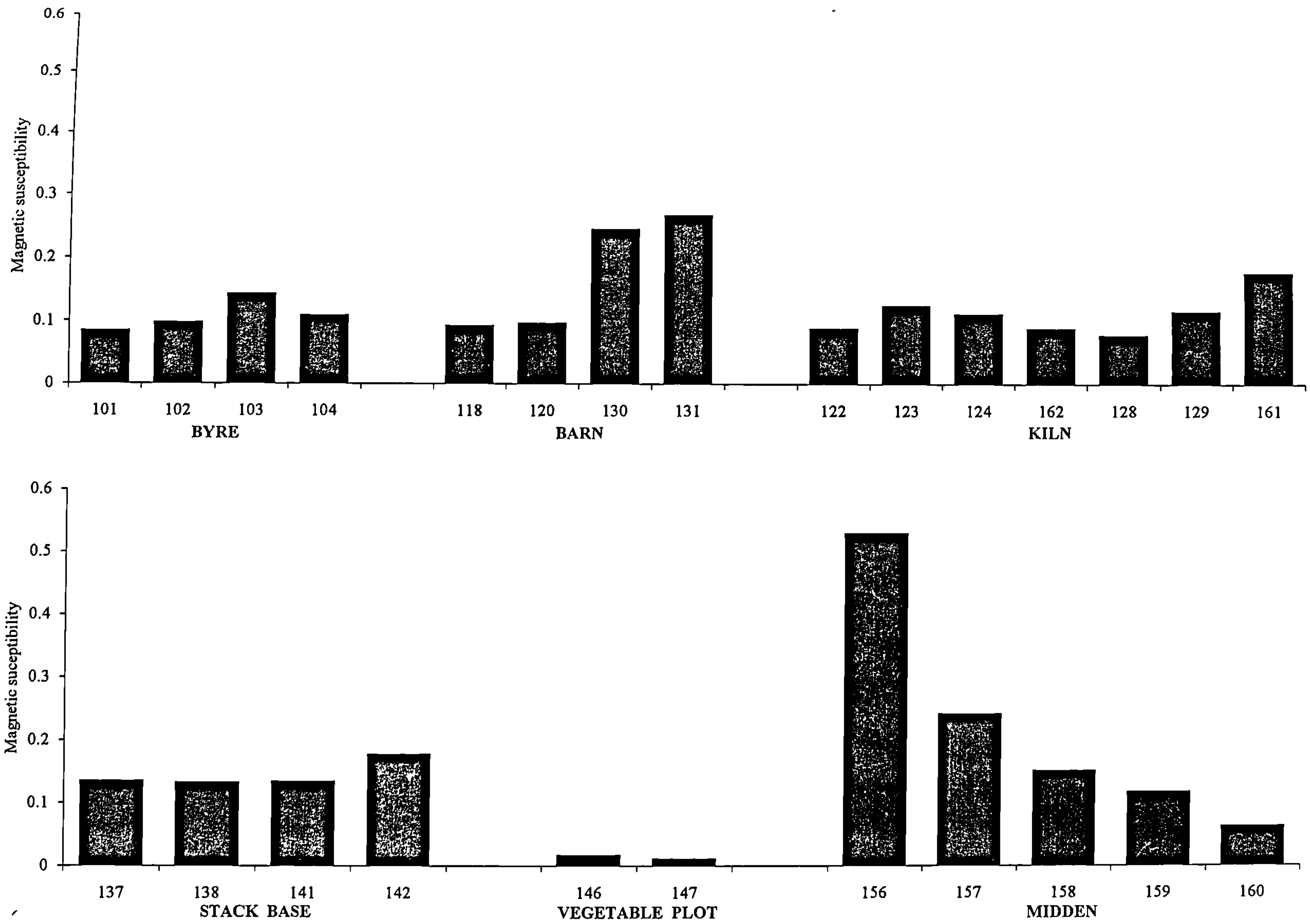


Figure 6.19: Magnetic susceptibility within each functional area.

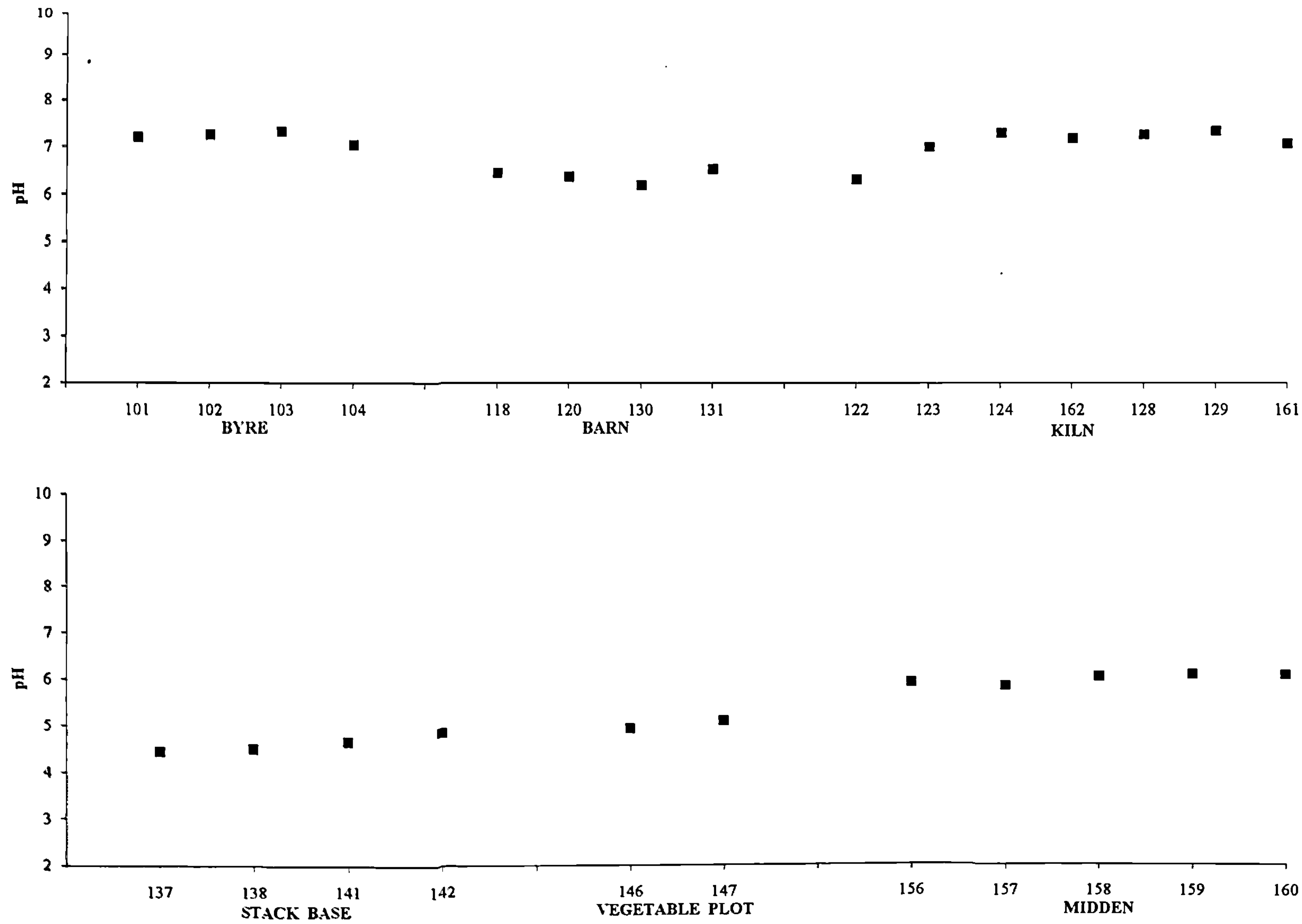


Figure 6.20: pH values within each functio

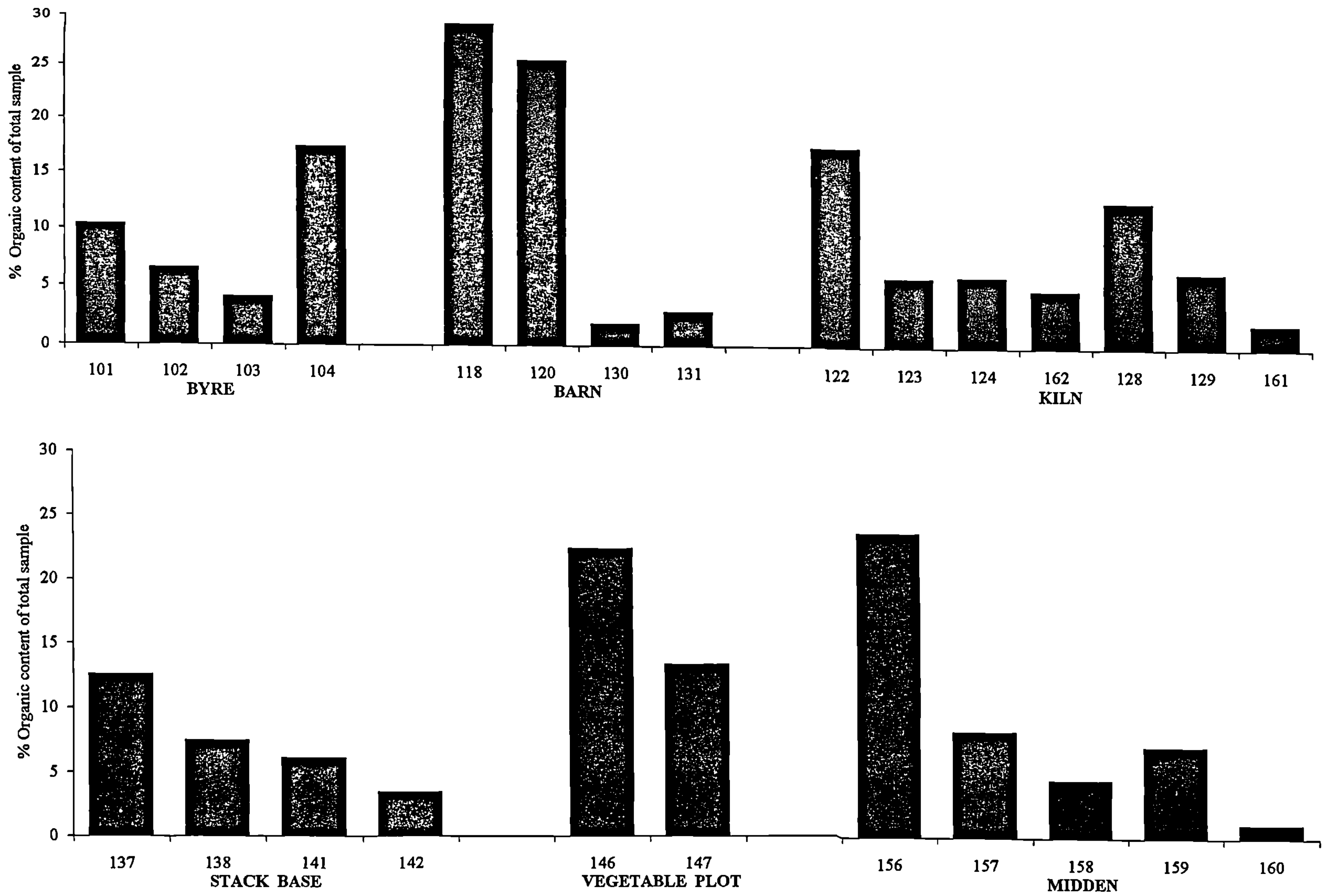
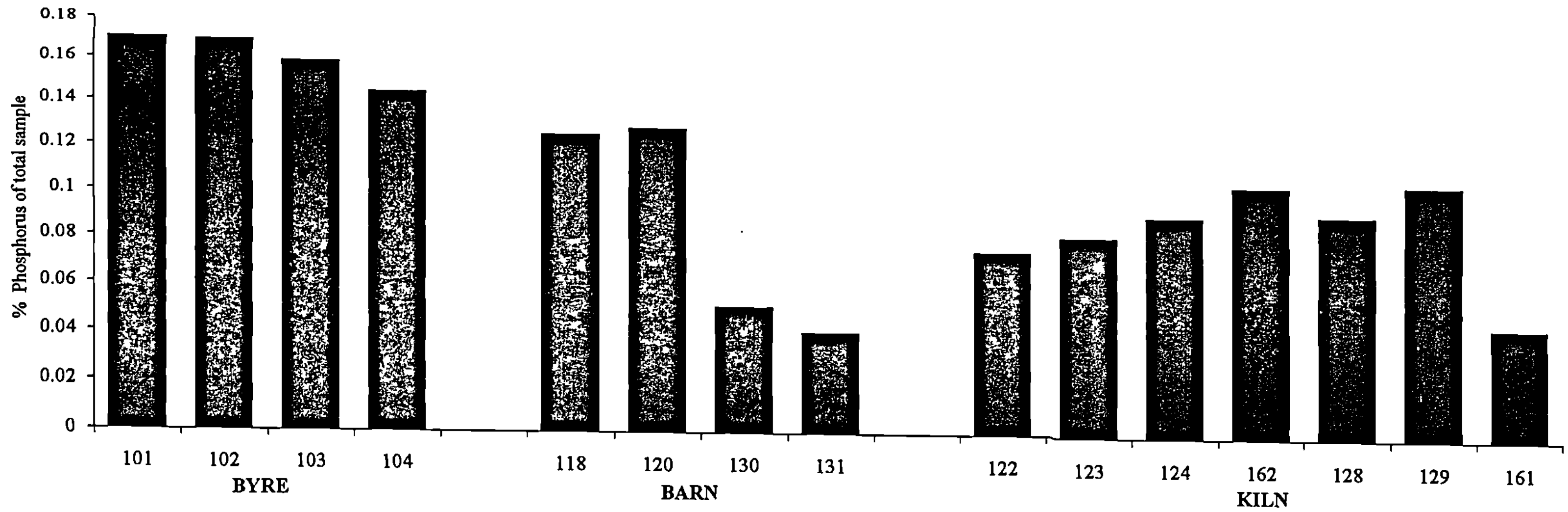


Figure 6.21: % Organic content within each functional area.



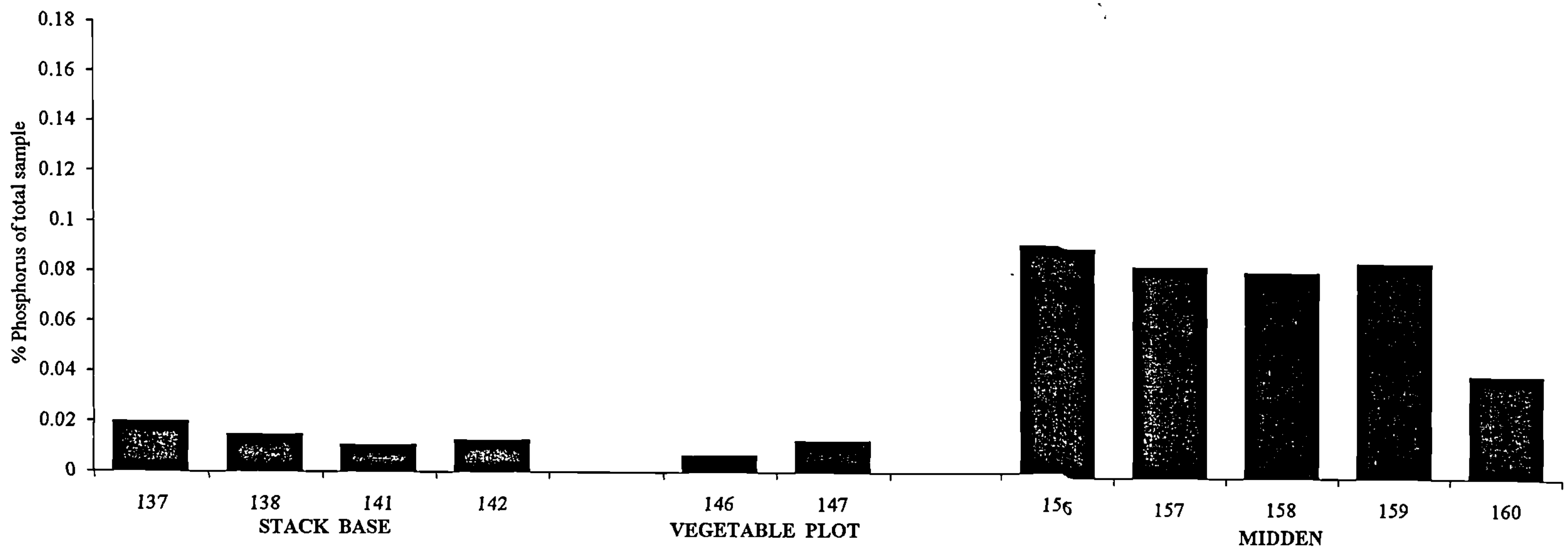


Figure 6.22: % Phosphorus content (sodium hydrogen carbonate extractable) within each functional area.

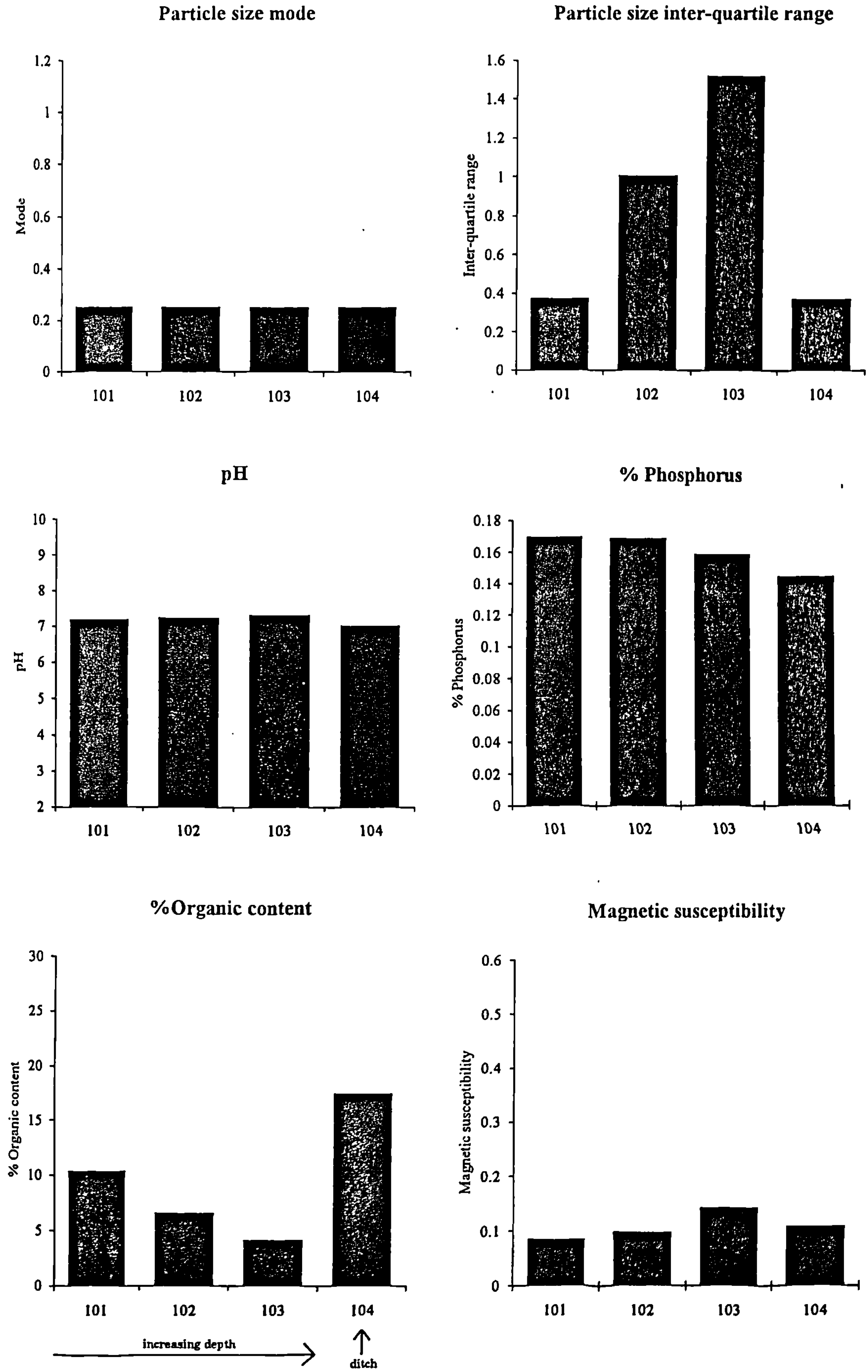


Figure 6.23: Physical and chemical soil properties in the byre.

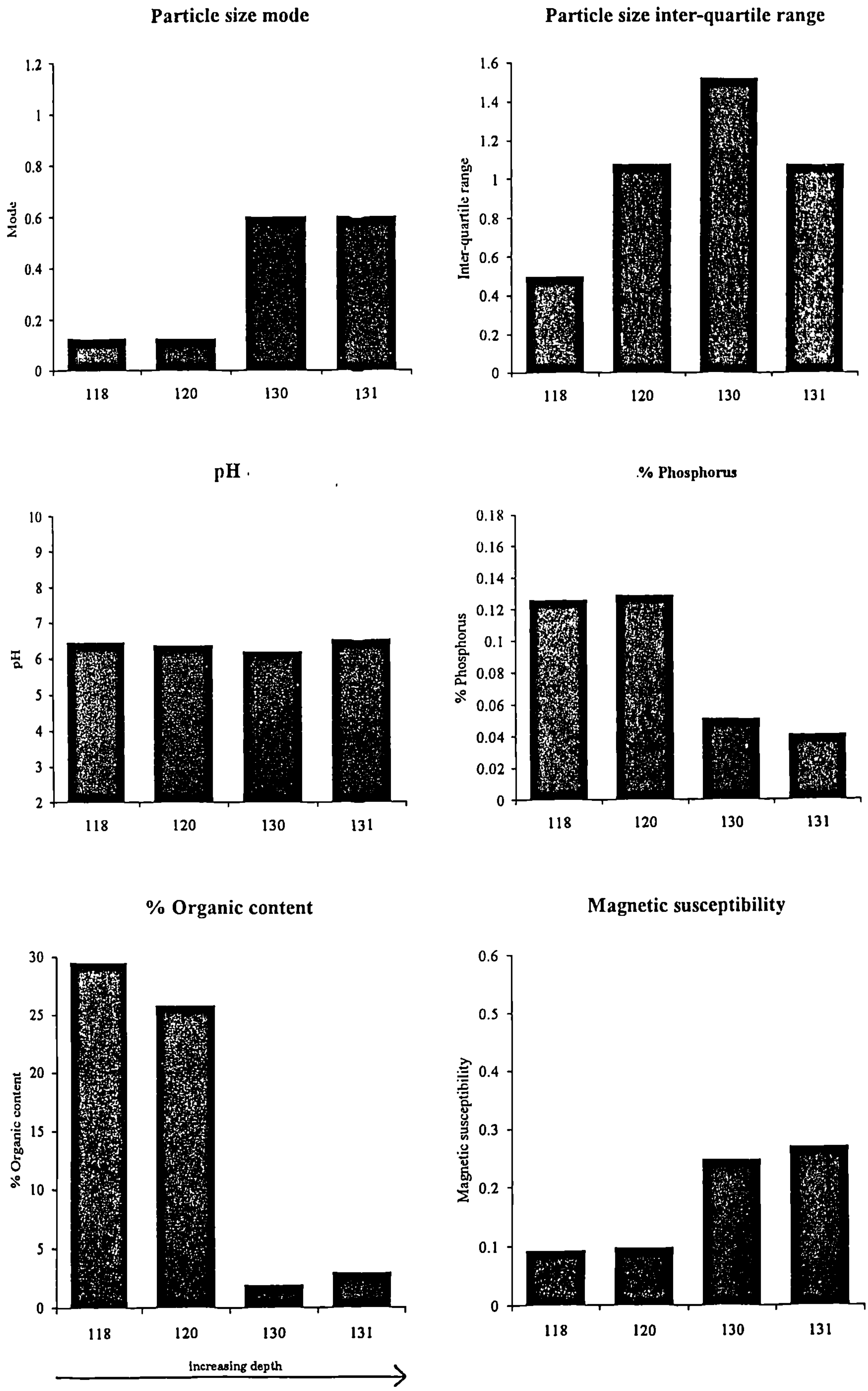


Figure 6.24: Physical and chemical soil properties in the barn.

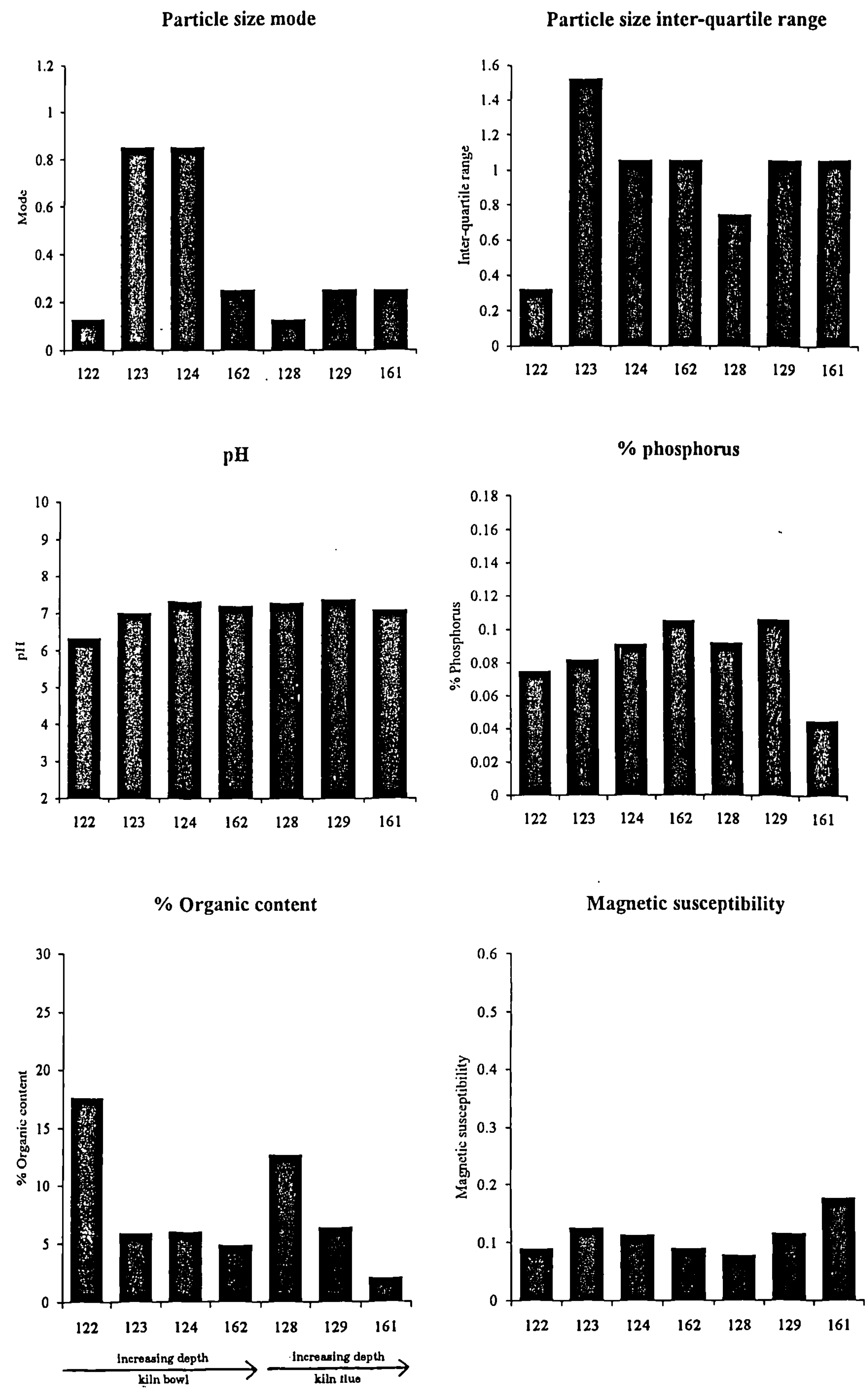


Figure 6.25: Physical and chemical soil properties in the kiln.

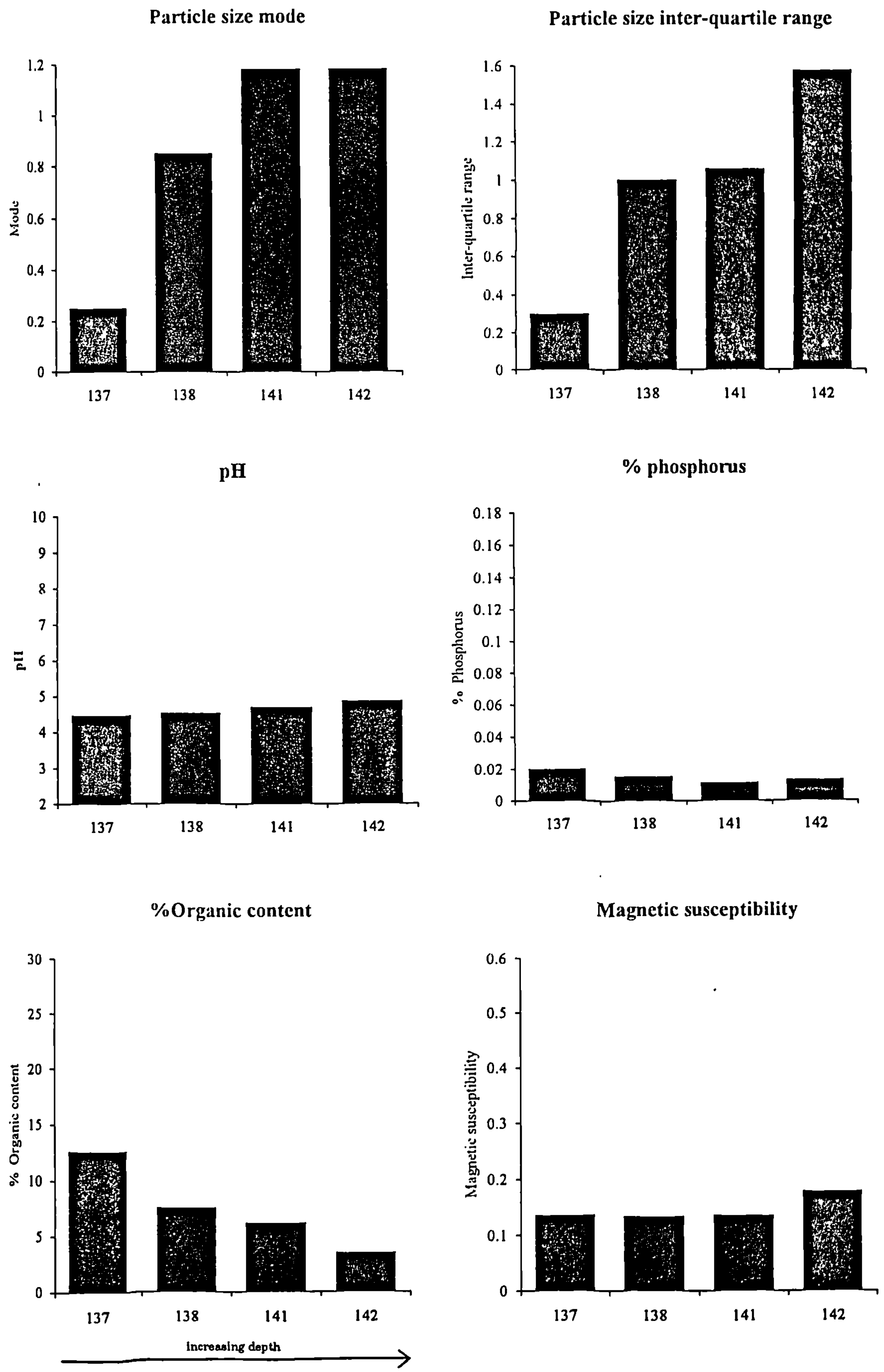


Figure 6.26: Physical and chemical soil properties in the stack base.

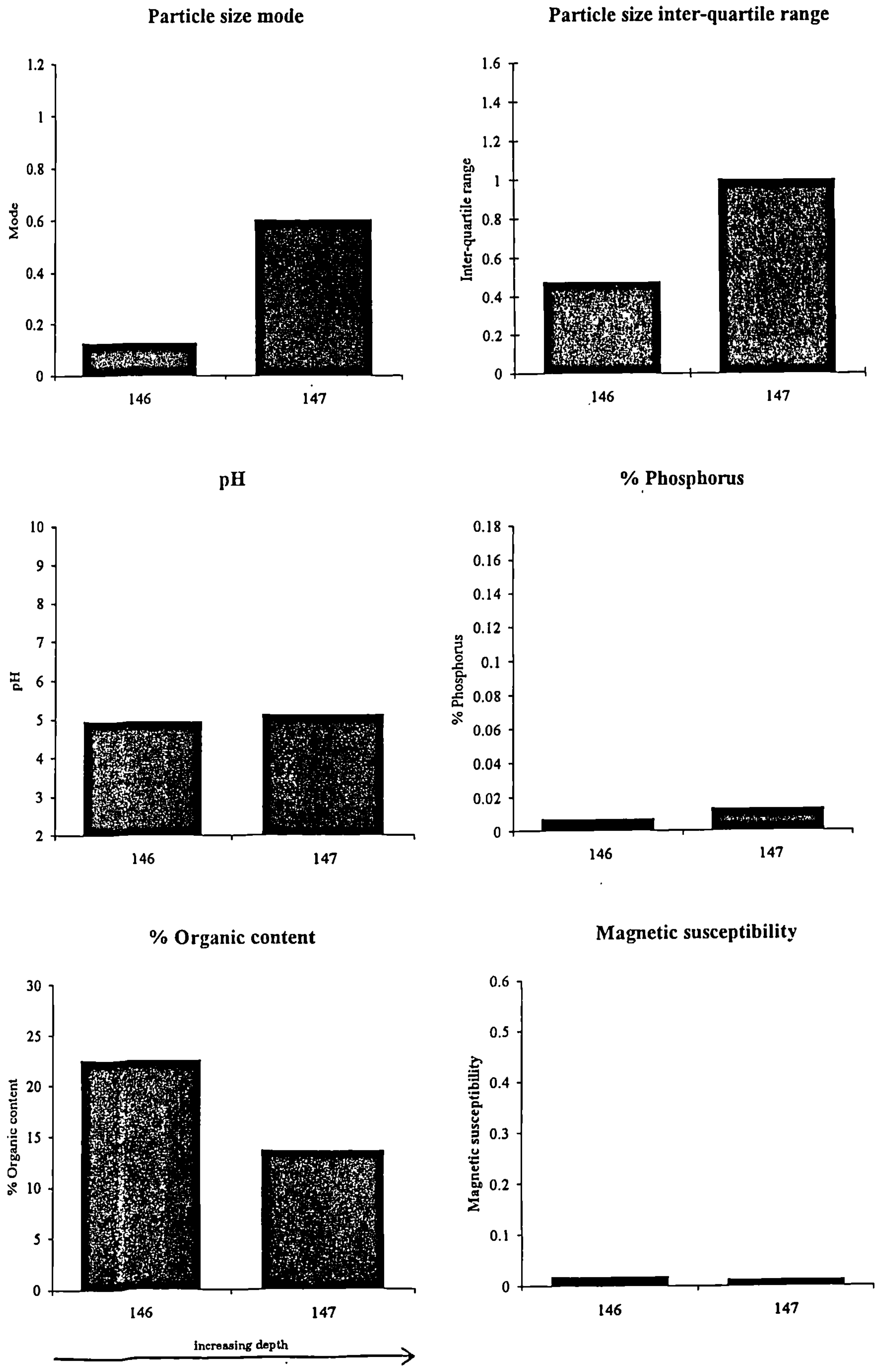


Figure 6.27: Physical and chemical soil properties in the vegetable plot.

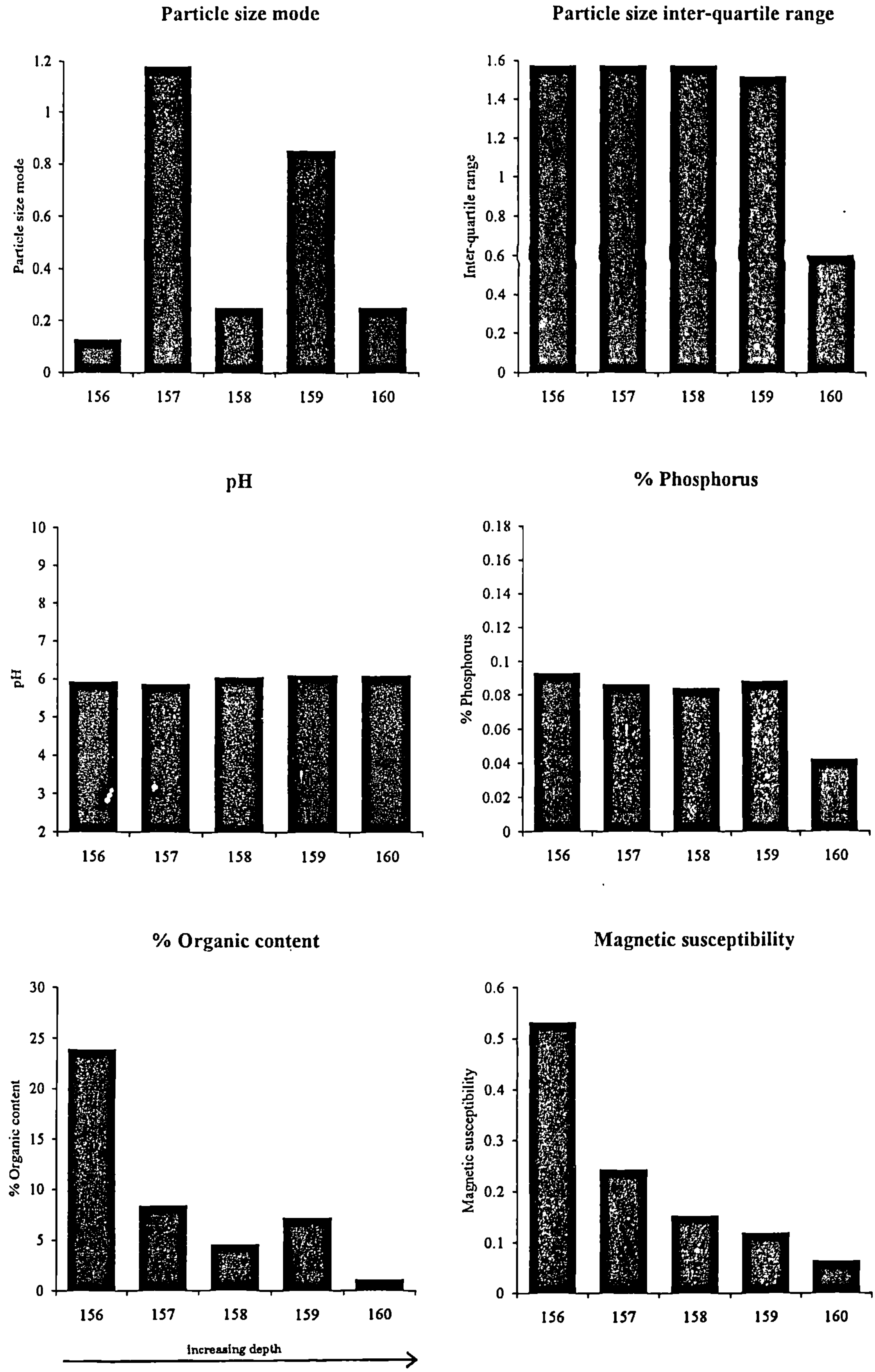


Figure 6.28: Physical and chemical soil properties in the midden.

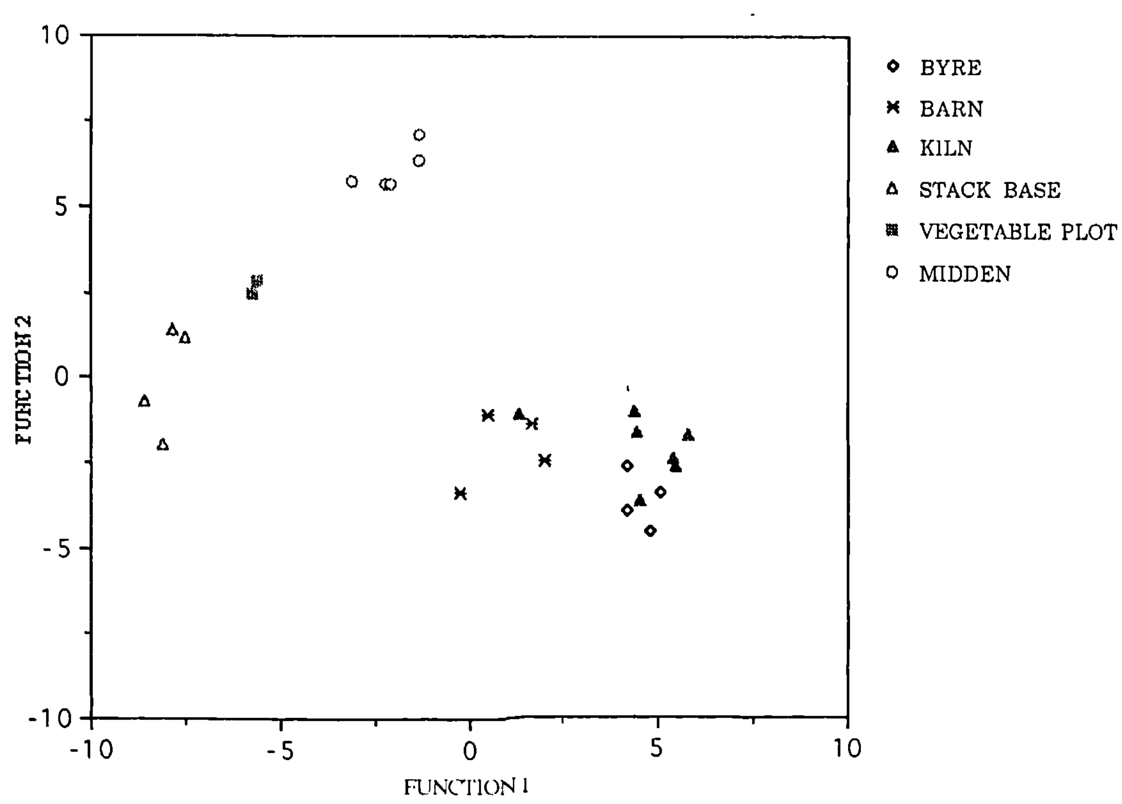


Figure 6.29: Discriminant analysis 1 (functions 1 and 2)

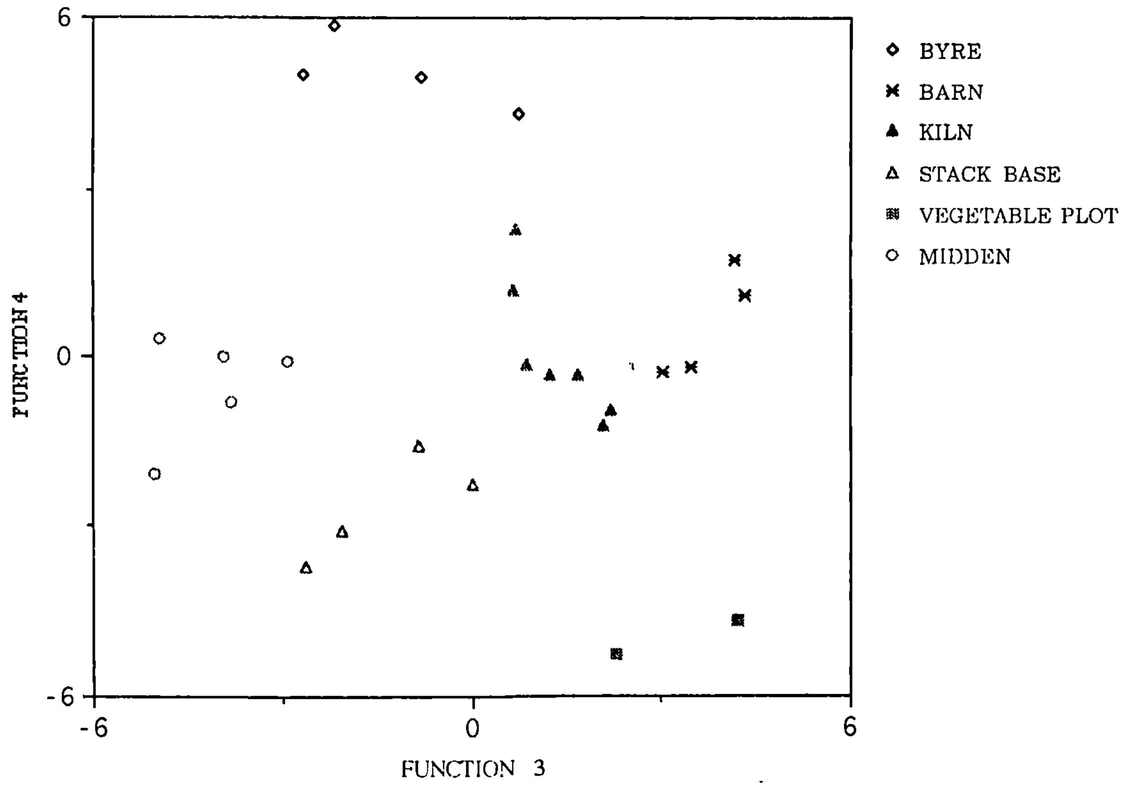


Figure 6.30: Discriminant analysis 1 (functions 3 and 4).

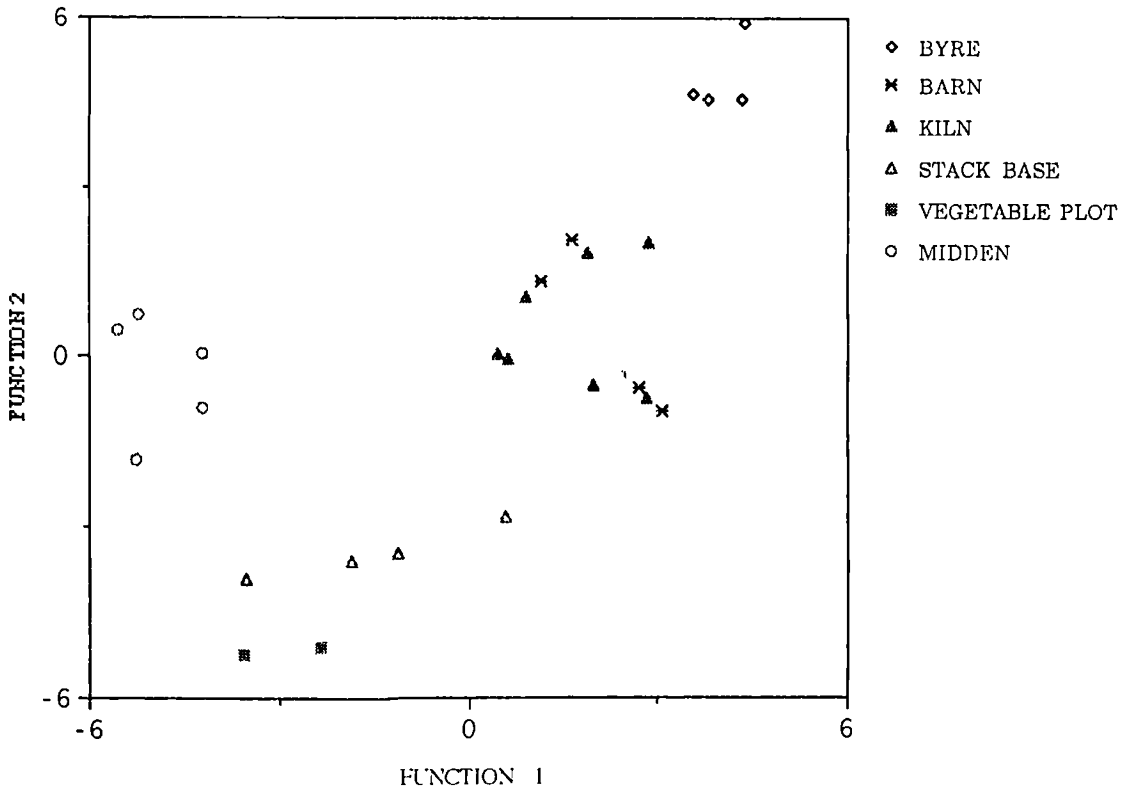


Figure 6.31: Discriminant analysis 2 (functions 1 and 2).

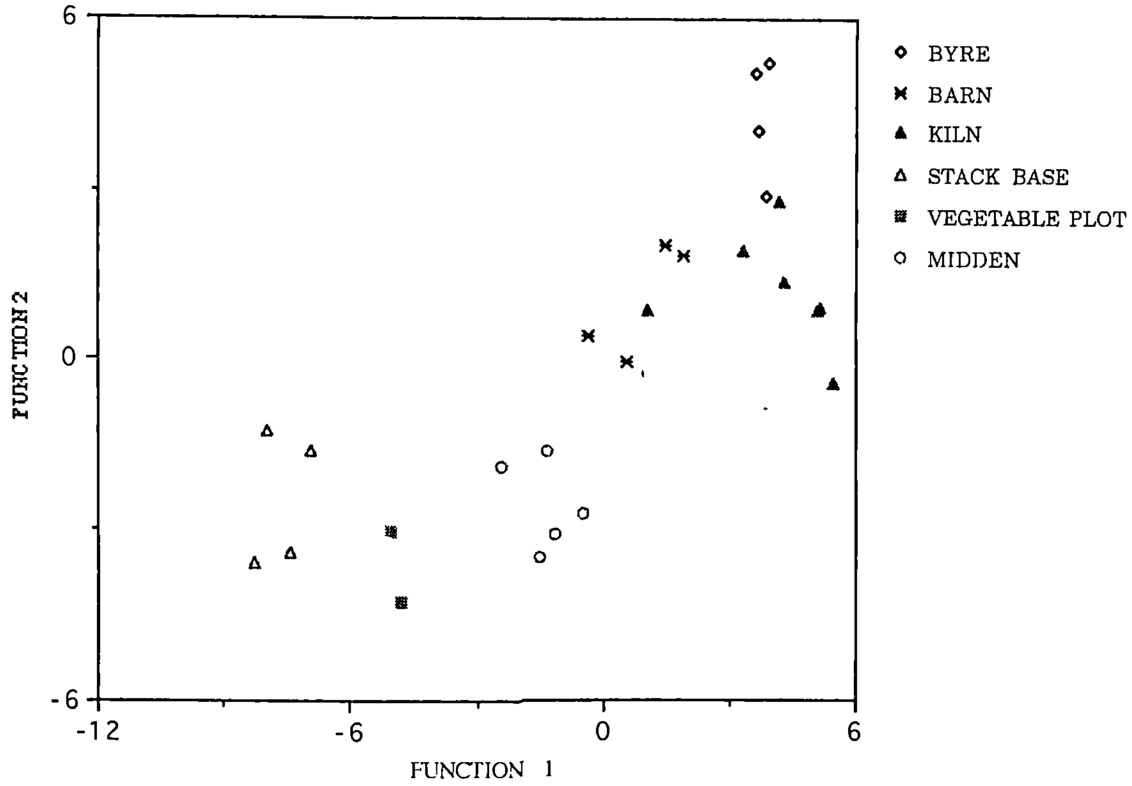


Figure 6.32: Discriminant analysis 4 (functions 1 and 2).

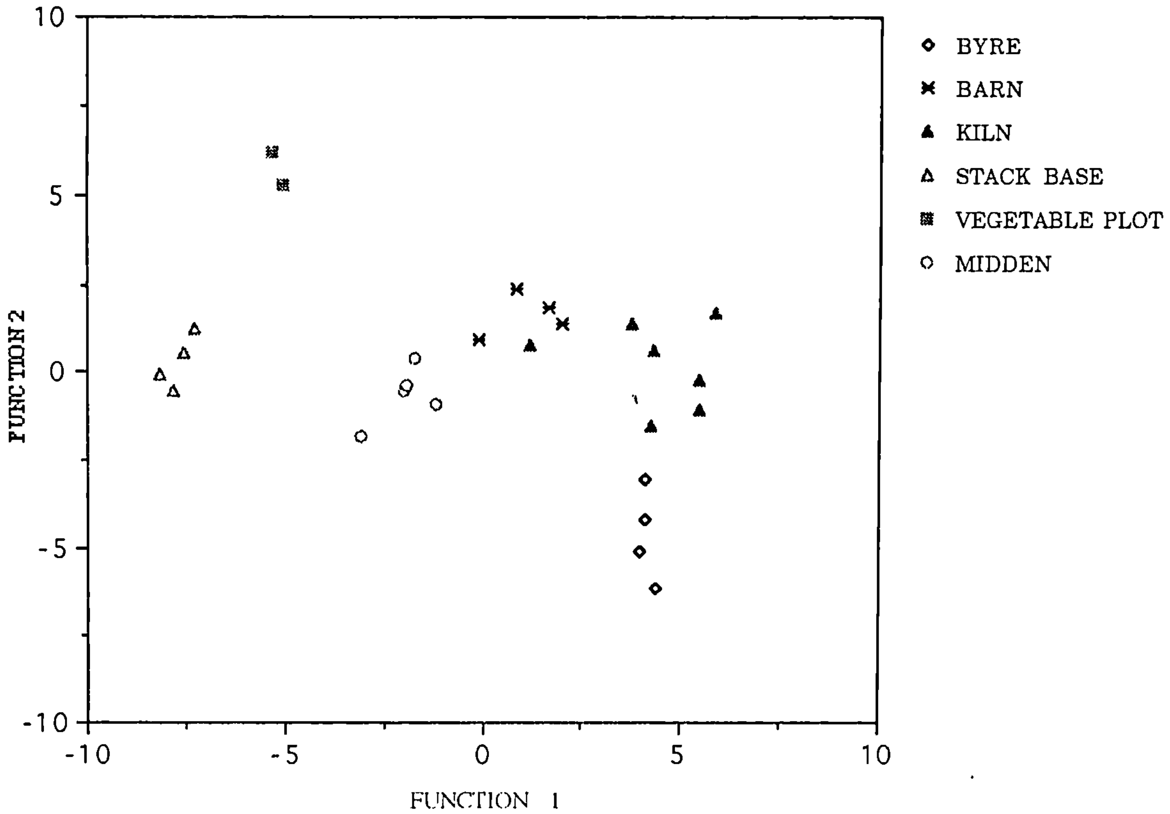


Figure 6.33: Discriminant analysis 5 (functions 1 and 2).

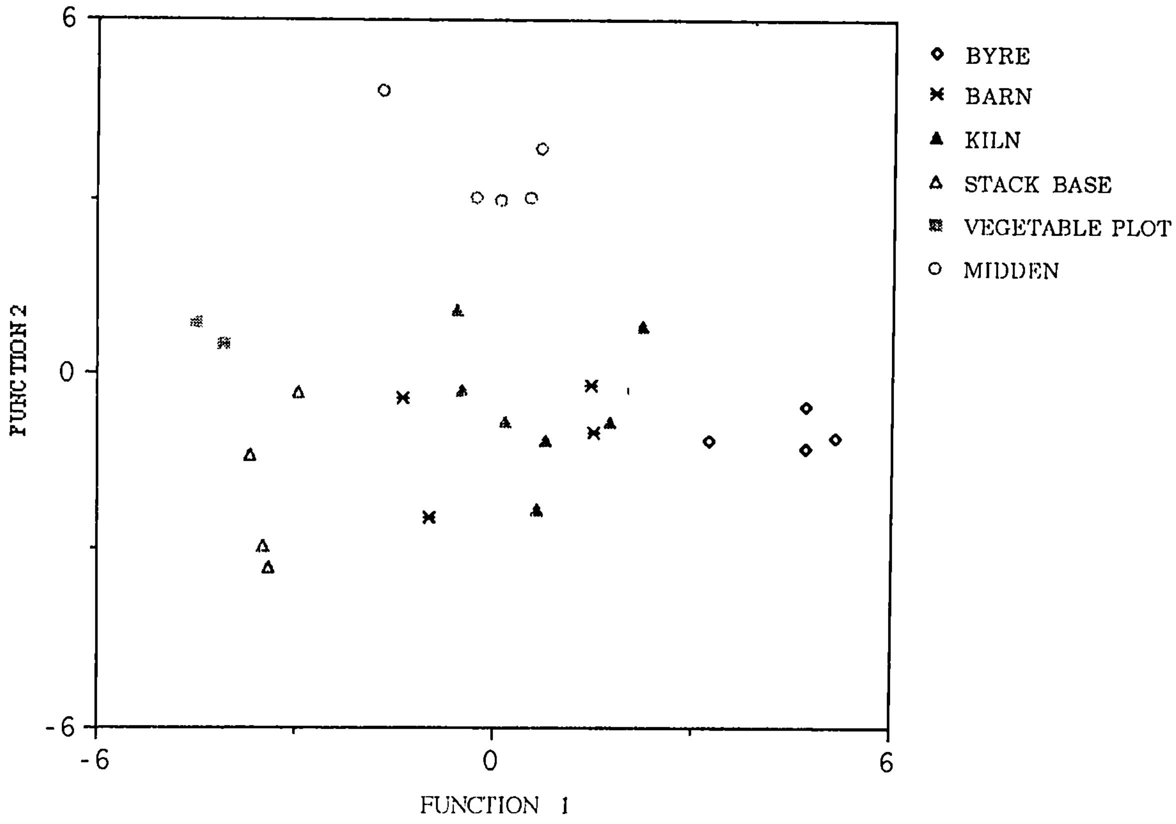


Figure 6.34: Discriminant analysis 8 (functions 1 and 2).

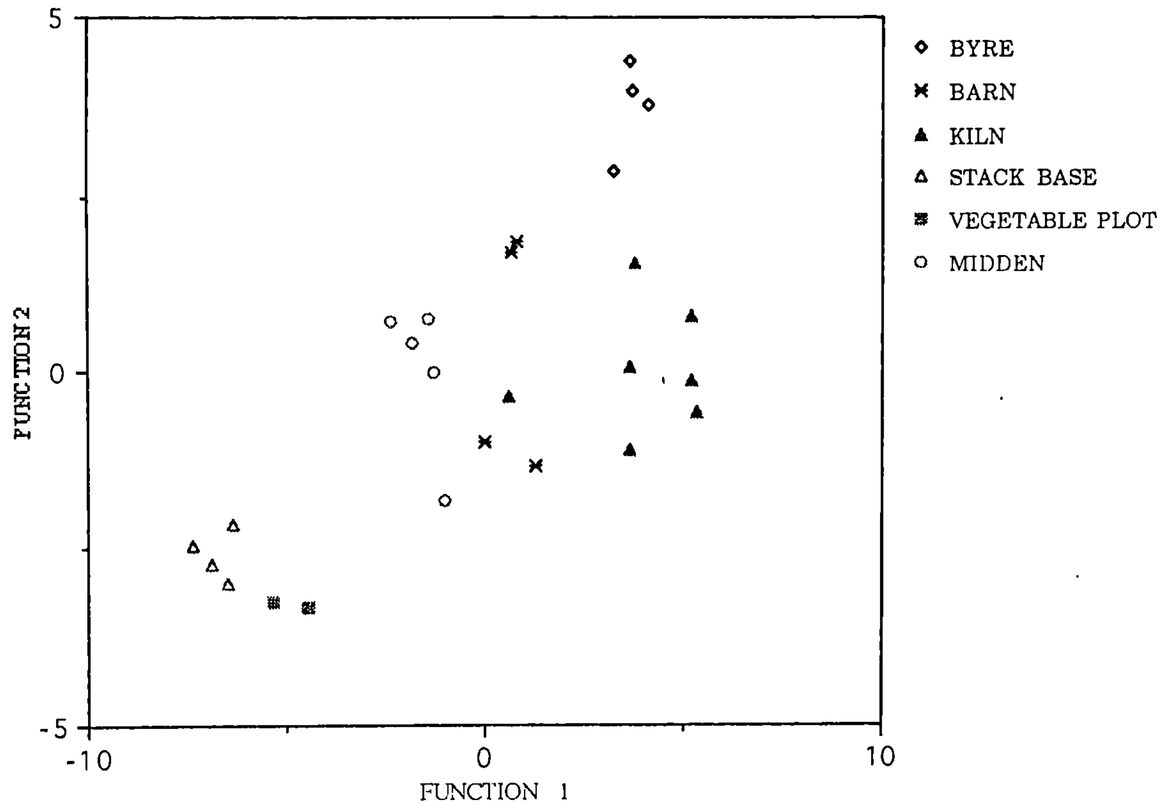


Figure 6.35: Discriminant analysis 11 (functions 1 and 2).

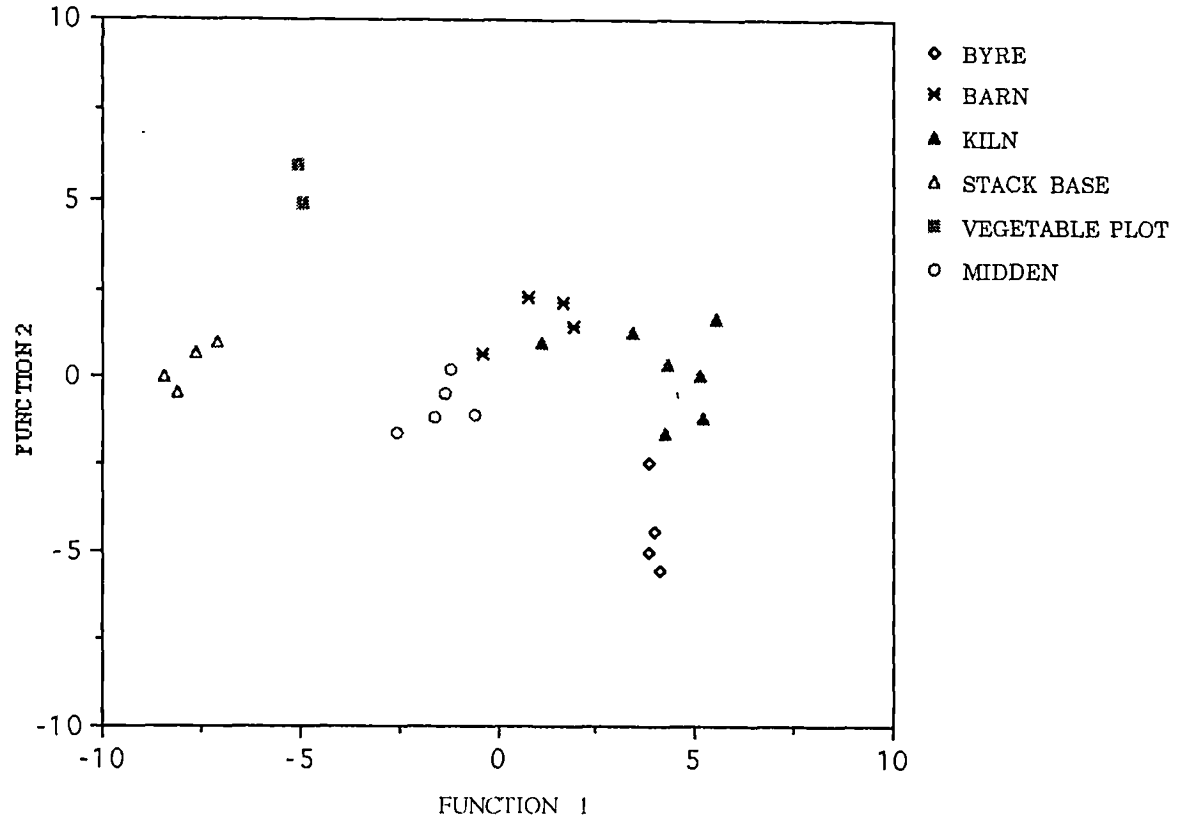


Figure 6.36: Discriminant analysis 34 (functions 1 and 2).

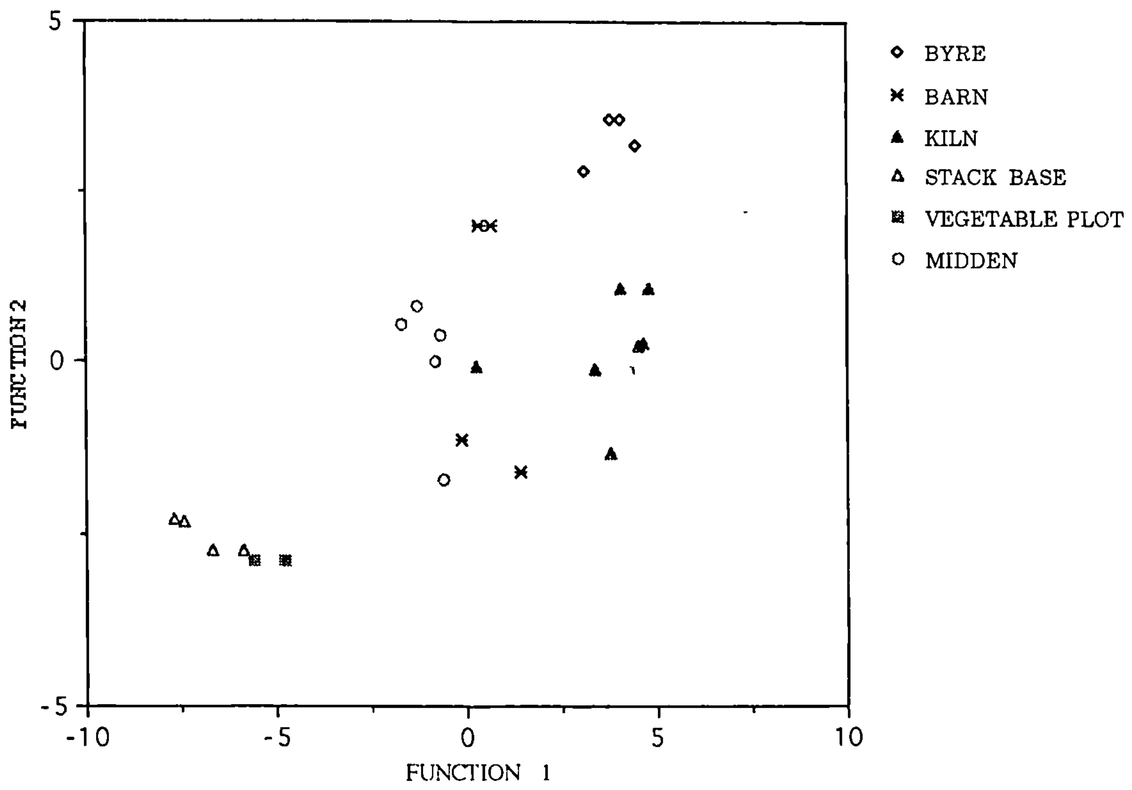


Figure 6.37: Discriminant analysis 38 (functions 1 and 2).

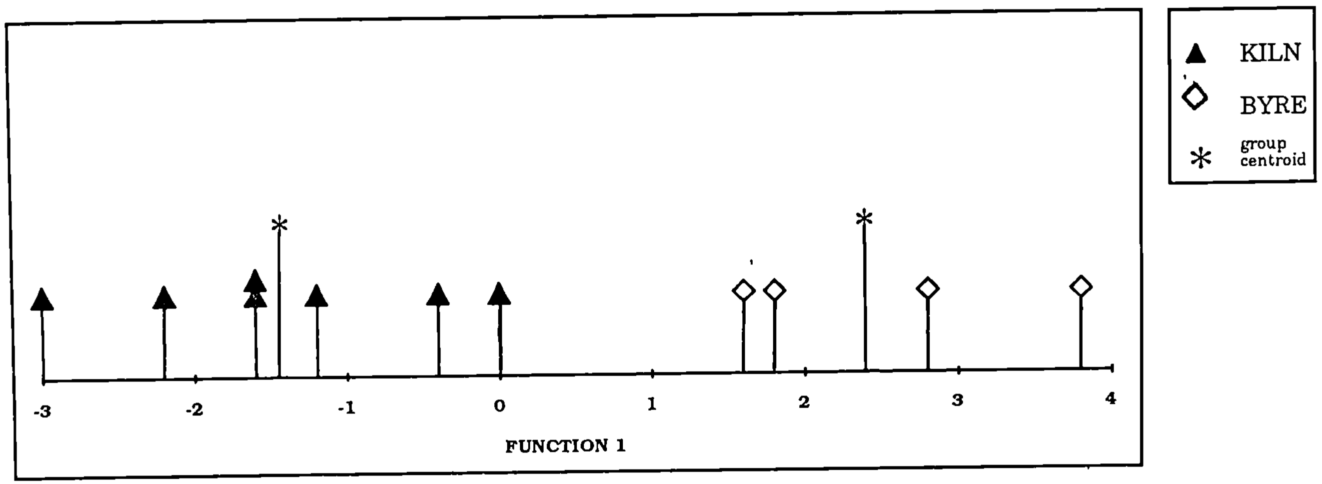


Figure 6.38: Discriminant analysis 41 (function 1).

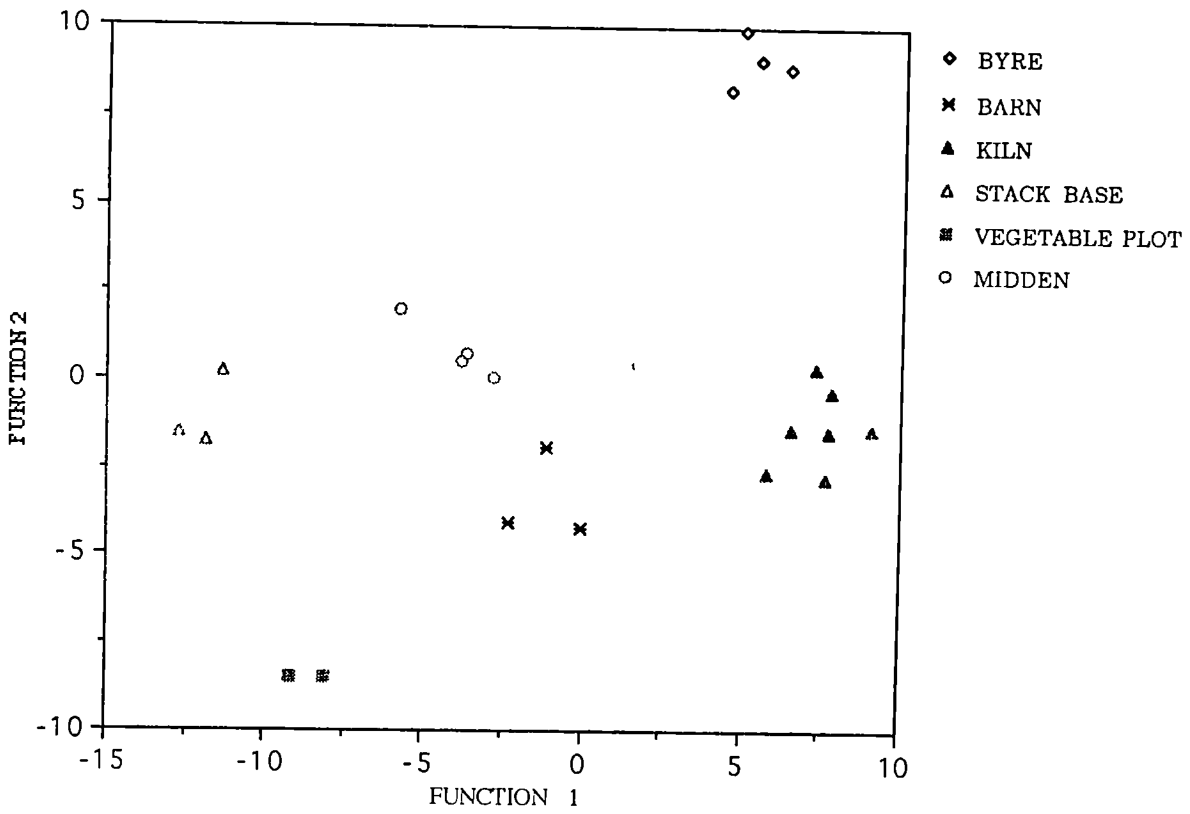


Figure 6.39: Discriminant analysis 43 (functions 1 and 2).

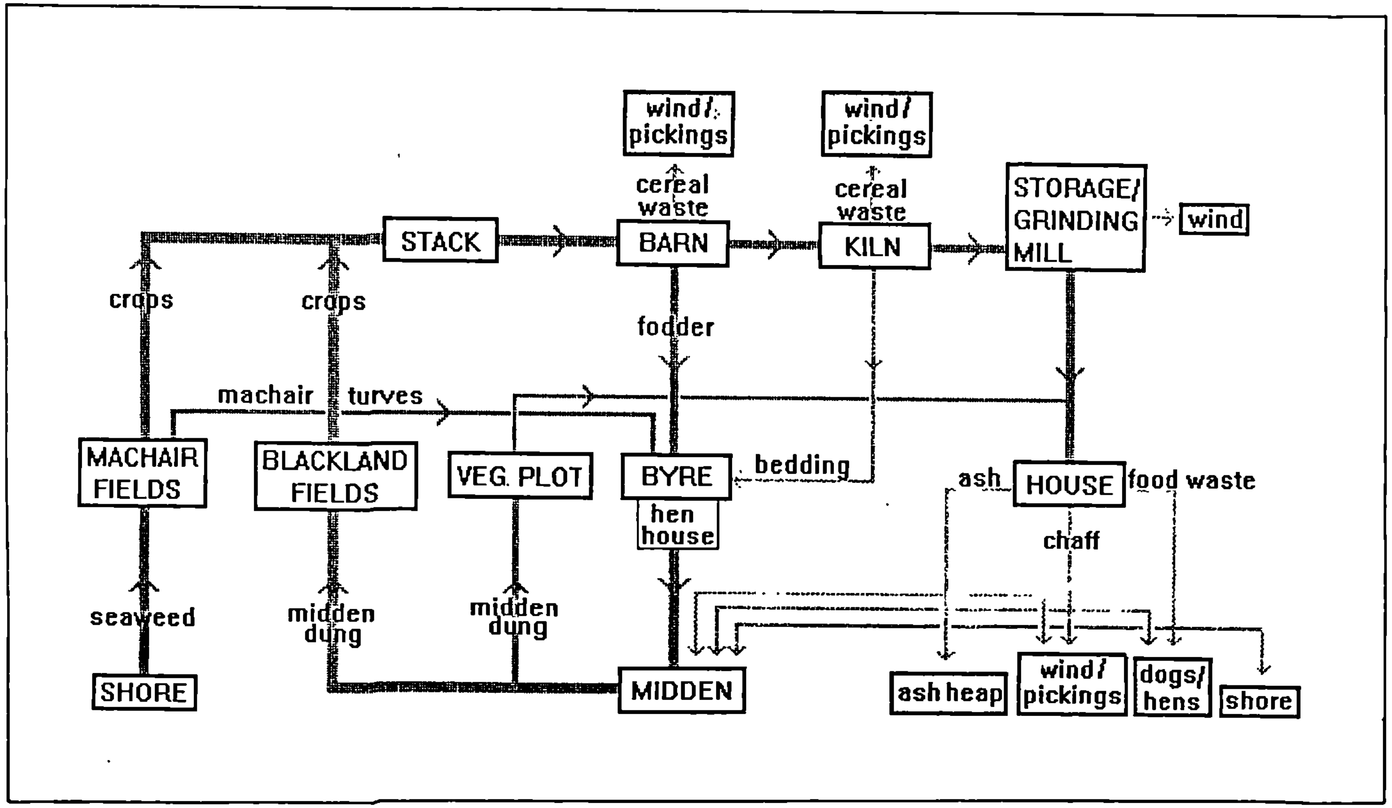


Figure 7.1: The use and disposal of resources.