EARLY MEDIEVAL LANDSCAPES: LINDISFARNE - A CASE STUDY

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by

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Preface

This research is an integral part of an ongoing archaeological field project on the Northumbrian island of Lindisfarne (also known as Holy Island) directed by Deirdre O'Sullivan and Rob Young of the School of Archaeological Studies at the University of Leicester. The project is multi-period, and has investigated sites spanning from the Mesolithic to the industrial period. The specific aim of the work for this thesis is the reconstruction the environment contemporary with the early medieval settlement site of Green Shiel on the north shore of Lindisfarne, and to consider the relationship of environment to site function and economy. The principle aim of the work is to show how no site can be interpreted without recourse to a wide range of data sources including archaeological data, environmental evidence and historical sources. Fundamental to such a synthetic approach is the analysis of spatial scales beyond the site itself as no settlement can be interpreted in isolation from other settlements and the broader landscape.

The reconstruction of the environment around the Green Shiel site is located within a broader discussion of the early medieval period in Northumberland. It is argued that the interpretation of this site, and indeed any site, is limited if off-site environmental reconstruction is not attempted. Such work should then be integrated within a broader historical framework that considers the nature of socio-economic systems that would have obviously influenced the ways in which any environment was exploited.

This research was carried out as a part of the Lindisfarne Excavation Project which many people have been involved with. Other than thanking my two supervisors, Tony Brown and Deirdre O'Sullivan, special thanks must also go to Rob Young, co-director of the Lindisfarne project. I am also indebted to a number of other people who have contributed to the project and have allowed me to consult the results of their own work, most notably Pete Boyer and Sarah Crane. I should also like to thank the following people for their assistance and advice during the period of research: Martin Bell, Neil Christie, Gerraint Coles, Tony Gouldwell, Graham Morgan, Andy Plater, Alex Powers, Michael Tooley, Marijke van der Veen, and David O'Connor and Phil Davey of the English Nature NNR.
CHAPTER 1
APPROACHES TO ENVIRONMENT AND SUBSISTENCE IN HISTORICAL ARCHAEOLOGY

Introduction

This thesis examines approaches to the investigation of early medieval settlement with a particular emphasis on the study of the immediate environmental context, but with the broader aim of understanding the relationship between settlement and landscape. The thesis is concerned to show that any site's function cannot be understood without an investigation of the site's immediate environs. To put it simply, no site is an island functioning in an hermetically sealed environment that is comprised of the settlement site itself and nothing else.

In the light of this observation, a working definition of the term "site" is required. In this thesis I take site to mean the locality where an identifiable group of buildings would have functioned as a unit, where the inhabitants exploited common resources, and spent the majority of their working and resting lives. The immediate environs, beyond the site itself, is usually an area that would have been key to the function of the site. This is where the potential for local economic activity would have been located. The thesis argues that the investigation of this area, as well as the wider landscape, or region, is a prerequisite for any real understanding of economy and subsistence. The study of the relationships with, and the exploitation of, these different elements of the landscape that lie beyond the settlement itself is crucial to our understanding of both site function, and wider social processes in the past. For example, we must understand the nature of socio-political organisation in a region if we are to understand the specific economic practices at an individual site. The multiple-estate, as manifested in early medieval England, organised and promoted quite specific socio-economic practices at the level of the manor and in some cases, the region. The multiple estate can be considered as a collection of territories whose environments were exploited in co-operation for the mutual benefit of each member of the multiple estate. During the medieval period the central administration of such an estate was often ecclesiastical, although the structure and organisation of multiple estates clearly varies from their possible origins in the prehistoric period, through to the later medieval period (see O'Sullivan 1984: 146-148). This type of inter-settlement organisation clearly influenced the ways in which a particular community exploited a particular environment or landscape. A multi-layered approach to the study of early medieval settlement and economy is necessary if we are to elucidate fully, not just the function of individual settlements, but the socio-economic networks of the region as a whole. This approach is illustrated in the thesis through the
case-study of the Green Shiel Anglo-Saxon settlement on the north shore of Lindisfarne, Northumberland. The thesis considers a broad range of environmental reconstruction techniques and shows how an understanding of the immediate environs, the regional environment, as well as the socio-economic structures within which the site functioned, is crucial if the settlement's economy is to be elucidated fully.

Whereas prehistorians have long recognised the value of investigating the physical/environmental context in which archaeological sites are located (for example, Fox 1933), archaeologists who work in the historic period have often neglected environmental research. In the first part of this chapter this problem will be considered in the context of the development of the archaeological investigations into medieval rural sites/settlements.

The following section outlines the development of medieval studies since the Second World War in conjunction with a discussion of the range of approaches to medieval archaeology that have dominated the discipline during the post-war period. This discussion is pursued with reference to a series of excavations of medieval settlements, specifically outlining the different approaches to environmental studies (if any) that have been adopted by the various practitioners. In the light of these discussions, the approach taken during this research is briefly discussed: it is argued that the investigation of any site's environmental context is a prerequisite to our understanding of that site. However, it is also argued that the indiscriminate use of environmental evidence without a critical awareness of its shortcomings is a serious problem. Working in the historical period there is danger of one type of "strong" evidence being used to reinforce another "weaker" piece of evidence. Accepting that the integration of environmental data with both archaeological and historical evidence is a prerequisite to understanding human interaction with the landscape, we should be aware that this approach is not without its own problems.

**Approaches To Medieval Rural Settlement**

**Introduction**

Since the Second World War the archaeological investigation of medieval settlement has been dominated by approaches which emphasise artefacts and chronology, and the structural detail and morphology within settlements. More recently there has been some emphasis on broader landscape and environmental approaches where some attempt has been made to understand the subsistence and economic processes related to medieval settlement. However, it is only during recent years that any effort has been made to integrate these approaches.
While archaeological research into medieval rural settlement has been quite limited in its aims and approach, the study of early medieval settlement has in some ways been even more restricted in its outlook. During the early phase of research into deserted medieval villages, many practitioners appeared to work on the assumption that such settlements would literally have Anglo-Saxon foundations (e.g. Hurst & Hurst 1969; Beresford 1975). However, once it was realised that the development of most post-Conquest rural settlement was quite independent of any early medieval antecedents, research into Anglo-Saxon rural settlement developed in its own right.

As archaeological investigations of Anglo-Saxon settlement developed, the emphasis on the investigation of building form and the study of artefact types remained at the fore. The investigations of the buildings at Chalton in Hampshire are representative of this phase of enquiry (Addyman & Leigh 1972). Here, the principle aim was to offer a series of possible reconstructions of some of the buildings.

We should not be surprised that much archaeological research into medieval settlement has traditionally concentrated on the investigation of building structures, settlement morphology and artefacts. These approaches are obviously necessary if we are to understand past economic and subsistence structures. The investigation of buildings and material culture is obviously the foundation of all archaeology: we cannot hope to understand any socio-economic system without understanding the physical structures that constitute the settlement. However, this type of strategy, which places so much emphasis on the physical remains of the settlement itself without recourse to the occupants' interaction with the landscape as a whole, does not and cannot fully elucidate questions of economy and subsistence. The following section discusses recent trends in medieval archaeology through an examination of a series of themes which have been important in the study of medieval rural settlement since the Second World War. The themes are considered with reference to a series of archaeological projects. The majority of the sites considered in this section are from the north of England, particularly the north-east. The principle reason for this is that this area forms the region within which the case study site (Green Shiel, Lindisfarne) is located. Also, some of them have similarities with Green Shiel and they are good examples of the types of approaches adopted during the 1970s and 1980s; and finally, they highlight a diversity of preservation conditions, environment, and location. Other sites from outside this region have been selected as they are representative of certain types of approach to the study of medieval rural settlement.
Historical Approaches

Before discussing the various archaeological approaches to the study of medieval rural settlement, a brief discussion of the impact of historical studies on medieval archaeology is useful. In some ways it is easier to turn this on its head and consider the impact of medieval archaeology on historians. More often than not historians working in the medieval period have ignored archaeological research, even stating that it is an expensive way of telling us what we already know (Sawyer 1983: 44). However, this comment merely reveals some historians' preoccupation with producing a specific type of narrative. In many ways medieval historians, more than historians who work in other periods, have been true to Ranke's idea of history: a history which is almost obsessed with Kingship and nationhood (for example see Ranke 1875). As Marwick observes, Ranke 'shared the belief that the national political state was vital to the progress of human society. Religious and political fervour came together in Ranke's conviction that nation states were "thoughts of god", and, partly because the newly opened archives in which he was particularly interested were necessarily the archives of princes and prelates (the poor do not leave much in the way of primary sources), he gave history a firm orientation towards "past politics" and the relations between states ("diplomatic history"), together known as Staatengeschichte or political history' (1989: 43-44). A review of some titles of recent books on early medieval history reiterates this point: The Origins of Anglo-Saxon Kingdoms (Bassett 1989); The Earliest English Kings (Kirby 1991); The Governance of Anglo-Saxon England (Loyn 1984); Kings and Kingdoms of Early Anglo-Saxon England (Yorke 1990). Of course all of these books include references to archaeological material, but only to substantiate hypotheses on the development of government and nationhood through references to perceived important sites such as Sutton Hoo or Yeavering. One of these volumes (that edited by Bassett 1989) does include contributions from archaeologists. A valuable contribution by Martin Carver shows how archaeological evidence can be employed to elucidate discussions of kingship and the development of so-called nations (1989: 147-170).

Much of the historical analysis of the period would seem to be founded on the idea of the inevitability of the emergence of England as a nation. The discussions revolve around an idea of ever coalescing localities and regions which "must" ultimately constitute the nation. Such histories concentrate on premises of continuity and have had an undeniable impact on archaeological interpretation, notably Hope-Taylor's discussion of Yeavering and his preoccupation with continuity from the British to the English (Hope-Taylor 1977). It is also important to realise that the Yeavering report was used by Hope-Taylor as a vehicle to discuss his ideas on settlement continuity in the 5th-7th centuries. There is a lengthy discussion of Yeavering's position as a
political centre and the development of Bernicia as a kingdom. The discussion covers battles and frontiers with very little consideration of the nature of the local economy and environment. This discussion is part and parcel of a wider discussion which is concerned with the Bernician "culture", art and religion, and the networks of influence which affected these. By its very nature, the Coastal Zone was bound ultimately to attract and foster all that was outward-looking and dynamic in the Bernician world. Offering its own rewards to the initiative of the more enterprising farmer, and doubtless to fishing communities also, it gave scope and economic basis for the growth of a new and more progressive society' (Hope-Taylor 1977: 26-27). Environmental determinism runs through much of the interpretation of Yeavering. There would seem to be an assumption that the economy and environment were passive contexts which served as an unimportant backdrop to these political, regal, religious and artistic developments.

Despite the fact that Hope-Taylor did appreciate that Yeavering needed to be placed within a broader spatial context which included social and cultural contexts, it is apparent that this was done because Yeavering was seen as a central place. Therefore, Hope-Taylor was largely concerned to describe the possible impact that Yeavering had on other places as a part of his wider preoccupation with cultural continuity. Hope-Taylor was not so concerned to detail Yeavering's economic relationships with other places and show that it would have been reliant on other settlements for many of its requirements.

Many of these historical discourses are founded on discussions of space, and the changing loyalties that people supposedly felt to new constructions and articulations of space: from the immediate locality to "the nation". These historical studies place their emphases of study on one or two particular spatial scales, usually the region and then the nation.

Even if we ignore the ideological problems of placing so much emphasis on the analysis of kingship and supposed natural and inevitable emergence of England the nation, there is a methodological problem with the historian's approach to the subject. Reliance on historical sources is problematical and does not require full discussion here. The reliance on documentary evidence when researching a subject which is clearly about changing patterns of organisation at different spatial scales is dubious. Historians, even when researching the development of kingship and nationhood, should exploit archaeological evidence which does provide detail of socio-economic development in both urban and rural landscapes, and at different spatial scales. The production of historical narratives based on very particular data types denies the potential of the synthesis of history and archaeology. This thesis is concerned to show
how the use of very different data types or sources can produce useful and rewarding interpretations.
**Artefacts and Chronology**

Unsurprisingly there has been much emphasis on the study of artefacts from medieval sites; this is quite justifiably the *raison d'être* and the foundation of much archaeology. However, research into medieval material culture has in many cases been dominated by an art historical approach where, more often than not, emphasis has been placed on aesthetics and the fetishisation of the object. As Dickinson has shown (1983:33-43), during the first two decades after World War II medieval archaeology, and early medieval archaeology in particular, tended to concentrate on the study of artefacts. Her survey of the contents of the first 24 volumes of *Medieval Archaeology* is quite revealing: artefactual studies dominate the journal during the 1960s and 70s (1983: 37). The emphasis on artefact studies continued as a lynchpin for the subject into the 1970s and 80s. Medieval archaeologists have been much concerned with artefacts, their classification and art-styles (Dickinson 1983: 35). The study of metalwork in particular has been, and still is, a mainstay of Anglo-Saxon artefact studies.

The emphasis on the collection and analysis of material culture above many other areas of study is epitomised by the fact that one of the most influential research groups in British medieval archaeology is undoubtedly the Medieval Pottery Research Group. In many ways the study of artefacts, especially pottery and coins, has always been a study of chronology first, and industry and economics second.

An accurate chronological framework is clearly necessary if the archaeological evidence is to be integrated successfully with historical evidence. The study of artefacts from medieval sites has taught us a great deal about medieval society. Discussions of pottery forms and grave goods has initiated much interest in ideas about status, power and ideology. However, the study of material culture is crucial to our understanding of medieval economy and society, the emphasis on this type of material does tend to detract from our ability to discuss broader historical processes and the nature of human/landscape development. This is especially true in a region where there tends to be a dearth of artefactual evidence on medieval sites. The labelling of northern early medieval settlements such as Ribblehead (King 1978), and Simy Folds (Coggins et al. 1983) as "poor" because few artefacts are recovered reveals the short-sightedness of a discipline that places too much emphasis on the study of objects, rather than considering the broader questions of human/environment interaction and what this kind of study can tell us about socio-economic process.
Structural Detail and Settlement Morphology

It would be misleading to state that the majority of archaeological research into the medieval period has concentrated largely on the study of artefacts. In recent decades, especially since the 1960s, there has been much emphasis on the study of settlement. The study of settlement, especially the description of buildings and sometimes, discussions of industry, have been key areas in early medieval archaeology. Dickinson's survey of contributions to Medieval Archaeology clearly shows that from the mid-1960s onwards site reports increased as contributions to this journal (1983: 37). The study of cemeteries was also of key importance during the immediate post-war decades. During the late 1960s and up to the current period, one important trend has been the movement towards the study of large settlement sites such as Mucking and Spong Hill (Jones and Jones 1975; Hills 1977).

Once archaeologists began to excavate medieval sites, they had clearly defined objectives and placed great emphasis on answering very particular questions. More often than not, excavations of deserted medieval villages aimed particularly to ascertain the date of abandonment (Beresford 1986; Taylor 1992: 6).

There can be no doubt that in the study of rural medieval settlement the Medieval Village Research Group has been the most influential body. This organisation was founded in 1952 with the specific aim of 'co-ordinating work on deserted medieval villages' (Beresford 1983: 91). As is transparent in the original name of the group, the fundamental research priority was the investigation of village desertion during the medieval period. The word "deserted" was dropped from the body's title in 1971, thus indicating a developing interest in all aspects of medieval settlement (Beresford 1983: 91). Initially the group concentrated its efforts on the identification of deserted villages, largely through ground visits and more importantly, through air photography.

During the 1940s through to the 1960s historical studies were carried out, most notably by Hoskins in Leicestershire (1955), and Beresford in Buckinghamshire, Warwickshire and Yorkshire (1954). During the late 1960s and into the 1970s as threats to a number of sites emerged, the total excavation of some of these was pursued.

As noted above, the investigation of many sites has concentrated on the building structures themselves and the morphology of the settlement as a whole. A number of recent examples of this approach, where the majority of effort was placed on the study of the building forms and little else, are detailed here.
One of the largest excavations of a medieval site in the north-east of England was that at West Whelpington (NY 974837) (Evans & Jarrett 1987; Evans et al. 1988). This site is located on the north bank of the River Wansbeck, 2.4 km west of Kirkwhelpington in Northumberland. Over a period of fifteen years, during the 1960s and 1970s, an area of 14,000 m² was uncovered. A total of 95 medieval and post-medieval buildings was surveyed. The authors contend that 'this makes it possible to say something of value about the whole village and about building traditions there, as well as discussing individual structures within the village' (Evans & Jarrett 1987: 203). Emphasis was undoubtedly placed on the investigation of the building structures, with the declared aim of investigating part of every building.

The excavation report includes some discussion of the crofts, enclosures, folds and pens. The consideration of this important element of the site is largely confined to the construction of the crofts. The broader discussion does briefly consider the function and importance of these elements. A final discussion of the later enclosures and their exploitation in relation to changes in the methods of animal husbandry is based on morphological evidence pertaining to the early nineteenth century strategy of husbandry in Northumberland, where young poultry, pigs and coals were kept in the inner yard, while the outer fold yards were kept for cattle (Evans & Jarrett 1987: 303).

This project placed priority on the investigation and description of the various building structures. No attempt was made to understand the settlement's relationship with the surrounding environment. What little discussion there is of site function is based on the morphological similarities of some of the excavated structures with nineteenth century equivalents (though even if the function of these buildings was the same, it does not necessarily follow that the settlement's economic function was the same).

A similar emphasis on building structure and settlement morphology was placed on the investigation of the medieval settlement at Thirlings (NT956322). This site is located on the terrace surface in the Milfield basin (O'Brien & Miket 1991). The site was first excavated in 1973 after a series of buildings were spotted on an air photograph. The settlement consists of thirteen structures, some of which conform closely to the minor halls of Anglo-Saxon date (Miket 1974: 183; O'Brien & Miket 1991). The first building excavated measured 12m x 6.1m and some sherds of Anglo-Saxon and later date were discovered. Another building, 10.4m x 5.6m, was excavated during the following season. Also, some linear features were discovered which were '...tentatively identified as part of medieval ridge and furrow' (Miket 1975: 226-7).

In 1976, perhaps more interestingly, a series of five post pits were excavated. These were interpreted as the inner posts of a fenced compound associated with one of the
buildings. There was however no discussion of the possible function of this feature and one can only assume that it served as some kind of animal compound.

The final report on the early medieval settlement at Thirlings includes a very extensive discussion of the 'architectural and structural aspects of the buildings'. This section considers the various possible forms of plank construction and the possible roof forms (O'Brien & Miket 1991: 78-87).

In all of the notes on this excavation, and in the final report, the emphasis is on the description of the characteristics of the buildings: there is no consideration of the economy and the site's relationship with, and exploitation of, the environment. The excavations seem to have been primarily concerned to recover structural remains.

Investigations into crop marks at New Bewick (NU 060 206) and Milfield (NU 050 380) adopted a similar approach to that outlined above. At New Bewick the excavation area selected included one of the larger, and three smaller, examples of these presumed Grubenhäuser. The largest pit-like feature was confirmed as a Grubenhaus. It was 0.5m deep, with steeply cut sides and a flat bottom. It was sub rectangular in plan and 4.7m long and at its maximum, 3.9m wide. Post holes were identified within the pit at each end and against the edge (Gates & O'Brien 1988: 5).

In some cases the interpretation of some sites has been based on the interpretation of earthwork morphology alone. The impact of air photography was of great importance to medieval archaeology, with many new sites being discovered, especially during the 1960s. An example of a project where air-photography was the main approach to the study of the site is Milfield where no excavation has been undertaken (Gates & O'Brien 1988). Consequently the interpretation of this site is based on the morphology of crop-marks. The air photographs of this site indicate the existence of over 60 'small spots or blobs' as well as about 40 sub-rectangular markings which vary between 2-5m in length and 2-4m in width. The main conclusion drawn from the study of these is that the site contains features which conform to other Grubenhaus sites (Gates & O'Brien 1988: 3). The authors are confident that the fact that the crop mark at New Bewick was proven to be a Grubenhaus means that the other similar crop marks at this site along with those recognised at Milfield and Thirlings can also be identified as similar structures.

The investigations at New Bewick and Milfield are an interesting example of the approaches taken in the study of Anglo-Saxon sites. The excavation of the crop-marks at New Bewick are quite typical in their emphasis on the study of building morphology and structure. However, the interpretation of the crop-marks at Milfield based purely on their appearance in an air-photograph takes the paradigm to its extreme.
As before, there is a clear problem in studying any site in isolation: West Whelpington, indeed, any site, cannot be understood by making simplistic inferences based on site morphology. The position of the site within an ever changing socio-economic and cultural context must be understood before any reliable discussion of site function can take place.

*Landscape and Economy*

Although all excavations necessarily place a great deal of emphasis on building structure and site morphology, not all have failed to locate the site within the broader context of landscape. During the 1970s and 1980s especially, a number of projects started to consider the broader landscape contexts within which sites were situated. These approaches have included investigations of some palaeoecological data, geomorphology (especially soil characteristics) and subsistence evidence. However, in most cases these new approaches were not extensively pursued and most effort was still put into the investigation of buildings and material culture. There was rarely any explicit attempt to reconstruct the extent and nature of the landscape elements at different spatial scales: for example, the importance of the immediate locality moving up to the region and then ultimately, the nation was rarely considered; and neither was the study of the extent and nature of a settlement's various economic relationships and networks.

An important project which did move beyond traditional site-based approaches to a certain extent was that at Wharram Percy. In more recent years the Wharram Percy excavations have emerged as one of the most important medieval projects in Britain. It should be noted that despite the publication of a popular monograph (Beresford & Hurst 1990), much of the material (including much of the environmental evidence) from the excavations has not yet been published. Despite the fact that this project was innovative in its research strategies and made every attempt to employ state of the art excavation techniques, the majority of effort was nevertheless put into the investigation of structures and artefacts.

The general discussion of settlement history considers the location and numbers of buildings. Apart from observing the obvious, such as, the fact that farming was the main form of economic practice, there is little specific discussion of environment and economy.

The authors go on to consider the location of a "high status" middle-Saxon site. In terms of economic practice we are told that 'The general picture is similar to that in the Roman period, with farms spaced irregularly in the landscape' (Beresford & Hurst
1990: 84). It is suggested that during the middle Saxon period Wharram was a small monastic site. Between the ninth and twelfth centuries it is hypothesised that the transition from a scattered settlement to a village with compact groups of houses took place (Beresford & Hurst 1990: 84).

Again, this report is largely concerned with a consideration of the structural evidence and the plan of the village and its development through time. Considerations of environment and subsistence are secondary, although the site reconstruction drawings by English Heritage have been drawn with the environment contemporary with the settlement in mind.

As stated earlier in this chapter, the investigation of buildings and artefacts is of course crucial to any study of past human practices. However, the problem arises when we consider the reasoning behind the inferences that archaeologists have made from these datasets: does the data produced during the archaeological investigations actually support the inferences made regarding economy and subsistence? As medieval archaeologists have become more concerned with discussions of site economy and subsistence they seem to have placed too much emphasis on site-based evidence.

At Heslerton, another important medieval research project, a broader landscape approach was taken. The ongoing Heslerton project was designed to investigate a "...representative archaeological sample of an extensive landscape..." in North Yorkshire (Powlesland et al. 1986: 55). A parish transect running perpendicular to geological, topographical and environmental regions measuring roughly 80 km² is being investigated. Some pedological analyses were carried out, and as a result of some of this work an environmental and activity diagram was produced (Powlesland et al. 1986: 168). This diagram is divided into three sections which describe the following: the broad ecological characteristics of the area; the fundamental characteristics of the soil in the area; and the nature of the processes responsible for this soil development. All of this is correlated with trends in human settlement through time.

The environmental work included in this first report of the Heslerton project is typical of many such reports which often divorce the environmental data from the rest of the archaeology, or employ it to make generalised and unsubstantiated observations. In the conclusion to the report it is noted that the light soils in this area "...provided a setting for very early agriculture" (Powlesland et al. 1986: 169). This statement is quite typical of a certain style of archaeological investigation which tends to perceive the environment as an inactive setting without the dynamics of human/environment relationships, where human understandings of the environment dictate the ways in which the potential resources in that environment are both exploited and influenced.
On a smaller scale at Simy Folds some effort was also made to understand the site's relationship with the immediate landscape, albeit at a relatively superficial level. Simy Folds (NY888277) is an early medieval site on Holwick Fell which forms the higher slopes of the Tees Valley. Bone material from this site has been carbon 14 dated to the mid-eighth century (1210±80 b.p., HAR 4034; 1170±70 b.p. HAR 1898). The site was comprised of single long, narrow buildings with one or two small sub-rectangular buildings at right angles to the larger buildings. These were arranged in such a way so as to enclose a yard. Each of the excavated buildings contained a hearth, and therefore it is assumed that these structures were for human habitation and not just for livestock. A field system adjacent to the site was also identified, and is thought to be of prehistoric origin. This is inferred from a polished stone-axe from beneath the wall of one building, and a prehistoric clearance level in the pollen diagram. It is proposed that this field system continued to be used into the medieval period (Coggins et al. 1983: 20-21).

Despite the lack of direct evidence for economic practices, some attempt was made to locate the site in its broader landscape through pollen work undertaken by Alison Donaldson. A peat column from a hollow directly above the whin sill (volcanic intrusions which form ridges in many parts of Northumbria) some 200 m NW of the site was investigated. The third zone in this column, which post-dates a carbon 14 date of 2440 ± 80 b.p. (HAR 3791), is dominated by herbaceous pollen and also contains cereal-type pollen. The cereal pollen is only present in this final zone, and only for a part of this zone. This final zone also includes pollen of weeds associated with pastoral activity, including docks. The authors contend that part of this final zone corresponds to the period of Anglo-Saxon settlement. Despite the lack of artefactual evidence for arable farming, from the facts that three of the buildings were undoubtedly integrated into the area's field system and the pollen diagram indicates both arable and pastoral activity, it is suggested that a mixed farming strategy of some sort was pursued. The lack of animal bone was also a problem in terms of interpreting the subsistence strategy of this site. The dearth of this type of material was a consequence of bad preservation due to the acidic soils.

At Simy Folds it was clearly difficult for the type of evidence available to contribute anything specific to the discussion of the early medieval environment and subsistence strategies. Despite this, the pollen diagram does indicate a period of relatively intense agricultural activity some time during the early part of the first millennium AD.

The work carried out at Simy Folds can be considered typical of excavations of relatively small medieval sites. The explicit aim is the investigation of the structures and any artefacts that might be found. It is important to appreciate the different levels of spatial scale that archaeologists work at. Projects such as that at Simy Folds are usually
only concerned with the immediate site, and not with surrounding landscape, or the wider scale of the region which would probably have been important to the settlements' economy. The interpretation of site function at Simy Folds is partly based on a loosely dated pollen diagram and a certain amount of supposition. Although the author is obviously aware of the restrictions and problems of the data types employed, there is no critical discussion of these problems, and the attempt at contextualising the site in its broader landscape is limited, although some effort to do this has clearly been made. However, little attempt was made to consider the broader socio-economic processes in the region that would clearly have affected the settlement's function.

An integral part of the move towards investigating the broader issues of landscape and environment was the emphasis on attempting to understand economy and the exploitation of natural resources. Rather than concentrating on the industries and economies associated with artefacts such as coins and pots, medieval research began to consider subsistence patterns and different forms agricultural systems. For example, the authors of the Simy Folds report also attempted to estimate the potential crop yield for this site based on the probable field area. Their calculations take into account the lower yields of ancient crops and less efficient farming methods. Assuming that one third of a crop would have been kept for seed the authors estimate that Simy Folds could have maintained three families of six persons per year (Coggins et al. 1983: 21-2).

An early example of a medieval project which did employ a broad strategy that included environmental research in order to reconstruct economy and subsistence was that at Yeavering (NT925306). However, despite the fact that a comprehensive research strategy was adopted, the declared emphasis was still on the recovery of structural detail and sequence (Hope-Taylor 1977: 28).

The research into environment and subsistence which was carried out included a consideration of the faunal remains and some charcoal. Admittedly the acidic soil did much to contribute to differential, and probably, limited preservation of much evidence. The faunal record shows that "...systematic cattle breeding was an important activity in the surrounding areas" (Hope-Taylor 1977: 326). Over the site cattle comprised 91.7% to 97% of the assemblage with sheep, pig, goat, and horse contributing relatively small amounts of bone to the assemblage. The analysis of the assemblage shows that there were two killing peaks: the first between 6-12 months and the second between 18 and 35 months (Higgs & Jarman 1977: 331). There is no detail on the sexing of the cattle, and for this reason there is no clear suggestion as to the specific system of exploitation, for example, whether the herd was kept primarily for dairying or for meat production.
The Yeavering project was one of the first medieval excavations that placed some emphasis on the study of the site's environmental and landscape contexts. At the local level an attempt was made to understand its relationship with the pre-existing Celtic field-system. The field-system is tentatively dated to the first century BC or the first century AD. Of the field system Hope-Taylor observed that it resembled the "most regular" of the various "Celtic" field-systems found in southern England (Hope-Taylor 1977: 204). It is assumed that this system was considered adequate and was continually exploited into the early middle-ages. However, despite the fact that there is an extensive faunal report in the Yeavering monograph, it is interesting to note that Hope-Taylor himself was primarily interested in the site's buildings, any emphasis on subsistence patterns was due to the work of the Cambridge palaeoeconomists Higgs and Jarman (see their report in Hope-Taylor 1977).

One piece of environmental evidence which is given some emphasis is a series of modern land-use and soil quality maps which are considered to explain why settlement occurred where it did. The distribution of known sites is compared with the distribution of modern soil types and land-use categories: "...a striking correlation is revealed between areas of exceptionally intensive occupation and the incidence of pervious soils such as gravel and sands' (Hope-Taylor 1977: 17).

In a more general discussion of the site's function the following observations were made. The economy of this area was predominantly pastoral. As the upland areas were probably covered with snow from November to April it is likely that any settlements located here were not occupied all year round. Such sites could have been in areas of summer grazing for livestock. The report does not refer to any settlements in particular, the implication being that Yeavering was a central place from which the surrounding area was exploited.

It is clear that during the last two decades especially, there has been a small, but discernible, trend towards the study of the broader landscape contexts of medieval sites. However, there is no accepted framework or approach for this type of study, and much of the work that has taken place still seems to be secondary to the site-based approach and the investigation of structures and artefacts.

**Environmental Approaches**

In this section, projects that have put a clear priority on the sampling and analysis of environmental evidence and its synthesis with other types of evidence are considered. This type of approach is still relatively rare in medieval archaeology, and some might
argue that rigorous environmental strategies are only employed when there is a dearth of artefactual and structural evidence.

For the greater part of the post World War Two period, environmental approaches have not been an integral element of pre-excavation research design. Environmental techniques were first employed on long-term projects where the use of "innovative" techniques could be applied as a kind of experiment. Even where environmental techniques have been applied on medieval sites in Britain, their extent of use has been quite restricted.

The investigations at Wharram Percy were not only innovative in their consideration of surrounding landscape development (albeit quite restricted in outlook), but also in their inclusion of environmental work, including geomorphological research. The most important geomorphological features investigated were the terrace-like features along the valley sides where the church, the vicarages and cottages were built (Stamper 1982: 17). Other geomorphological work included investigations into some of the soils and sediments. Comparisons between archaeological and "natural" deposits were made. We are not given any specific details as to the provenance of these samples, the methods employed, or the results of the work. However, we are given some general conclusions. The investigations indicated that the area where the church is sited was formerly covered with "reddish brown deposits", and it is thought that intensive use of this area led to the erosion of this soil (Stamper 1983: 25-26). The association of dark grey or black, rendzina type soils with later Saxon and medieval deposits across the site indicated that much of the original reddish brown soil had been eroded from the upper slopes by the Saxon period.

Unlike the majority of their British counterparts, most Scandinavian medieval archaeologists have approached the investigation of settlement with environmental analyses as an integral part of the research strategy. For example, investigations into human response to climate change in north east Iceland have shown that the population here exploited an increasingly wide range of animal resources once the climate began to deteriorate (Amorosi 1992). This project, and others in Scandinavia, have placed a great deal of emphasis on the study of both faunal, botanical and palaeoecological evidence (see Zutter 1992; Buckland et al. 1992). This projects also attempts a broader synthetic approach, considering not just the environmental evidence, but artefactual, settlement and historical evidence as well. This approach is of course facilitated by working in the high- and post- medieval periods, where, in most cases, more data is available.

One British early medieval project which has placed continual emphasis on environmental research is the Birsay Bay project on Orkney. It is one of the few
projects in British medieval archaeology that has attempted to integrate fully research into settlement structure/morphology, artefacts, palaeoenvironmental data, and historical evidence. Most importantly, the project has placed some emphasis on off-site environmental investigations. One such investigation of a buried soil exposed in section around the shore-line of the point of Buckquoy examined the land molluscan assemblage. These assemblages indicate the existence of woodland during the prehistoric period, but not contemporary with Scandinavian settlement (Morris 1989: 51).

As noted above, all of the sites excavated as a part of this project were subject to extensive environmental investigations. The trial excavations of a building and the sampling from the exposed buried soil beside the Brough road are representative of the strategies followed during this project.

During the excavations all faunal material was collected by hand, and bulk samples were washed through large sieves. The excavations of cliff sections and middens included the analysis of material from monolith samples. Pollen and faunal evidence from these samples were analysed. Pollen was absent from these samples, probably due to the high pH levels of the sediments.

In the synthesis chapter of the Birsay volume a useful review and interpretation of the cultural and environmental material are presented. The evidence presented clearly points to a community involved in mixed agriculture with contributions from "wild" resources also making an important contribution to the resource base. Despite the rigorous approach to the investigations of the archaeology of Birsay, however, the final synthesis does not include a full synthetic account of site function and economy which appreciates the relationships that the sites would have had with other places. Essentially, the report does not locate the sites within their broader historical context. This is presumably largely due to the fact that other volumes from this project will be forthcoming.

Discussion

From the above discussion it should be clear that in the last 50 years there has been a growing recognition of the need to carry out environmental investigations as an integral part of the more orthodox archaeological enterprise. This development is partly illustrated by the Wharram project which began just after the war and continued for over forty years. The Wharram project undoubtedly both initiated and reflected developments in post-war archaeology. This project, like that at Heslerton, was a major
research project which after a while attempted, to a certain extent, to integrate environmental research with the rest of the project. It would seem that such strategies tend to be adopted in longer term projects where it is felt that less orthodox methods and strategies can be risked. Also, it is quite probable that these techniques were exploited as part of a need to follow new popular trends. Despite this, such developments should be welcomed even if their results do not seem to have been used to their full potential. At both Heslerton and Wharram, despite the environmental programmes initiated as part of these projects, little has been made of the potential of such work.

Few medieval projects have employed environmental evidence to any great extent, and usually when environmental work has been carried out it is often published as a secondary report, removed from the "primary" archaeological interpretations concerned with artefacts and structures. This is partly the case with West Whelpington where the reports on both the plant remains and animal bone are brief and quite insignificant. This may of course be a direct consequence of the lack of reasonable samples for analysis due to the probably acidic nature of the soil. However, one might expect a site in an upland locality to produce a greater range of botanical remains, and at the very least some discussion of local pollen diagrams would have been useful.

In many of the projects considered in this chapter, the emphasis appears to have been placed on naming and describing archaeological characteristics, such as artefacts and structures. In the examples where there was little or no description, let alone discussion, of environmental evidence there was also little or no synthesis of the material, or discussion of process, such as the nature of economic/subsistence strategies. It is not clear whether the archaeologists involved in these projects assumed that the successful identification of a structure type immediately placed it within an implicitly acknowledged system of environmental and economic exploitation. For example, if Grubenhäuser-like structures are identified, should the corollary be that they were necessarily weaving-sheds, huts or shops? As Rahtz observes, these interpretations have often emerged without a strict "...regard for the evidence" (Rahtz 1976: 76). There is undoubtedly a need for a more rigorous examination of all forms of evidence, especially that pertaining to the environment. As mentioned in the discussion of the site at New Bewick, the excavators suggested that because they had shown that the excavated site here was a Grubenhaus, the other morphologically similar crop mark sites in the area could be identified as being the same. Such shortcomings may be a result of a perceived incompatibility in data types, such as artefacts and environmental evidence, or of the expertise and research interests of those archaeologists responsible for these projects. It is only those projects which have been multidisciplinary in outlook that have broached this problem, but to date such approaches to the study of the early
medieval period have been few and far between and consequently many discussions of environment and subsistence have been partly conjectural.

In the majority of the projects described in this chapter there has been little evidence of an appreciation of the importance of studying settlement at different spatial scales, and the relationship between these scales and different types of evidence. For example, off-site environmental analyses often include the analysis of a pollen core from a nearby lake or peat column. The aim of such an investigation is not necessarily to develop an understanding of broader landscape characteristics, but to tie one part of the pollen diagram directly to the period of occupation at the site in question. This is certainly the case with the Simy Folds example detailed earlier in this chapter. Such a diagram should not only be used to infer economic and subsistence strategies that relate directly to the site, but it should, if possible, be related to, and contrasted with, other diagrams from the region.

As Dickinson observes, 'what is notably lacking in the publication record is synthesis, particularly of Anglo-Saxon archaeology as a whole' (1983: 34). Some attempt has been made at synthetic studies, notably in The Archaeology of Anglo-Saxon England (Wilson 1976). However, the individual authors in this book concentrated on very specific aspects of the subject and little attempt was made to look at the relationships, or the potential relationships, between these different areas.

An example of a recent synthetic volume is The Countryside of Medieval England, where a broad range of approaches are discussed (Astill & Grant 1988), rather than in primary research projects, which still (in the majority of cases) emphasise a very particular approach. Other attempts to produce broad synthetic accounts include Klaus Randsborg's The First Millennium AD in Europe and the Mediterranean and Richard Hodges' Dark Age Economics. However, despite both of these books being useful attempts at integrating and synthesising an extensive range of data, there is still a clear need for rigorous investigations of sites, or groups of sites, located within their broader regional contexts.

This thesis shows that an integrated approach is required at the outset of any archaeological project. Accepting that our understanding of medieval sites is greatly enhanced by the study of their associated landscapes, we must be careful not to directly graft the strategies and interpretative models employed by prehistorians directly on medieval archaeology. For example, despite the fact that many of the ideas associated with Vita-Finzi's (1978) site catchment analysis have been questioned, much of the analysis of environmental potential is informed by the notion that the exploitation of resources by any given group is limited to that which is available within the local area (defined in some instances as an area bounded by a circle with a radius of 5km (Vita-
Finzi 1978: 86-87)). Consequently, many prehistoric sites are considered to have had well-defined and bounded exploitation areas. As this thesis argues (see especially chapter 8), this rigid form of site catchment analysis does not always work for more complex societies where socio-economic networks operated over much greater spatial scales. However, despite these provisions, the employment of both, site catchment analysis, and broader regional landscape approaches, is clearly of great potential for medievalists. During the 1980s many prehistorians realised that subsistence and economy could only be understood by locating archaeological sites in their broader regional contexts: The consequences of social and economic complexity can also be investigated through the study of settlement patterns, which make up the regional framework that is the essential counterpart to effective contextual analysis at the level of the individual site' (Barker and Gamble 1985: 13).

It is crucial that archaeologists researching periods where economic networks are more extensive across space, realise that the landscape within which they are working would have been profoundly influenced by processes beyond the locality in which most of their daily lives were carried out. The study of sites in the historic period (and the prehistoric to a lesser extent) demands that the wide range of processes affecting a site be investigated at a number of different spatial scales, and using a wide range of data types. Moving from the smallest scale to the largest, archaeologists are obviously concerned with the investigation of the settlement site itself (this is in fact where much medieval archaeology stops). The next area of investigation must be the site's immediate environment (we might term this the area of direct exploitation) which will often yield more information pertaining to site function than the site structures themselves. It is this scale that this thesis is largely concerned with. In particular, this research has been concerned to unravel geomorphological processes, and thus reconstruct the past topography and the related ecology of the area around Green Shiel. Despite the commitment to the study of environmental processes at this 'mesoscale' it is realised that this evidence by itself is of little use without recourse to the economic, political and cultural processes that were taking place within the estate structure of which Green Shiel must have been a part, and in the wider region as a whole. These processes must have had a direct bearing on the way that the site actually functioned. Although there is a relative dearth of documentary evidence for Northumbria during the Medieval period compared with other parts of the country, our knowledge of social-economic, religious, and political structures is quite well served (see chapter 8).

The Approaches to Green Shiel, Lindisfarne
This thesis therefore investigates the environment and economy of the Green Shiel site on Lindisfarne at three spatial scales. The first scale is the settlement site itself, which is discussed in chapter 2, where the nature of the Green Shiel site, and the material excavated from these buildings, is considered. The second spatial scale is the surrounding environment, the investigation of which forms the principal focus of the new research developed for this thesis. This area includes the shoreline, the sand dunes, and to a lesser extent the island of Lindisfarne as a whole. These topics are covered in depth in chapters three to six. The third and final spatial scale in the region of Northumbria itself. Chapter seven discusses the pollen diagram from the Lindisfarne Lough and relates this to other diagrams from the region, while chapter eight brings all of the evidence for the function of Green Shiel together in synthesis which includes a discussion of historical evidence from the region. Here, the nature of medieval economic practices is considered with recourse to the evidence for socio-economic structures in the region and their possible relationship with a site such as Green Shiel.

Although the Green Shiel settlement is located in an environment which most palaeoecologists would consider as poor in terms of the potential for environmental reconstruction, this environment is a dynamic and important one which does lend itself to extensive geomorphological investigation. Notwithstanding this, the settlement itself is quite enigmatic, with no known parallels in Britain and it was clearly an important early medieval settlement which must have had connections with the established monastic community on Lindisfarne. The importance of the island and the region of Northumbria means that this study is provided with a relatively rich range of sources that allows us to place the Green Shiel site in some kind of socio-economic context. The synthesis of site-based data, environmental data (geomorphological and palaeoecological evidence from around the site and the island) - and regional data (palaeoenvironmental and historical evidence from the north east of England), allows us to consider the function of Green Shiel in a more rigorous manner. It is shown that the contextualisation of such a site within the broader scale of the island and the region allows us to reconsider notions of marginality. Such notions often seem legitimate when a site which is geographically marginal is investigated in isolation without recourse to the wider landscape and regional socio-economic structures. Sites that have been considered as being located in geographically marginal places have consequently been interpreted as economically marginal. This thesis shows how such interpretations are misplaced.

In conclusion the thesis sets out to understand the environment and economy associated with a specific site. The key to this reconstruction is the use of very different data types: archaeological, environmental and historical, used at a number of different spatial scales. In order to articulate a hypothesis regarding economic and subsistence patterns,
each different data type must not only be internally consistent, but each group of data must confirm, or be consistent with, the others. This thesis tests these notions through a critical awareness of the strengths and weaknesses of the different data types used. The dangers of self-reinforcement are also considered, where one weak piece of data is "bolstered" by a stronger one without critical awareness.
CHAPTER 2.

INTRODUCTION TO THE CASE STUDY

Introduction

This chapter considers the history of archaeological investigations on Lindisfarne, concentrating on the work carried out by the School Of Archaeological Studies at the University of Leicester, and between 1983 and 1987, the archaeology unit at St David's University College, Lampeter. An outline of all of the various projects investigating different periods of the island's past is given, but emphasis is placed on the investigations carried out at the Anglo-Saxon site at Green Shiel, on the north shore of the island.

Archaeological Investigations on Lindisfarne

The island of Lindisfarne, or more precisely, the tombolo (tidal island), lies off the extreme north-east coast of England, just to the south of Berwick-Upon-Tweed. Research on the island has shown that human occupation has been almost continuous throughout the Holocene. The following section introduces this work, and considers the background to the research into the Dark Age site at Green Shiel on the north shore of the island. Much of the archaeological work on Lindisfarne before the present project was concentrated on the area in and around the area of the modern village (see figure 2.1 for the location of all the sites mentioned in the text). The emphasis on excavation in and around the modern village is clearly misplaced, or rather, it is the result of the desire of previous researchers to elucidate the ecclesiastical history of the island above all else. The Lindisfarne research project is redressing the balance through research covering the whole of Lindisfarne, throughout the prehistoric and historic periods.
The first documented excavation on Lindisfarne took place during the late nineteenth century. An excavation in the cloister of the medieval priory was carried out by Sir William Crossman, the Lord of the Manor of Holy Island (Beavitt et al. 1987: 1). Crossman also produced the first detailed plan of the priory and the remains on St Cuthbert's Island (Crossman, 1892a; 1892b). Building work in the village before and after World War I produced fragments of Anglo-Saxon sculpture. No other work in this part of the island was carried out until 1977 when Deirdre O'Sullivan directed an excavation on the site of the new English Heritage museum (O'Sullivan et al., 1985). After a period of "reconnaissance fieldwork" in 1980, the Department of Archaeology of the University of Leicester and the archaeology unit of Saint David's University College, Lampeter, began a series of excavations on the island in 1983.

Despite the fact that this thesis is largely concerned with a consideration of the Dark Age environment, one important theme of this, and any environmental research, is the need to consider human exploitation, environmental processes, and the relationship between the two, on either side of the period with which the research is concerned. The research project has a number of fundamental aims. The most basic is the investigation of the entire settlement record of the tombolo for both the prehistoric and historic periods: as the record stands at the moment; from the Mesolithic through to the industrial exploitation of the island during the nineteenth and early twentieth centuries. In each of the areas investigated so far, the project has been concerned to elucidate the changing relationships that the inhabitants of
Lindisfarne have had with their own immediate environment, as well as the mainland and the sea. Another important area for discussion is how the nature of the current perception of the island, and especially the north shore, as a "marginal" environment relates to the reconstruction of this palaeoenvironment (see chapters 8 & 9).

At the moment (1993), the project has investigated three principle chronological periods. As well as the early medieval settlement at Green Shiel (which serves as the case study for this thesis) the project has also investigated evidence for Mesolithic settlement, and late- to post-medieval occupation on the island.

The evidence for prehistoric activity on the island, although sparse for some periods, does indicate continued settlement on the island throughout the Holocene. The evidence for early exploitation implies that Lindisfarne (or the place that became Lindisfarne) was visited by Mesolithic hunter-gatherers. The majority of this evidence comes from an area on the northern part of the island known today as Nessend (see figure 2.1).

Nessend is an exposed area of clay till, covered in some areas by blown sand. A scatter of struck flints was first noticed in 1980 (Beavitt et al. 1987: 2), and a systematic programme of collection was carried out during 1983 and 1984. A grid was laid down to allow the two-dimensional recording of all finds and the fact that all of the material was collected from the current land surface, and none was retrieved during the excavation of two small dunes in the area, is significant when considering the nature of geomorphic processes at Nessend. It is clear that rather than being an environment that is subject to net sediment deposition, this area is currently a deflationary environment (see chapter 4). This characteristic is considered extensively in chapters three and four.

Included in the assemblage from Nessend were both early and late Mesolithic microliths, as well as arrowheads dated to the late second and third millennia BC.

It should be noted that during the early Mesolithic the shoreline would have been three to five kilometres further to the east than it is today, and Lindisfarne would have been a part of the mainland (Beavitt et al. 1987: 2). Therefore, the inhabitants would not have had the same type of ecotonal environment to exploit as did subsequent inhabitants of the area.

This fundamental difference in Lindisfarne's environment is clearly of profound importance and illustrates both the dramatic geomorphological changes that have taken place in the area and why these need to be investigated if subsistence patterns and the nature of human settlement in the area is to be understood. As was argued in chapter one, we cannot hope to understand human settlement and its relationship with landscape evolution unless we situate
the archaeological evidence within broader spatial and temporal categories, i.e. the evidence for early prehistoric settlement on Lindisfarne must be related to broader geomorphological and ecological changes both in the immediate area and over the region. The archaeological evidence for this particular locality must also be related to evidence from the region as a whole.

These principles are also true for the investigation of settlement during the historic period on Lindisfarne. As stated earlier in this chapter, the majority of the archaeological work carried out on the island has taken place in the area of the modern village. Apart from the investigations into the priory (O'Sullivan et al. 1985), the main excavation in the area of the modern village took place in 1986 at the site of Jenny Bell's Well. Initial observations at this site indicated the existence of a midden constituted by large amounts of medieval and post-medieval rubbish.

The excavation produced large amounts of mammalian and fish bone and large numbers of marine molluscs were also found. Artefactual evidence included pottery, dated to the thirteenth and fourteenth centuries, as well as quantities of slag.

Once again, the fundamental aim of this part of the project has been to elucidate the island's relationship with its own environment, the sea, the mainland and ultimately, in the case of this excavation, the relationship with the continent. The medieval and post-medieval pottery from both the Museum site and the priory includes a range of regional imports from the Tees Valley, Humberside and the Scottish Borders, as well as more exotic tin-glazed earthenwares and stonewares which would have been traded around the North Sea littoral (O'Sullivan, pers. comm.) This research highlights the importance of not limiting the scales at which we investigate settlement. It has shown how even a supposedly "marginal" settlement had certain, even if indirect, links with continental settlements. The local midden serves as a record of human interaction with both immediate and distant landscapes or environments.

All of the research on Lindisfarne is in some way concerned to understand the extent to which an island such as Lindisfarne is bounded and therefore operates as an independent entity. In each of the project's excavations, evidence for both local, regional and even international, human/environment interaction has been found. These questions of settlement and landscape evolution have been addressed most extensively as part of the research into the early medieval site at Green Shiel.
The Early Medieval Settlement At Green Shiel

The greater part of the Leicester research programme on Lindisfarne has concentrated on the investigation of the early medieval settlement site at Green Shiel on the north shore of the island. There are many reasons why this site is of great importance, not least because of the fact that its period of occupation coincides with that period in the history of the island for which there is little or no historical record.

After the Viking raids on Lindisfarne, the first of which took place in AD 793, it is not known what form settlement on the island may have taken, especially after the abandonment of the monastery in the mid- or late- ninth century. What we can be sure of, however, is that the island was not abandoned after the first raid in AD 793; this is testified to by the existence of the settlement site at Green Shiel which is firmly dated by coin evidence and an Anglo-Saxon spearhead to the mid-late ninth century.

The site consists of five buildings linked to one another forming a rough cross shape (see figure 2.2). Today the site is situated in a flat area with large dunes to the south and to the north, the beach is situated under 100 metres away to the north-west of the settlement site.

The site was first identified during the nineteenth century when the area was being cleared for trackways for the limestone extraction industry on the island. During this work, much of the site was robbed out for construction material. The trackways are still visible to the east and west of the buildings today. Despite the nineteenth century development in the area, the buildings still survive in an easily recognisable form and excavations have revealed some quite impressive standing walls. The final feature visible in this area is a narrow ridge running east-north-east from building "A"; this was once tentatively described as a trackway, but is now thought to be a storm beach.

In 1984 a preliminary survey of the Green Shiel site was carried out; this included a magnetometer survey of building "A". An anomalous area was picked up and a small excavation carried out. The anomaly turned out to have been caused by an Anglo-Saxon spear-head which has been dated to the late ninth or early tenth century.

The first structure to be fully excavated was building "C", the southernmost structure (see figure 4.2). This building was excavated over three seasons from 1985 to 1987. It is roughly aligned north-south and measures 18.5m x 4m internally. As with all of the buildings so far excavated, the walls are of dry stone construction. The most obvious source for this material is the storm beach less than 100m from the site. Despite the fact that much of the stone walling was robbed out during the construction of the nineteenth century
wagonway, both the external walls and internal dividing walls have survived remarkably well, up to a height of c. 1.3m in some places (O'Sullivan & Young 1991: 64).

**Figure 2.2: Plan of Green Shiel settlement site.**

The other buildings which have been excavated so far (buildings "A" and "B") are considered together as they share common walls and were probably built as one structure (O'Sullivan & Young 1991: 59). The internal measurements of buildings "A" and "B" are, c. 19m x 4.5m and c. 20m x 5m. All of the external walls are about 1.5m thick. Other important internal features include three post holes which run centrally down the mid and western parts of the building "A" (O'Sullivan & Young 1991: 62). These features constitute the only real evidence relating to the roofing of the buildings at Green Shiel.
Area "D" is currently being excavated and its initial identification as another building has been confirmed (O'Sullivan & Young, *pers. comm.*).

**The Finds**

The most important finds from the site, in terms of dating, are the nineteen coins found at the site (by 1992); this figure includes two found in the area of the site during the nineteenth century. The coins include six Northumbrian stycas, two stycas of Eanred (c. AD. 810-41) and Aethelred (c. AD. 841-859) and one penny of Aethelred of Wessex (AD. 866-871). This evidence clearly points to the site being occupied during the middle of the ninth century; however, as O'Sullivan and Young observe, this dating evidence does not really help us answer the question of how long was the site occupied for. They argue that the site was possibly occupied for a relatively short period and was abandoned some time during the last quarter of the ninth century.

Other finds from the excavations include much animal bone, and large quantities of marine molluscs, especially from building "C".

The marine mollusca and faunal remains are described below while the consideration of their importance is considered in the synthesis (chapter 7). Most of the material considered originates from building "C"; partly because the analysis of material from this building is complete, and also because in the case of marine mollusca, this building has produced more material than any other to date (July 1993).

**On-site Methodologies**

A brief description of site methodology follows as some material retrieved from the buildings themselves is discussed as a part of this thesis.

Prior to excavation the entire area of the Green Shiel site was surveyed three-dimensionally, allowing the production of a digital model of the site. This model is considered in conjunction with other Digital Terrain Models in Chapter Three.

Throughout the excavations at Green Shiel a comprehensive programme of sieving and sampling has been pursued. Ideally, by the end of the project all of the material from every archaeological context will have been subjected to sieving of some description.
During the first two seasons of excavation at Green Shiel material sieved on site was passed through hand-sieves with a mesh of 0.70cm, and from 1986 onwards rocker sieves with a mesh of 0.35cm. During 1985 and 1986 one bucket in ten from each context was wet-sieved on site while one bucket in 50 was kept for flotation back in Leicester. From 1987 the strategy was slightly modified with a ten per cent sample being kept for sieving in Leicester and the remaining ninety per cent still being sieved on site. Recently, a more judgmental approach has been adopted.

This strategy is considered to be absolutely necessary partly as a consequence of the nature of the depositional environment in a sand dune area. It is quite apparent that the site has been subjected to excessive "scouring out" by the wind, therefore producing archaeological contexts with potentially low artefact and ecofact densities.

In order that all finds could be plotted to at least a one metre resolution, a metre grid was laid out over the entire site. Single context recording, and levelling every half metre, is normal practice. This single context recording system is based on the Central Excavation Unit's procedures.
The Marine Mollusca

The marine mollusca material described was retrieved through both on-site dry- and wet-sieving, and flotation and wet-sieving at Leicester University. The original investigation of the material did not employ any statistically-based sampling strategy; in hindsight, an obvious short-coming of the original analysis (Walsh 1988).

In the original analysis all of the marine molluscan material was identified and quantified by context and metre grid-square. The data was then entered onto an INGRES database on the University Mainframe. Once all of the material had been recorded in this way, the database was interrogated using Structured Query Language (SQL). Initially a calculation of the proportions of all the species across all contexts in and around building "C" was made. The results of this query are shown in table 2.1 below.

<table>
<thead>
<tr>
<th>Species</th>
<th>Quantity</th>
<th>%'ge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cerastoderma edule</td>
<td>15</td>
<td>0.082</td>
</tr>
<tr>
<td>Littorina littoralis</td>
<td>2073</td>
<td>11.35</td>
</tr>
<tr>
<td>Littorina littorea</td>
<td>12463</td>
<td>68.26</td>
</tr>
<tr>
<td>Littorina neritoioides</td>
<td>48</td>
<td>0.265</td>
</tr>
<tr>
<td>Littorina saxatalis</td>
<td>48</td>
<td>0.265</td>
</tr>
<tr>
<td>Mytilus edulis</td>
<td>31</td>
<td>0.17</td>
</tr>
<tr>
<td>Nucella lapillus</td>
<td>80</td>
<td>0.44</td>
</tr>
<tr>
<td>Ostrea edulis</td>
<td>47</td>
<td>0.26</td>
</tr>
<tr>
<td>Patella*</td>
<td>3455</td>
<td>18.9</td>
</tr>
<tr>
<td>Total</td>
<td>18260</td>
<td></td>
</tr>
</tbody>
</table>

Table 2.1. Marine molluscs from building "C".

* N.B. The Patella species are clearly dominated by Patella vulgata, however, Patella aspersa was also present but in many cases the examples from Green Shiel lacked the distinguishing features required for identification; Therefore all Limpets were placed in one group.

As the above table shows, the assemblage as a whole is dominated by Littorina littorea (Common periwinkle), which constitutes almost 70% of the assemblage. The Patella species (Limpets), constituting almost 20% of the assemblage, were the next most common. Littorea littoralis (flat periwinkle) constitutes just over 11% of the assemblage and Nucella lapillus (common dogwhelk) is the next most common. However, at only
0.4% of the assemblage the subsistence/economic importance of this species and the others found on the site is open to question. The other species found on the site are as follows: *Littorina neritoides* (small periwinkle), *Littorina saxatalis* (rough periwinkle), *Mytilus edulis* (common mussel), *Cerastoderma edule* (common cockle) and *Ostrea edulis* (native or European oyster). Although all of these species exist in double figures in terms of real numbers in building "C", they all constitute less than one half of one percent each of the total assemblage.

The context by context analysis of the proportions of the various species of marine molluscs revealed a similar pattern to that shown in the analysis of the assemblage as a whole. Four "important" contexts were identified during the original investigation of the building "C" assemblage: contexts 31, 35, 87, 153 and 158. These contexts were deemed important because they produced large quantities of material and were also identified as occupation levels. The relative proportions of the different species for these contexts can be found in table 2.2.
<table>
<thead>
<tr>
<th>Species</th>
<th>Context</th>
<th>Number</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>L. littorea</td>
<td>31</td>
<td>2088</td>
<td>51.88%</td>
</tr>
<tr>
<td>L. littoralis</td>
<td>31</td>
<td>1127</td>
<td>28%</td>
</tr>
<tr>
<td>Patella</td>
<td>31</td>
<td>757</td>
<td>18.81%</td>
</tr>
<tr>
<td>L. saxatalis</td>
<td>31</td>
<td>27</td>
<td>0.66%</td>
</tr>
<tr>
<td>Nucella lapillus</td>
<td>31</td>
<td>20</td>
<td>0.5%</td>
</tr>
<tr>
<td>Ostrea edulis</td>
<td>31</td>
<td>2</td>
<td>0.05%</td>
</tr>
<tr>
<td>L. neritooides</td>
<td>31</td>
<td>2</td>
<td>0.05%</td>
</tr>
<tr>
<td>L. littorea</td>
<td>35</td>
<td>687</td>
<td>6.1%</td>
</tr>
<tr>
<td>Patella</td>
<td>35</td>
<td>316</td>
<td>29.2%</td>
</tr>
<tr>
<td>L. littoralis</td>
<td>35</td>
<td>66</td>
<td>6.1%</td>
</tr>
<tr>
<td>Nucella lapillus</td>
<td>35</td>
<td>6</td>
<td>0.6%</td>
</tr>
<tr>
<td>L. Saxatalis</td>
<td>35</td>
<td>4</td>
<td>0.4%</td>
</tr>
<tr>
<td>Ostrea edulis</td>
<td>35</td>
<td>1</td>
<td>0.09%</td>
</tr>
<tr>
<td>L. littorea</td>
<td>87</td>
<td>3150</td>
<td>88.8%</td>
</tr>
<tr>
<td>Patella</td>
<td>87</td>
<td>310</td>
<td>8.7%</td>
</tr>
<tr>
<td>L. littoralis</td>
<td>87</td>
<td>52</td>
<td>1.5%</td>
</tr>
<tr>
<td>L. neritooides</td>
<td>87</td>
<td>14</td>
<td>0.4%</td>
</tr>
<tr>
<td>Nucella lapillus</td>
<td>87</td>
<td>13</td>
<td>0.4%</td>
</tr>
<tr>
<td>Ostrea edulis</td>
<td>87</td>
<td>5</td>
<td>0.14%</td>
</tr>
<tr>
<td>Mytilus edulis</td>
<td>87</td>
<td>2</td>
<td>0.05%</td>
</tr>
<tr>
<td>L. littorea</td>
<td>153</td>
<td>1479</td>
<td>85.1%</td>
</tr>
<tr>
<td>Patella</td>
<td>153</td>
<td>213</td>
<td>12.3%</td>
</tr>
<tr>
<td>L. littoralis</td>
<td>153</td>
<td>27</td>
<td>1.6%</td>
</tr>
<tr>
<td>Nucella lapillus</td>
<td>153</td>
<td>14</td>
<td>0.8%</td>
</tr>
<tr>
<td>L. neritooides</td>
<td>153</td>
<td>3</td>
<td>0.17%</td>
</tr>
<tr>
<td>C. edule</td>
<td>153</td>
<td>1</td>
<td>0.06%</td>
</tr>
<tr>
<td>Ostrea edulis</td>
<td>153</td>
<td>1</td>
<td>0.06%</td>
</tr>
<tr>
<td>L. littorea</td>
<td>158</td>
<td>790</td>
<td>61.6%</td>
</tr>
<tr>
<td>Patella</td>
<td>158</td>
<td>482</td>
<td>37.6%</td>
</tr>
<tr>
<td>L. littoralis</td>
<td>158</td>
<td>9</td>
<td>0.7%</td>
</tr>
<tr>
<td>Nucella lapillus</td>
<td>158</td>
<td>2</td>
<td>0.15%</td>
</tr>
</tbody>
</table>

Table 2.2: Marine mollusca quantities from four major contexts in building "C".

Context 87 in building "C" is obviously an occupation level which has produced many important small-finds, these include some of the stycas and much of the metalwork, including a key with a ring bow, a tongue of a buckle, a copper-alloy hinge and two pierced plates.

In every case within the selected contexts *Littorina littorea* is the most common species represented, the Patella species are always the second most common and *Littorina littoralis* the third. This pattern is also clearly reflected in the sample assemblage from the building "D" excavation which is still ongoing (see table 2.3).
There is, however, a high level of variation in the relative proportions between each of the contexts in building "C". In some, *Littorina littoralis* comprises almost 90% of the sample, whilst in others it is as low as 51.8%. In some contexts *Patella* comprises almost 30% of the total, whilst in others it comprises only 8.7%. It should be pointed out that in some places *Patella* dominates contexts as discrete dumps of shell. Within building "C" eight such dumps were identified and these are obviously important as they may indicate single exploitation activities.

Despite the fact that there is a recurring pattern in the order of relative proportions of marine mollusca across the site, it is important to note that the assemblages are rarely statistically similar between buildings, and even between recognised contexts. The chi square tests carried out on the assemblages clearly illustrate this point.

The tests carried out only compared the most common species *Littorina littorea*, *Patella*, *Littorina littoralis*, and in the first test, *Nucella lapillus* also (see appendix 1 for full details). Test 1 compared the entire assemblage with the four major contexts and the sample from the building "D" excavation; these samples were clearly significantly different. Test 2 compared the same cases, but only used the two most common species, *Littorina littorea* and *Patella*. Again there was a significant difference. Tests 3 and 4 were tests of the entire building "C" assemblage against the sample from building "D". Test 3 compared *Littorina littorea*, *Littorina littoralis* and *Patella*. Test 4 compared the *Littorina littorea* and *Patella*. Both of these tests indicated a significant statistical difference between the samples.

### Table 2.3: Sample of marine molluscs identified from building "D" excavation 1991.

<table>
<thead>
<tr>
<th>Species</th>
<th>Quantity</th>
<th>%'ge of assemblage</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Cerastoderma edule</em></td>
<td>20</td>
<td>0.39%</td>
</tr>
<tr>
<td><em>Littorina littoralis</em></td>
<td>404</td>
<td>7.8%</td>
</tr>
<tr>
<td><em>Littorina littorea</em></td>
<td>3394</td>
<td>65.47%</td>
</tr>
<tr>
<td><em>Littorina neritoides</em></td>
<td>10</td>
<td>0.19%</td>
</tr>
<tr>
<td><em>Littorina saxatalis</em></td>
<td>99</td>
<td>1.9%</td>
</tr>
<tr>
<td><em>Mytilus edulis</em></td>
<td>3</td>
<td>0.06%</td>
</tr>
<tr>
<td><em>Nucella lapillus</em></td>
<td>22</td>
<td>0.42%</td>
</tr>
<tr>
<td><em>Ostrea edulis</em></td>
<td>3</td>
<td>0.06%</td>
</tr>
<tr>
<td><em>Patella</em></td>
<td>1229</td>
<td>23.7%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>5184</td>
<td></td>
</tr>
</tbody>
</table>
Little can be inferred from these tests in interpretative terms: they only serve to show that the deposition of the marine molluscan material was not the result of a set of continuously similar processes, or one single event.

The Distribution of the Material

The distribution plots show that there were not only concentrations, or, dumps, of Patella, but there were also concentrations or spreads of *Littorina littorea*. Context 87 is one such spread: it comprises 3150 examples concentrated in the central room of building "C" (see figure 2.3). Figure 2.3 (context 158) shows a concentrated dump of just under 500 shells of Patella in the centre of building "C". This dump was concentrated mainly in metre square grid (942/960), but did spill over into the area just to the right.

This type of analysis of marine mollusca is not only useful in the study of subsistence, and to a lesser extent, past shoreline ecology, it is also contributes to our understanding of certain types of taphonomic process. The types of taphonomic process considered in the context of this study are the macro-scale shifting of deposits, and the micro-scale chemical diagenetic processes which effect the survivability of marine molluscan shells.

The spatial analysis of the material allows the reconsideration of the definition and identification of contexts on the archaeological site. An examination of the spatial distributions by context of the most abundant species, i.e. *Littorina littorea* and the Patella species, helps to link contexts, which by their very definition are representative of one process only until it is demonstrated otherwise. Such analyses therefore permit the articulation of relationships between contexts and thus facilitates phasing.

The analysis of the material from building "C" showed that the overlying (post-depositional) contexts (especially context 31) had been identified as one single spread of "loose sand and rubble". This general spread of marine mollusca, which was dominated by *Littorina littorea*, covered most of the building "C" area and obviously represents the latest deposit of marine molluscan material (see figure 2.3). However, its origin must be open to question. Such a spread may have been blown on to site at any time, or it may be the result of the mixing of lower deposits through wind action, or, rabbit burrowing, and anthropogenic disturbance, especially during the nineteenth century.
Figure 2.3: Concentrated spread of *Littorina littorea* (context 87, building "C"); Dump of 482 Patella (context 158) in the centre of building "C"; General near-surface spread (context 31) of *Littorina littorea* over building "C".
A number of contexts below this general spread were originally identified as mutually exclusive, but when the spatial distributions of the marine mollusca from these contexts are brought together, along with the on-site sediment descriptions that were made of these contexts, it is apparent that such contexts are indeed one and the same, as the initially discrete spreads of material abut one another (in many instances) and therefore constitute a single general spread across the whole of the site. This was certainly the case with contexts 46, 50, 55, and 72 (see figure 2.4).

The spatial analysis of the marine molluscan material shows that most of the assemblage was deposited within the building; only 1200 of the shells counted (from a total of 18260) were exterior to the building walls. However, such a distribution is obviously a function of the area actually excavated.
Figure 2.4: Spread of *Littorina littorea* across building "C"; contexts 46, 50, 55, and 72.
Chemical Analyses of Molluscan Survivability

An obvious question to ask of any assemblage, whether it be comprised of artefacts or environmental evidence, is the extent to which post depositional chemical processes have affected the material. In order to assess the relative, and to a certain extent, the actual, survivability of different marine mollusc shells, a series of experiments designed to simulate acidic and alkaline environments was set-up. Even though it is known that the sediments around the Lindisfarne dune system possess a very high pH level (up to pH 9), a range of tests using acidic solutions was carried out in parallel, as the results of these tests may also prove useful for work in non-alkaline environments.

Methods

Samples of the following species of marine mollusc were selected for the two experiments: *Patella vulgata, Littorina littorea, Mytilus edulis, Cerastoderma edule* and *Nucella lapillus.*

Before any weight measurements were taken, every sample was left in hydrogen peroxide overnight in order to remove any excess organics. Once thoroughly washed the sample shells were weighed using a Bosch semi-automatic analytical balance (the full list of weights and results can be found in appendix 1a). Once all of the samples had been weighed they were placed in their individual flasks of acid and alkaline solutions.

For the acid test three different 5% acid solutions were used: acetic acid, formic acid and one inorganic acid; hydrochloric acid. The alkaline solutions employed were 5% solutions of sodium carbonate monohydrate and potassium hydrochloride. After two weeks of immersion the alkaline experiment had to be modified as it was clear that the solutions could have little effect in such a short period of time. Consequently it was decided to place the flasks containing the alkaline solutions into an oven at a constant temperature of 55 °C in order to intensify the chemical process. After one week these samples were removed from their solutions, washed and then weighed. On discovering that they had lost little or no weight all of these samples were re-immersed in 10% alkaline solutions (the same alkalis as before were used). The flasks containing these solutions were placed in the oven at a temperature of 55 °C and left for one month.

Once the period of immersion was complete, each shell was washed and then dried in the oven for 48 hours. Each sample was subsequently weighed and the weight loss calculated.
The weight loss is shown as the percentage of the original weight remaining. Notes were also made of any observable changes in terms of decomposition of the shell.

_results_

(see Appendix 1a for full results)

The acid solutions

The results of this set of tests were unsurprising. All of the species' shells experienced high levels of deterioration and weight loss. The Formic acid solution was the most corrosive, leaving only 45.6% of the original weight of the Patella sample; the *Littorina littorea* sample was completely dissolved, while *Mytilus* and *Cerastoderma edule* were reduced to weights below 30% and 20% of their original weights respectively. The *Nucella lapillus* sample proved more resilient to the Formic acid solution, but only 26% of the original weight of the sample placed in Acetic acid remained at the end of the immersion period, while 88.75% of the original weight of the sample left in Formic acid remained.

The full ramifications of the acid test will only be worthy of extensive consideration in the investigation of an environment comprised of sediments with a low pH; it is the results of the alkaline tests which are of relevance to this study.

The alkaline solutions

As was expected the weight loss of the samples placed in alkaline solutions was minimal in the majority of cases; however, the tests did yield some interesting and useful results. The percentage weight lost for each sample can be found in table 2.4, while the full results, including actual weights before and after immersion can be found in appendix 1a.
As table 2.4 shows, in most cases the shell samples survived well in the alkaline solutions. However, whilst the Sodium Carbonate solution had little effect on the samples (almost no affect on the Patella shell), the potassium solution did cause a certain amount of dissolution and therefore weight loss in the *Littorina littorea* and *Cerastoderma edule* samples. It should be noted, though, that in the case of *Littorina littorea* the weight loss had little obvious effect; the shell remained strong and intact and still appeared resilient. This was not so with the *Cerastoderma edule* and the *Mytilus edulis* samples. Despite the relatively low levels of weight loss, both samples showed extreme signs of deterioration and would have started to break-up if left immersed in alkaline for any great length of time.

**Conclusions**

The results of this experiment indicate that *Littorina littorea* and the Patella species survive quite well in alkaline conditions, while *Cerastoderma edule* and *Mytilus edulis* tend to loose strength and begin to disintegrate after time in sediments with high pH levels. Such a taphonomic process may explain to some extent why there is a relative dearth of these two species in the assemblage as a whole. However, as the discussion below will elucidate, it is believed that in the specific instance of the Green Shiel site, the assemblage examined is probably an accurate sample of the range of material originally exploited in the site's environs.

<table>
<thead>
<tr>
<th>Species</th>
<th>Sodium</th>
<th>Potassium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patella</td>
<td>0%</td>
<td>1.9%</td>
</tr>
<tr>
<td><em>Littorina littorea</em></td>
<td>1.5%</td>
<td>15.5%</td>
</tr>
<tr>
<td><em>Mytilus edulis</em></td>
<td>1.5%</td>
<td>5.5%</td>
</tr>
<tr>
<td><em>Cerastoderma edule</em></td>
<td>3.5%</td>
<td>12.2%</td>
</tr>
<tr>
<td><em>Nucella lapillus</em></td>
<td>3.4%</td>
<td>5.4%</td>
</tr>
</tbody>
</table>

Table 2.4: Percentage weight loss of shells immersed in alkaline solutions (actual weights can be found in appendix 1a).
Discussion of the Marine Molluscan Evidence

The Spatial Distribution of the Material

The analysis of the marine molluscan assemblage produced useful information on the nature of the site stratigraphy by enhancing our ability to make links between contexts that had previously been identified as being discrete. The occurrence of the large dumps and spreads in the same contexts as the indicates a certain coherence in the identification of "occupation" horizons. However, we must question the idea that such contexts are in fact occupation horizons when the spreads and dumps of marine molluscs obviously imply that the building interior was not being cleaned out. We must therefore assume that such dumps and spreads represent a final period of building use. It is also important to note that the quantities of marine molluscan shells retrieved during the excavations of buildings "A" and "B" have been noticeably lower. Therefore the large assemblage from building "C" may indicate that this building was used to process marine molluscs and perhaps even maintain a supply of sorts.

The Palaeoenvironmental Implications

The palaeoenvironmental information that can be yielded from marine molluscs is limited, although a discussion of the implications of variation in the morphology of Nucella lapillus can be found in chapter 4. Any other information is largely concerned with general observations of the shoreline types on which the species found in the assemblage would have lived. Unsurprisingly the building "C" assemblage from the Green Shiel site is comprised of species which live on rocky shores, although Cerastoderma edule is a sand-burrowing species. It is therefore most likely that the marine molluscs in the Green Shiel assemblage were collected from the limestone platform just to the north of the site. The relative dearth of Cerastoderma edule and Mytilus edulis might be explained by chemical destruction (as described earlier) or it may imply that the areas where these species do flourish on the island were not harvested to the same extent as the more local rocky shoreline. The modern distribution of the most common marine mollusc species is shown on figure 2.5.
Figure 2.6: The distribution of the different species around Lindisfarne today. (See text below)

The Distribution

**Area 1:** Species present: *Mytilus edulis, Cerastoderma edule, Littorina littorea, Littorina littoralis, Nucella lapillus.*

 Comments
This area is dominated by large mussel beds.

**Area 2:** Species present: *Mytilus edulis, Cerastoderma edule,* the *Littorina species.*

 Comments
The Littorina species are not very abundant, and mussels are only in limited quantities.

**Area 3:** Species present: *Mytilus edulis, Cerastoderma edule,* the Littorina species, *Nucella lapillus.*

 Comments
This area consisted of relatively small quantities of the above species.

**Area 4:** Species present: *Mytilus edulis,* the Littorina species, *Nucella lapillus,* *Cerastoderma edule.*

 Comments
Except for *Littorina littorea,* the marine mollusc population was small.
Area 5: Species present: this area was dominated by large quantities of *Littorina littorea* and *Littorina littoralis*.

Area 6: Species present: *Mytilus edulis*, the Littorina species.
Comments
This area is largely dominated by *Littorina littorea*.

Area 7: Species present: the Littorina species, some Patella, some *Nucella lapillus*.
Comments
This area is dominated by small populations of *Littorina littorea* and some *Littorina saxatalis*.

Area 8: Species present: the Littorina species, Patella. Comments
This area has relatively low distributions of the above two species.

Area 9: Species present: the Littorina species, Patella, and *Nucella lapillus*.

Area 10: Species present: the Littorina species, *Nucella lapillus*, *Patella vulgata*.
Comments
Small populations of *Littorina littorea*, with some Patella and *Littorina saxatalis*.

Area 11: This area is a sandy beach and has few marine molluscs.

Area 12: Species present: the Littorina species, *Nucella lapillus*, *Patella vulgata*.
Comments
*Littorina littorea* is very abundant while *Patella vulgata* is present in small numbers.

Area 13: This area is a sandy beach and has few marine molluscs.

Area 14: Species present: the Littorina species, *Patella vulgata/aspersa*, *Mytilus edulis* and *Nucella lapillus*.
Comments
The Patella species are at their most prolific on this part of the island. The beds of Mytilus consist almost purely of very small baby Mytilus and would not be worth exploiting on any scale. *Littorina littorea* is also present in large quantities, especially in rocky areas uncovered at low tide.
The distribution is clearly dominated by rocky shore-loving species such as the Patella species. These archaeogastropoda always live on hard surfaces and are usually vegetarian, feeding on the algae growing on rocky shores. The other predominant species are the Littorina species. As with the majority of mesogastropoda the Littorina species are vegetarian and feed on algae. The different species of Littorina occupy specific zones on the shore. *Littorina neritoides* occupies the highest levels of the shoreline. *Littorina saxatalis* is usually found lower down the shore, in the same zone as *Littorina littorea* (the edible periwinkle) which also extends further down to the lower zones. *Littorina littoralis* occupies the widest range of zones of all this family; it can be found from the highest zone down to the low water, spring tide, zone.

The other relatively common species on Lindisfarne are *Cerastoderma edule* and *Mytilus edulis*. The *Mytilus* species are usually found on rocky, stony and muddy shorelines. Today these species are concentrated on the southern and western shores of the island. *Mytilus* species do occupy areas on the northern shore of Lindisfarne, but as dense beds of tiny, baby mussels. There could be a number of reasons for the reduced size of individuals here: there may have been a failure in recruitment in recent years, or the population may be subject to heavy predation. However, the most likely reason may relate to the nature of wave action and force on this part of the shore. This shore is probably the most exposed of all those on the island, and possesses a relatively high tidal-range, therefore wave action may be responsible for removing *Mytilus* when they reach a certain size, thus offering a relatively large surface area and resistance to the force of the sea.

*Cerastoderma edule* prefer sandy or muddy shores where a good supply of plankton is guaranteed. On Lindisfarne this species is most common on the southern and western shores, and flats.

Considering the various niches preferred by the species considered in this section, it is apparent that the Green Shiel assemblage is dominated in the main by species which are predominant on the north shore of Lindisfarne (areas 14 and 13 (figure 2.5)); *Littorina littorea* and the Patella species being the most common. The lack of *Mytilus edulis* and *Cerastoderma edule* is possibly explained by chemical diagenesis responsible for the complete or partial disintegration of these species' shells. However, it is more likely that the dearth of these species in the assemblage is explained by the fact that the majority of shell-fish collection was carried out on the north shore where these species did not flourish,
or that they were not favoured for some other reason. The importance of the shell-fish resource is considered more extensively in chapter 8.

The Animal Bone

Introduction

Every building excavated to date has produced relatively large quantities of animal bone, the detailed analysis of which is beyond the scope of this research. However, some analysis has been carried out by other workers over the period of the project. The site has not been finally phased; however, in view of the total absence of any kind of occupation evidence other than that directly associated with the settlement, it is overwhelmingly probable that the butchered bone dates to the ninth century. (O'Sullivan and Young, forthcoming 1994).

The most extensive analysis is that carried out on the assemblage from building "C" (Virr 1989). This work included a detailed examination of two cattle skeletons and the entire sample of metapodial bones from the cattle. The detailed analysis of the two articulated skeletons was concerned to sex, assess the age at death, and measure the stature of the animals.

Ageing

The two articulated skeletons were aged through an examination of tooth eruption and tooth wear (see Grigson 1982; Grant 1982). The first animal (referred to as specimen "A") is considered to have been between three and five years old when it died, while the second animal (specimen "B") still possessed its deciduous teeth, although its permanent molar was in wear when it died. The inferences made from a range of tooth-wear scales place the age at death of this animal at between 11 and 18 months (Virr 1989: 15).

The examination of the bone fusion patterns indicates that animal "A" was between 3.5 and 4 years of age when it died, while animal "B" was between 1 and 1.5 years old.
The Sex and Height Of The Animals

Both of the fully articulated specimens were shown to be cows, the older one (specimen "A") having a withers height of 101cm (based on the mean of five different calculations). The younger animal has a withers height of between 84.5 and 89.9cm (Virr 1989: 25).

The Analysis of the Metapoidal Evidence

The metapodial bones from the entire assemblage found in building "C" were examined in order to establish the minimum number of individuals present as well as their sex.

A minimum number of 17 individuals was arrived at from this analysis, and a maximum number of 55 if all of the bones that are different are considered as being from separate individuals; 45% of these bones come from animals under 2 years old, 37% are from young adults and 17% from older cattle.

Discussion

In this section the possible inferences that can be made from this assemblage are considered, while a fuller discussion of this evidence and its relationship to the rest of the research project is given in the synthesis chapter (chapter 8).

An examination of the assemblage as a whole shows that there are few disarticulated bones that might be considered as prime cuts, especially as the majority of the evidence is comprised of metapoidal bones.

The preponderance of calves in the assemblage is possibly indicative of dairying as the yearly production of calves would be required to induce lactation. Also, the fact that the bone assemblage is dominated by cows supports the contention that only a small number of males would be required for breeding, and surplus males would have been slaughtered. In general terms, the low numbers of mature cattle along with the predominance of cows over bulls indicates that Green Shiel is unlikely to have been involved in meat production (Virr 1989).
Conclusions

This chapter has described, and briefly discussed, the major archaeological projects that have been undertaken in the past on Lindisfarne. Emphasis has obviously been placed on the recent work by colleagues in the School of Archaeological Studies at the University of Leicester. This programme of research has covered periods ranging from the Mesolithic up to the nineteenth century (surveys of the industrial archaeology having been carried out in 1993). However, the research project has concentrated on what is, so far, the most important and enigmatic site on Lindisfarne: the Dark Age site at Green Shiel.

The excavations at Green Shiel have produced a wide range of finds, including coins, small-finds, and faunal evidence dominated by bones and marine mollusc shell. The site is however completely aceramic and the number of small-finds relatively low. Although this evidence allows us to make a number of well founded inferences about the nature and function of this site, there is little doubt that the key to enhancing our understanding of it lies in the investigation of its surrounding landscape. No site can be fully understood without an appreciation of its environmental contexts and the site's relationships with these contexts. A number of key questions need to be asked: how did the environment affect settlement location, how did the inhabitants exploit this environment, and what was the relationship of this site to other contemporary sites?

This thesis is largely concerned with answering these broader questions that relate to the environment beyond the specific locality of the site itself, and as the following chapters show, key to this problem has been the investigation of the geology, and more important, the geomorphology, of the Lindisfarne dune system, the area within which Green Shiel is located.
CHAPTER 3
GEOLOGY AND GEOMORPHOLOGY: SITE AND ENVIRONS STRATIGRAPHY

Introduction

This chapter initially considers the regional geology and then describes the geology of Lindisfarne itself. The main part of this chapter goes on to discuss the nature of the modern topography around the Green Shiel area, and then moves on to describe the relationships between the Green Shiel settlement site stratigraphy, the stratigraphy of the immediate environs, and the relationship between these and the sub-dune topography in the ridge and furrow area. The discussion of the processes behind the topography and the history of the dune system are considered in the following chapter, which discusses at length the characteristics of the topography and geomorphological processes contemporary with the occupation of the Green Shiel site.

Regional Geology

The north east of England is located on the margin of the North Sea basin. In northern Northumberland the Cheviot Hills, formed from granite and andesite, are a dominant feature (see figure 3.1). These emerged during a volcanic episode about 400 million years ago. Characteristic of this area are the grass-covered hills and valleys which cut the granite rocks and the lava pile. Moving east from the Cheviots towards the coastal plain, Carboniferous lithologies are encountered; these are rocks that were laid down some 300 million years ago and include cementstone and fell sandstones. This part of north-east England is characterised by the streams and rivers which flow out over this plain. Further east towards the coast, the middle and lower limestones are dominant; the majority of these are dated to the early part of the Carboniferous period. These deposits are broken only by the relatively numerous outcrops of whin-sill, dykes: dolerite intrusions about 300 million years old. One of the best-known dykes is the Holy Island echelon which is visible on the southern side of the island, as the Heugh and the Castle Rock (figure 3.2).
It is the processes that took place during the Quaternary period that have had the most dramatic influence on the topography of the lowland coastal zone of north-east England. As Lunn comments, "...most of the region is mantled by drift of glacial or periglacial origin, and the land has been shaped in detail by glacial and periglacial processes" (1980: 48).

No part of this region was left unaffected by glaciation: large areas of the north-east are covered with glacial drift. These deposits reach a maximum thickness of about 92 metres in County Durham. However, deposits are usually no more than about fifteen metres thick over the rest of the region. The drift deposits have a profound influence on the topography of the lowlands in this part of England. Relief amplitude is greatly reduced by the infilling of cavities in the solid geology. Much of the coastal area is only above sea-level today as a result of the thickness of these drift deposits. Consequently much of this area is characterised by a relatively featureless or irregularly undulating topography.
Another important geomorphological characteristic of the north-east coastal plain is the existence of relatively extensive sand dune systems. The dating of these systems, as well as the related sea-level changes in the area, is problematic and will be discussed later in the thesis. However, in the context of this discussion of the geomorphology of the area it is important to illustrate the importance of such phenomena. King (1976) observes that dune systems are especially extensive along drift sections of the Northumbrian coast from Cheswick Rocks, south to Ross Links, Budle point and Seahouses. They also cover areas in the bays of Beadnell, Druridge and Embleton. Sand dune systems are a recurrent and important feature of the Northumbrian coast.

The Geology of Lindisfarne

The tombolo of Lindisfarne is geologically a continuation of the middle limestone groups of north-east Northumberland. Prior to the Holocene, Lindisfarne would have been just a small part of a more extensive North Sea plain, as late-glacial sea-levels in this region are estimated to have been 58 metres below current sea-levels (King 1976: 151).

Lindisfarne, like many places, has a complicated geological and geomorphological history. Despite the fact that Lindisfarne possesses some clear similarities with the geology of the adjacent mainland, much of its current topography is the result of a complex series of geomorphic processes which have taken place during the comparatively recent past.

The Sequence of Rock Strata

Despite the small size of Lindisfarne, the island possesses a varied geology. The oldest rocks on the island only surface to the north of the Snook; here the Eelwell Limestone can be seen at low tide as an area less than 200 m wide. The next layers of rocks in this sequence are shales, but these cannot be seen anywhere on the island. The next youngest rock on the island is the Acre Limestone. This limestone is most obvious along the North Shore (figure 3.2). In many ways, this is one of the most important rocks on the island, and has been used by the islanders for building material since at least the early medieval period. It was most extensively quarried for lime-burning during the nineteenth century (see Jermy 1992). More shales follow on from the limestone in this chronological sequence. These shales can be seen on the northern part of the island at Coves Haven and on the south coast, immediately south of the Heugh.
The youngest rocks on Lindisfarne are a sequence of sandstones interrupted by yet another layer of limestone. The oldest of these sandstones are visible as near vertical cliffs at the eastern end of Coves Haven. The final layer of limestone is known as Sandbanks limestone. This appears on the north shore of the island as the Castlehead Rocks. Immediately to the south of this outcrop is the now disused quarry at Nessend, a testament to the extensive working of these rocks during the nineteenth century. The Sandbanks limestone can also be seen on the south of the island below the eastern section of the volcanic intrusion. More sandstones are found on the eastern shore of the island at Lough Head.

As mentioned earlier, in many ways the most important geological features are the superficial deposits such as the glacial till (boulder clay) which covers much of the island (figure 3.2). The other important superficial deposits are the storm beaches and alluvium. At some point during its history the area now occupied by Lindisfarne did not exist as a single island. The Lindisfarne tombolo is constituted of three islands linked with shingle ridges and a dune-covered northern projection known today as The Snook (see figure 3.2). The Snook and the Snook neck are probably mid-Holocene features, formed by dunes which have built up over a low gravel ridge. The piling up of superficial deposits has contributed to the formation of new areas of dry land, and in the case of Lindisfarne, this material has served to link together the previously separate islands.
areas that were often breached by the sea during high tides and storms. On Lindisfarne, the Snook was such an area. As well as coarse sediments, alluvium has also been deposited on the island to the north of the Ouse, the island's harbour. It should be noted that the identification by Robson (1982: 3) of some of these superficial deposits as alluvium should be questioned. It is more likely that these deposits are in fact colluvial, re-worked till.

At some point after these events and possibly during the last 1000 years, the size of the Ouse was reduced as a result of the continuation of these sedimentation processes. As sediments were washed in by the sea the area of dry land on this part of the island increased in size. Today a marshy area above the visible storm beach is evident. Above this marshy area is a terrace, the edge of which is clearly defined by a curving bank just to the east of the priory and the edge of the village (see figure 3.2). This is the edge of the old shoreline, and that the priory and the village were rather closer to the sea's edge than they are today.

**Topography**

The processes of sedimentation considered above have obviously largely dictated the modern topographic characteristics of the island. The relationship between these sediments is considered in this section.

Excluding the dune hills along The Snook and the dune system along the northern part of the tombolo, the main body of the island is a relatively low-lying flat area (see contour map, figure 3.3). The lowest part of the main island is just to the west of The Ouse; this contour (3.05m OD.) is below the raised beach bank and is the area that would have once been the high water area of the harbour (see earlier discussion of raised beach). The other low-lying area is around the Lough where the average height is around c. 4.3m OD.
Figure 3.3: The topography of Lindisfarne; contour plan of the island (after Galliers 1970).

The highest solid part of the island is on the Heugh; the igneous intrusion in the southern-most part of Lindisfarne, is 18.7m OD. On the main body of the island, the highest contour is the 13.7m contour in the south-western area of the island where the northern part of the village is located today. The eastern half of the village is on a relatively steep slope down to the low lying area around The Ouse discussed above. The other relatively high areas of the island are the south eastern corner of the island just to the north of the castle, and the north western area of the main island body just to the south of the dune links.

Apart from the sand dunes and the Heugh, the highest areas of the island are those overlain by clay till (compare figures 3.2 and 3.3). The low-lying areas of the island are the areas that have been infilled by later deposits; the storm-beaches and alluvium. The lowest area of the island (after the Ouse), around the Lough (the island's small lake), has clearly formed within a natural depression.

The nature of the island's topography has obviously had an important impact on the subsequent development of soils and on later sedimentation processes. There is even
some indication that the distribution of the clay till influenced enclosure on the island. On the eastern side of the island it appears that many of the field boundaries observe the extent of the till on this part of the island (plate 3.1).

Plate 3.1: Air-photograph of the island with the extent of the clay-till on the eastern side of the island indicated by white dots.

The Sand Flats

Lindisfarne is fringed by extensive sand-flats which cover the area between the mainland and the island; the extent and full characteristics of these sands are discussed in chapter 4. However, it is useful to give a brief description here.

There are two principle sand/mud flat areas. The area to the north-west of the island, known as Goswick Sands, abuts the Snook arm and just fringes the main body of the
island near the Green Shiel area. This area is characterised by relatively poorly sorted quartz and shell sands and possesses no littoral vegetation as such. The second, more extensive area, Holy Island Sands, stretches almost 5km to the south (if Fenham Flats is included). Holy Island Sands cover the area to the south of the Snook arm and the eastern side of the island. Although at a superficial level the two flats abutting Lindisfarne seem quite similar, they are in fact very different. Holy Island Sands is in fact a typical silty, mud flat, dominated in areas by Zoestra (Eelgrass) species, and in other areas, by Spartina townsendii (Cord-grass). This grass traps sediment washed in by the tides and consequently the mud flat seems to be expanding (Cartwright 1976: 26).

The Modern Climate

Today Lindisfarne and the Northumbrian coastal plain enjoy a mild maritime climate. The average January temperature is 3.4°C, frosts and snow being relatively rare on the island. The average July temperature is 14.5°C, relatively cool, but relatively dry as this part of Northumberland falls under the rain shadow of the Cheviots. Average rainfall is about 600mm. It should be pointed out that these figures are taken from Berwick-upon-Tweed which is about 15 km to the north of Lindisfarne. Also, a tombolo will obviously be susceptible to a wide range of microclimatic influences, and certain meteorological forces having a greater significance for an island than a mainland area. One of the most important is the impact of extreme winds (see chapter 4). This area tends to experience westerly gales from the mid-autumn period through to the mid-winter, while from February through to the early spring northerly winds are more likely. Wind data from Boulmer (Meteorological Office 1988), about 32Km to the south of Lindisfarne, indicate that the majority of strong winds, that is those about force seven (near gale), are predominantly south-westerly to westerlies, although winds of this magnitude can come from any direction. 15.0% of winds are from the south-west while 14.5% are from the west; easterlies are the least common.

Conclusion

This section has set the geological, geomorphological and climatic scene for the rest of the thesis which considers the environmental history, and specifically the nature of the early medieval environment of Lindisfarne. It has shown that the island is a low-lying tombolo, linked to the mainland by superficial sediments; storm-beaches and blown sand. Similar deposits are important on the main area of the island where they have served to fill in the gaps between the "high" clay till areas of the island. It is these areas
which have clearly formed the foundations for much of the human activity of the island, and their importance will be considered subsequently.

The Stratigraphy Of Green Shiel and its Environs

Introduction

This section focuses the discussion of geomorphology onto the area of the Green Shiel site itself. This part of the research is founded on the premise that the reconstruction of past topography and an understanding of geomorphological processes, and the sequences of deposition, is of fundamental importance to the study of the palaeoenvironment contemporary with the occupation of the Green Shiel site.

Methods

As discussed in chapter 2, the settlement site at Green Shiel is being excavated and recorded employing the single context system. The entire site is gridded, and excavation usually carried out on the basis of one metre grid squares. Each single context plan is levelled at every 0.5m, thus potentially allowing the three-dimensional reconstruction of each archaeological layer. This means that there is a two-dimensional plan of every site feature and layer which can be ordered in three dimensions. All two- and three-dimensional recording, including surveys of the surrounding environs, have been tied into this original site grid.

For the purposes of the topographical reconstruction, the most important site data is that which relates to the contexts that have been recognised as the occupation 'horizons', and the so called "natural", which includes the sediments on top of which the site was originally constructed.

As mentioned above, the entire site, including all contexts and finds, has been recorded three-dimensionally on the same grid. Throughout this discussion, and the entire thesis, the three co-ordinates are referred to in the following manner. The first two co-ordinates are "X" (eastings) and "Y" (northings), while the third co-ordinate is "Z", which refers to depth or elevation.

The recording of contexts and finds within the archaeological excavation has always been based on referring to the "X" and "Y" co-ordinates of the south-western corner of the relevant metre square and measuring in from the square edges for accuracy to the centimetre level. The elevations within the excavation area have usually been recorded
with an automatic level, using a single secure point as a temporary bench-mark with a notional elevation of 100m above sea-level. This was tied into an Ordnance Survey bench-mark using a total station in 1991. Consequently it has been possible to convert all "Z"-co-ordinates into actual heights above sea-level.

Apart from comparing and discussing actual differences in height across the site and its environs, and between different units/contexts in the same two-dimensional space, much emphasis has been placed upon the production of two- and three-dimensional models of the topography of the Green Shiel area. Much of this work is derived from two periods of surveying using a total-station Electronic Distance Measurer (EDM) to record automatically three-dimensional co-ordinates of the modern topography of the Green Shiel site and its environs, as well as the buried land surfaces within this area.

Two principle surveys were carried out with the EDM. The first was an extensive survey of the modern dune and slack topography in and around the Green Shiel area. In seven complete days of continuous survey, over 3,300 points were recorded.

The second was a survey covering the area of the initial survey, but with the aim of recording units buried beneath the modern land surface. For this second survey emphasis was placed on recording the buried soil in the ridge and furrow area to the south and east of Green Shiel, and the associated clay till underlying it, as well the till edge which manifests itself as a buried till cliff to the south of the Green Shiel settlement site.

Using the EDM with a "Huskey Hunter" field computer running the survey software module, which allowed the automatic calculation and logging of three-dimensional co-ordinates based on the site grid, an area totalling roughly 3 km square was surveyed. It should be emphasised, however, that only an area of about 1Km square was surveyed in detail.

Once set-up, three-dimensional surveying with such a system is very straight forward. The EDM was set up over a station from which grid pegs of known co-ordinates could be seen; ideally at least two known points were kept in sight in order to confirm that the grid co-ordinates established on the field computer were correct. In order for the EDM, in association with the field computer, to "know" its position within the grid, the co-ordinates of the point over which the instrument was set-up were entered into the field computer, followed by the co-ordinates of another known point, where the person holding the staff and prism would stand. The EDM was sighted on the prism, and a reading taken, thus orienting the EDM within the grid. Subsequently all survey readings taken with the EDM are comprised of co-ordinates which relate directly to the site grid.
Figure 3.4: Map of Lindisfarne, and detail of the north shore.

The actual process of surveying involved one person with the prism rod moving to points which they felt should be recorded, for example a break of slope and the base of a slope (the number of points recorded is entirely dependent on the detail required). For the surveys carried out in the Green Shiel area, the first priority was to cover as much of the area around the Green Shiel settlement as possible and then once the relevant area had been covered, to go over the same area adding in detail.

The Auger Survey

During the five week period of field work carried out on Lindisfarne in 1991, the main work comprised an extensive auger survey and soil sampling programme across the entire ridge and furrow area, down into the slack to the west of the ridge and furrow, and also around the Green Shiel site and the till cliff to the south of it.

The aim of this survey was not only to trace the extent of the buried soil, an area of which had been excavated during a previous season's fieldwork, but also to record its topography and ultimately consider its relationship with, and influence on, the modern
The auger survey was carried out using a Dutch auger. The survey was started at the easternmost end of the ridge and furrow near Nessend where the clay till emerges as the modern land surface. Sampling across a pre-defined grid at a uniform sampling distance would not have been appropriate and would not have yielded any extra information as little variation was expected in the subsurface features. Augering was carried out at roughly every ten to fifteen metres up and down transects oriented roughly north-south. After a transect had been completed another was commenced moving gradually further west with each transect. If any anomalies such as a sudden changes in the relative depth of the buried soil or the clay till were observed then another hole was augered between the current and the previous hole. At each augered point the depth of the buried soil and the clay till were recorded and the hole assigned a number which was written on a plastic marker attached to a peg left adjacent to the auger hole so that it could be relocated and its three-dimensional co-ordinates recorded with the EDM. Soil and till samples were also taken from the auger for analysis back in Leicester (see Chapter 5). Once the ridge and furrow area had been covered, attempts were made to trace the till under the dune slack to the west of the ridge and furrow. The final stage of the augering programme concentrated on the area immediately around Green Shiel itself, tracing the extent and nature of the clay till and the cliff edge. A section had been put through this during the previous period of fieldwork (see below, this chapter). This survey of the buried land surface is based on about 230 survey points, of which 150 are augered levels. The remainder were taken from excavated areas and modern beach levels. Despite the obvious difference in the number of points surveyed for the modern dune topography and the buried surface survey, the reliability of the second survey need not be doubted, because of the obvious differences between an undulating, topographically complex dune system, and the relatively smooth surface of the buried soil and clay till.

All of the data from both surveys, i.e. the modern topographical survey and the auger survey, were placed on the University Mainframe computer as X, Y, Z co-ordinates. The survey of the buried land surfaces is in five columns as there are three Z-values: the top of the modern land surface where the auger hole was made, and the heights of the tops of the buried soil, and the clay till. These final two Z-values were arrived at by deducting the depths measured of these features recorded during the auger survey.

Once on the Mainframe in this format the data was viewed and manipulated using the UNIRAS, UNIMAP software. The UNIMAP option allows the visualisation of any type of spatial data, whether it be of a micro- or macroscopic order. For the purposes of this kind of research its ability to produce both two-dimensional and three-dimensional contour diagrams is not only useful in saving time, but its effectiveness in manipulating
data has clear benefits for such work. In general terms UNIMAP can manipulate and enhance spatial data in a number of ways. It allows the user to emphasise or reduce certain features through the exaggeration of the ratio of any of the co-ordinates; the ratio of all Z-values might be increased in order to exaggerate earthworks or geomorphological features which might not be visible on the ground. Certain parts of a data set can be focused on and viewed from different angles of elevation and azimuth. The distance from object to observer can also be manipulated in order to alter perspective. Another useful facility is that which allows the user to select portions of a dataset graphically; these proved most useful in this study when cross-sections across the area needed to be examined.

**Interpolation**

All of the output examined and interpreted was produced using interpolated data. A brief explanation of this process is necessary as in spite of the claim that interpolation `...is used to smooth-out datasets, without distorting their meaning or validity' (UNIRAS 1990: 35), this process can in fact profoundly alter the nature of the original data as collected in the field, and may hide underlying inadequacies in the data. For example, in some instances it is quite possible to produce a similar interpolated contour diagrams from two very different datasets: one containing over 3,000 points and a second containing only 300 points. Differences between the two will only be noticed when specific areas or sections are focused upon.

Interpolation allows the user to produce a continuous surface from discrete irregular data. The foundation for all interpolation is the assumption that the dependency of a data-point on others diminishes with increasing distance (UNIRAS 1990: 35). Related to this important assumption is the understanding that every data point within a set is dependent upon its neighbours. The interpolation process relies on the spatial autocorrelation of points. It is this dependence on neighbours which allows a smooth continuous surface to be drawn between points, filling in space where there is in fact no actual data.

Within the UNIMAP interpolation facility there are seven variations which are available, although not all of them are suitable for irregular data (data collected from randomly-spaced locations). The method employed for this study was bilinear interpolation which initially locates all of the data points onto a grid and then places an equal emphasis on the relationships between both of the variables being interpolated. The next stage involves an improvement of the original estimate, computing the gradients at each point. Finally the values are further improved by distance weighting
For the analysis of the modern dune system and the sub-dune land surfaces two plot types were produced using the interpolated data-sets. The first set were two-dimensional plots, as would be expected on a contour map, the second set of plots were pseudo three-dimensional.

The interpretation of these plots will include descriptions of stratigraphy and the relationship of the different sedimentary units across the site. The ultimate aim was the recreation of the pre-dune system and therefore, an indication of what the topography would have been like without the large dunes that characterise the Green Shiel area today.

The Modern Dune Landscape

The reconstruction of the sub-dune topography and the site's position within this system will be approached on a number of levels. Moving from the largest scale to the smallest, the first discussion will consider the history of the dune system at its fullest extent. In all of these studies it must be emphasised that only \textit{termini post quem} and \textit{termini ante quem} can be given for the various features discussed in this chapter. The purpose of this section is to assess the probable topography of the area in and around Green Shiel prior to extensive sand dune development.

Investigations of the modern dune system are based on a number of sources. One of the most important is the actual observation and recording of the system in the field. However, the most useful technique for recording the nature of the modern dune system as a whole has been the analysis and plotting of air-photographs. In fact the study of air-photographs taken between 1940 and 1989 has allowed a consideration of the important recent changes in dune morphology that have taken place around the Green Shiel area itself. The \textit{termini post quem} and \textit{ante quem} considered in this study can really only be relevant to the most recent dune development as many of the features used relate to the limestone industry on the island which dates from the end of the eighteenth century onwards. It is known from written sources and discussions with islanders that other buildings such as the fishermen's Shiel hut, to the west of the early medieval settlement, has been covered by sand and then re-exposed during recent years. It is this instability within the shifting dune system that inhibits the dating of specific areas of the dunes; in most instances it is only possible to consider the chronology of the system as a whole.

The dune system that exists today is relatively stable, and has only been in this state in
the Green Shiel area since the 1970s. There is of course no reason why the system may not have been in a similar state at other times during the past, and subsequently altered. However, there is no evidence that indicates that it has been any more stable in the past: if it had been, we might expect tree remains to have been found within the dune system.

As figure 3.4 and plate 3.1 show, the modern dune system covers the whole of the north shore of the tombolo. The Snook and the "arm" or "handle" which almost connects the main body of Lindisfarne to the mainland is also covered by the dune system, but discussion of this is kept to a minimum, although its relationship with, and influence on, the main body of the tombolo can not be ignored.

The north eastern corner of Lindisfarne is known as Emanuel Head; this is the easternmost extent of the dune system. From the earliest maps (even including that published by Speed; see below) it is apparent that the low sand hills/hummocks were certainly well established and had probably been stable for the greater part of the system's history. The earliest air-photograph, taken in 1940 (see plate 3.2), clearly indicates that this area was vegetated and stable. Moving westwards to the area below Sandham and then Keel Head, it is possible to argue that like the area at Emanuel Head this area has been well-established and stabilised for the majority of the system's history. However, an examination of the air-photographs clearly shows that where the dunes abut the western tramway immediately to the south of Sandham (figure 3.5), those to the north (seaward) of this mid-nineteenth century trackway are relatively larger than those to the south. It can be inferred from this that the trackway has operated as an obstacle to the continuous development of dunes to the south of its path. We might expect a gradual reduction in dune-size as we move landward, but not one that is so abrupt.

To the west, the area south of Castle Head Rocks, Coves Haven, Snipe Point, and Green Shiel itself, comprises the central dune area, with the widest expanse of dunes, and partly developed slacks. Along this part of the island, all of the Ordnance Survey maps (1860 onwards) and the air-photographs show that the main dune ridge occupies the southernmost area of the system, abutting the northern boundaries of the enclosed fields (see below, this chapter). As we can be reasonably sure that land within the dune system would not have been enclosed, it is possible to use the northernmost enclosure boundary as a *terminus ante quem* on the grounds that as much useful land as possible would have been taken into enclosure, and therefore, fields would have been extended as far as possible towards the dune area. The dunes must have developed in this area at some time prior to 1793 (Enclosure of the Common Land Act). In fact in one area the north-western corner of the enclosed land adjacent to the Old Kilns; and the trackway which would have led to the Nessend quarry, the sand has blown beyond the enclosure boundary and has built up against the raised trackway. From the air-photographs it is apparent that much of this build-up took place between the 1950s and the 1970s.
Plate 3.2: Air photograph of the north shore of Lindisfarne, taken in 1940.

Figure 3.5: Map of Lindisfarne showing limestone trackways.

In fact the trackways, and other works relating to the nineteenth century extraction of limestone from the north shore of the island, as well as written accounts of visits to the island, serve as useful chronological markers: in most cases, *termini post quem* for dune development. For example, the Kennedy Limeworks included limekilns which were located at the far top western-most corner of the enclosed farm land bordering the dune system. By 1860 these are referred to as "Old Kilns" on a map of the area (O.S. 1860, sheet N VIII.11). It is known that these kilns were only in operation for just under three years during the 1850s and it is inferred from this, and the map evidence, that the trackways from Nessend to these kilns on the western side of the island were
out of commission by this date as well (Jenny 1992: 29).

The route of these trackways is still apparent today, although sections are covered by blown sand. However, these trackways were certainly more visible during the 1950s, and it is only with the stabilisation of this area of the dunes during the last thirty years that they have become obscured. One trackway, just to the west of the Green Shiel site, disappears into one of the large dunes to the south of Green Shiel (see figures 3.4 & 3.5), a dune which seems to have stabilised during the decades following World War II. A building associated with the quarrying at Nessend was located next to the tramway at Nessend, but this building is no longer apparent and must have been buried by sand at some time during the late nineteenth century.

Speed’s map of 1610 (plate 3.3), based on a survey by James Burrell, gives an impression of the state of the dune system at the end of the sixteenth century. Accepting that maps from this period are inaccurate by modern standards, this map is a useful source. Its reliability is partly proven by the fact that it does indicate the existence of distinctive sets of dunes. These locations correspond to a certain extent with the location of the main areas of dunes in the system today, two of which are located on the eastern side of the island. Of the five sets depicted on the north shore, the small dunes on Emanuel Head support the contention that this area of dunes was well established and has been relatively stable for a number of centuries. Speed’s map gives a reasonably reliable *terminus ante quem* for this at the very beginning of the seventeenth century. Moving west to the area south of Castlehead rocks, a single sand dune is shown, possibly representing the area today where the central track from the village towards Castlehead Rocks disappears into a complex blow-out (figure 3.5). Further west, to the area just to the south of Snipe Point and in the Green Shiel area, there are two distinctive groupings: one of two, and the other of three, sand dunes. A dune ridge in this area is apparent on the 1855 Admiralty chart, but not on the 1860 Ordnance Survey map. It is most likely that this area was covered by dunes, perhaps of large dimensions, from time to time. These maps and the air-photographs can be seen as further evidence of the instability of this part of the dune system, a characteristic that will be considered more extensively below.
Plate 3.3: Speed’s map of Lindisfarne, published in 1610.

The final area of dunes depicted on Speed’s map is in the southern-most area of the system, close to the location of the Old Kilns.

Accepting the problems of inaccuracy and the possibility of artistic licence, it is fair to consider this map as being a reasonable representation of the major elements of the dune system as seen on the ground: such a map can serve as a useful terminus ante quem for the dune system on Lindisfarne. The fact that the dunes at Emanuel Head are depicted as a separate unit, when this part of this system could not be considered as prominent, does imply that a reasonable level of competence was achieved. It is also possible to relate the other major elements of the modern dune system with the different dune hills depicted on Speed’s map.
The Green Shiel Environs: The Dunes

The above discussion of the map and air-photographic evidence is especially important for the investigation of the dunes around the Green Shiel settlement site. The evidence indicates that this area of dunes, more than any other, has been one of the most unstable areas within the system.

The Green Shiel DTM

The two- and three-dimensional models of the Green Shiel area as it exists today are the starting point for the description of the topographical characteristics of the area around the settlement site (see figures 3.7 & 3.8).

Today there are two main sets of sand dunes in the immediate Green Shiel environs. The first, and probably the older of the two, is dominated by one major dune just to the north of the settlement site on the shoreline (the centre of this dune is located at c. 1000/1100 in relation to the site grid-system). This is a well-established dune measuring over 100m in length and about 60m in width. The top of this dune forms an undulating plateau which may be the product of coalesced smaller dunes. There is little doubt that this form has been stable for at least forty or fifty years as the air-photograph taken in 1952 shows it as a vegetated island of stability, almost surrounded by unvegetated blown-sand.

To the south of the settlement site are the most unstable dunes in the system (figure 3.6, area "B"). These are located between c. 740/840 in the west, and c. 1000/890 in the east (on figures 3.7 & 3.8). The maximum height of these dunes is almost 20m. This group is broadly made up of three or four large dune blow-outs which form a ridge of about 15-18 metres in height running along the southern edge of the Green Shiel area. This ridge suddenly comes to an end in the east at co-ordinate c. 920/890, where there is a gap, one of the main access points to the Green Shiel site. To the west of this point another relatively small dune has formed, about 14.5m in height. In an almost straight line east-north-east of this a group of low hummocky dunes extend, for a distance of about 120m, then this part of the system takes a sharp turn north-west joining up with the large dune considered at the beginning of this section.
Figure 3.6: Map of north shore showing areas discussed in text.

The settlement site itself (on the DTMs, figures 3.7 & 3.8, centred at c. 950/1000) is located within a flat area, the specific sedimentary characteristics of which are discussed below (this chapter, and the particle size analysis in chapter 4). This area extends right up to the edge of the dunes to the north and south, and to a gentle slope to the south-east. The edge of the beach lies to the north-east and east. The flatness of this area is only interrupted by the trackway to the west of the site, and the line of a storm beach which runs in a north-east-east direction from the settlement site (see figure 3.10).
Figure 3.7: Two-dimensional contour plan of Green Shiel environs and locations of the ridge and furrow trenches.
As should be apparent from this description, the map and the DTMs, the Green Shiel settlement site is located on a flat land surface which appears today as a sort of embayment, almost surrounded on three sides by dunes of various dimensions, and virtually open to the beach on the fourth side. Both the three-dimensional models and the two-dimensional contour diagrams highlight this topography. Although this area is undeniably flat in relation to its surroundings, there is a gentle slope seawards from the buildings. The south-east corner of this area is only c. 5.5 - 5.7m above sea-level; however, this is high enough to be well above tidal-surge range. In the south-west corner the height is lower at about 5.3m; north of this, moving towards the beach area north-west of the buildings, there is a further drop in height to just over 5m (see figure 3.9).
Although heights of five metres above sea-level imply a reasonable vertical distance between the site and sea levels, it should be remembered that these measurements are based on sea-levels at Newlyn in Cornwall; it is therefore the relative relationships of heights above sea level and local high tides which is important.

A series of measurements of the strand line, based on the mid-points of flotsam, jetsam, sea weeds and kelp, were taken as a part of the survey along the shoreline and beach near Green Shiel. The assumption here is that this line represents the average extent of high-tides. An average of the heights measured is +3.25m OD, only about two metres lower than the area on which the Green Shiel site is situated. However, it also necessary that the tidal ranges taken from tide tables for this area also be considered. During the Spring and autumn high tides can range from 3.9m to 5.4m. It is clear then that some spring and autumn high tides do reach a height comparable with the parts of the Green Shiel flat area. However, it is important to bare in mind that there is no evidence of this area ever having been inundated by the sea, and that during the early medieval period storm surges were probably far less frequent (see below, chapter 4). Despite this, it is important to note that Green Shiel was built very close to the edge of high tidal limits.

Moving inland to the south-east of the Green Shiel site is the area referred to as the ridge and furrow (see figure 3.4 & plate 3. 1). The visible ridges and furrows extend about 400m to the east, and at the widest part, about 200m across, north to south. The
central area of this ridge and furrow ranges between 12.5 and 13 metres above sea level (see DTMs figs 3.7 & 3.8), roughly seven metres higher than the Green Shiel flat. The ridge and furrow area slopes gently upwards to the east towards the Nessend quarry area, and slopes down to the north shore from its central area.

The final characteristic of the dune system in the Green Shiel area which is of importance to this study, is the slack area to the west of the ridge and furrow, and to the south of Green Shiel itself and the major dunes.

As is apparent from figures 3.7 and 3.8, the terrain immediately to the west of the ridge and furrow slopes down onto what is really the only true dune slack within the Lindisfarne system (area "C" on figure 3.6). This central area of this slack is on average 8.4m above sea level, just under three metres above the Green Shiel flat, and about 4.5m below the ridge and furrow area.

The Sub-Dune Topography

Introduction

Having considered the characteristics of the modern environment in the Green Shiel area, this section will go on to discuss the nature of the ancient environment, with the specific aim of reconstructing the early medieval topography and the situation of the settlement site within it.

As mentioned earlier in this chapter, much of this work is based on the results of augering, pit excavation, and EDM survey of the buried land surfaces in this area. The auger survey traced the extent of the buried soil and the clay till, and a series of pits were dug around the immediate area of the settlement site on the Green Shiel flat.

The Stratigraphy of the Green Shiel Flat

The auger survey followed the extent of the clay till up to the edge of the Green Shiel flat. The edge of the till is at the bottom of the cliff slope. This edge was also examined by excavation (see below, this chapter). No identifiable buried land surfaces as such could be traced in this area; therefore the various sedimentary units which underlay this part of Green Shiel were examined in a series of sections with reference to the stratigraphy of the settlement buildings revealed during the excavations.

Pits were dug in the four flat areas delimited on two sides by the cross shape of the
buildings (see figure 3.10). The pits were excavated in order to answer specific questions and their location was based on a purposive sampling strategy. They were dug at irregular intervals with the sole purpose of identifying the sub-surface stratigraphy. If there was any change in the characteristics of the stratigraphy, then another pit was dug between the two where the change had been identified. One of the first problems to be considered was the relationship between the sedimentary units in the flat around the site and those which abut, and underlie, the buildings. In many ways the most useful characteristic in all of these settlement/geomorphic problems is the comparative elevation between sedimentary units across the area. Specifically, this concerns the relationship between the "occupation" horizons within the buildings (including the elevations of bottoms of walls) and the sedimentary units external to the buildings such as those within the immediate flat area, but also all of the units which constitute the ridge and furrow, the slack and the beach.

The Occupation Levels

Key to the analysis of the stratigraphy across the archaeological site and the surrounding environs is the description and discussion of the heights above sea level of the occupation horizons and the comparative differences between these and the surrounding topography. As is made clear above, this is of profound importance on a site located on the shoreline and therefore potentially under threat from tidal surges.
Figure 3.10: Plan illustrating location of buildings, soil pits and trenches and their spot heights in metres above sea level.

As with any contour survey of a relatively flat surface of which macro-scale questions are being asked, relatively few points need to be used in order to characterise the nature of the surface. A total of forty-four points from buildings "A" and "C" were taken from plans, sections drawings and associated level record-sheets. Once converted into real heights this data was used on UNIMAP to produce figure 3.11. This figure comprises interpolated two-dimensional contour plots of the occupation horizons of buildings "A" and "C". The average height above sea level of the occupation horizon in building "A" is 5.83m, while in building "C" it is 5.7m. Considering that the maximum occupation elevation for building "C" is 5.9m there is little doubt that the occupation levels of this building are at least 20cm higher than the modern land surface adjacent to the building. In the case of building "A" the same relationship is true; occupation levels are at least 30cm above the current land surface (the descriptive statistics relating to the levels recorded for these occupation levels can be found in appendix 2). In order to consider the characteristics of the relationship of the surrounding units to these buildings an examination of the units recorded in the pits is necessary. Figure 3.10 gives the location and current land-surface elevation of test-pits and slit-trenches around the site, while figure 3.12 includes the section drawings of the test-pits; this diagram is organised so that each pit is located in its relative position, thus indicating the variation in the stratigraphy across the site. The particle size characteristics, and the comparison of these with the other sediments studied, are detailed in chapter 4.
Figure 3.11: Two-dimensional contour plots of occupation elevations for buildings "A" and "C".

In the following discussion of the various sedimentary units around the site, a letter (A to J) is given in order to simplify identification. The Munsell colour is also given on the first occasion that any unit is mentioned, and also is placed on the key on figure 3.12.

Pit 1a, which includes slit trenches running south from it, and pit 2a, run south of building "A", and were excavated in order to trace the extent of the blown sand that covers all of the buildings, and consequently to assess the relationship of the external sedimentary units to the buildings. As the slit trench section shows (figure 3.13), the red sand (unit B: 5YR 6/6) is a unit which has built up since the construction of the building and probably since its destruction, as relatively small lumps of rocks/rubble that are probably tumble from the building walls occur in lower units. Although the red sand (unit B) is the predominant unit, it is covered in some areas by sediments that were deposited more recently (unit C in pits 3a and 10 for example). The full variation of stratigraphic sequences can be seen in the test-pits (figure 3.12). But in broad terms, the unit usually found below the turf in most areas of the flat was a red (unit B) or mixed red/bleached fine sand (unit J: 5YR 7/6). The red unit (unit B) becomes thinner moving south away from the building and occurs in varying thicknesses around the flat. This unit virtually disappears in the north west area (pit 10, figure 3.12). Within the red sand (unit B) and the mixed red/bleached sand (unit J), a number of clay bands (unit D: 5YR 4/1) were found which varied greatly in frequency and thickness. The
frequency and thickness of the bands (thickness and frequency becoming confused where bands have fused) are at their greatest in the central south-eastern area of the flat, especially in the slit trench (figure 3.13) and pits 5 and 4 (figure 3.12). The interpretation of these features is not straightforward, partly due to the lack of comparable examples. The most likely explanation is that they are colluvial sedimentary products derived originally from the clay till cliff to the south and south-east of the settlement site. As a general rule the highest concentrations of the bands occur in areas closest to the cliff. Frequency and thickness fall off to the north of this area, and they are completely absent in pits 8, 9, 10 and 4a (see figure 3.12). The multiple occurrence of these features separated by sand units (units B and J) in some places, implies that the process occurred on more than one occasion; but it is impossible to tell what the interval between each deposition was. However, there is little doubt concerning their stratigraphic position and their relationship with the other units discussed. In every instance the bands occur above the beach sand base unit (unit I: 7.5 YR 7/2), and also in the trench of pit 1a and in pit 2a they occur above what is taken to be tumble from the settlement. They are therefore most probably a feature which developed some time after the site had been abandoned.
Figure 3.12: Diagram of section drawings of test pits in their relative positions around the Green Shiel flat. N.B. facing direction of each section is denoted by bracketed letter above section.
Below the clay bands, and the sand units within which they occur, the final unit, the coarse "beach" sand (unit I), completes this stratigraphic sequence. In every case this final unit was augered to about 1.5m below the bottom of each pit to ensure that it did not alter. The average elevations of the beach sand taken from each pit and trench can be seen on figure 3.12. As with the current land surface, the beach levels are higher to the south and east (moving away from the shoreline). In the central south-eastern flat area the level of the beach sand unit (unit I) varied between c. 5.0m and 5.15m (pits 1a, 2a, 4, 5 & 6). Moving to the east, in pits 1 and 2 the beach unit elevation rose to c. 5.35m OD. The elevation in the southern area, moving towards the cliff, was about 5.4-5.5m OD (pits 3, 7 & the cliff section, figure 3.12.). To the north and west of the settlement buildings (moving towards the shoreline) the level of the beach unit (unit I) is lower: between 4.6m and 4.8m OD (pits 4, 9, & 10) in the north and about 5.1m OD just to the west of building "C" (pit 8) in the west.
Discussion

The investigations of stratigraphic relationships between the site and the surrounding flat revealed that the site was constructed on and occupied an elevation roughly 30cm higher than the modern surrounding land surface. The immediate significance of this is that the surrounding flat is quite probably a deflationary environment. The land surface that was once contemporary with the settlement site has at some point been removed. It is apparent that the so called "beach" sand (unit I), observed in the test pits and trenches, influences, and has always influenced, any subsequent sedimentary deposition, in that its slope towards the shore is always reflected in the layers which overlie it. There is little doubt that the units which overlie this basal layer have all been deposited since the site was abandoned. In pit1a (figure 3.12) rock/tumble touches the beach unit illustrating the point that many, if not all, of the sedimentary units in this area which lie above the beach sand (unit I) are the result of processes that have taken place after the initial occupation of the settlement.

The Till Cliff

As mentioned above, to the south of the settlement site a clay till cliff, now covered by blown sand, forms what is today a relatively gentle slope which leads up to the ridge and furrow area.

The cliff was initially discovered during a preliminary auger survey, and was examined in detail through excavation in 1990 (see plate 3.4, & figure 3.7 for trench location). The excavation revealed that the cliff had a slope of c. 25-30°, which is relatively steep for till. The clay is clearly glacial in origin and is the edge of what is perhaps the most important geological unit on the island as it forms the foundation for the highest areas on Lindisfarne (see chapter 2). Large boulders were discovered at the surface and within the clay. A series of boulders along the top of the cliff were traced with the auger. The possibility of an anthropogenic origin for these was considered and might be evidence for a field boundary of some description. However, on other parts of the island, where the till outcrops as cliffs, a number of boulders can be seen in the section face. Boulder clays are exposed on the south-west and on the east coast of the island. In both areas the clay contains large, sub-angular to sub-rounded boulders, similar to those found in the Green Shiel section. The till itself is undoubtedly of Pleistocene origin (Robson 1982: 3), however, it is the date of the Green Shiel flat at the bottom of the cliff that is important. As figures 3.7 and 3.8 clearly show, the Green Shiel area is essentially a low embayment backed by sand dunes which have built up against the till cliff. This embayment area is approximately 6m OD. This height clearly corresponds
with the main postglacial shoreline altitudes for the coast of south-east Scotland (see Sissons 1976: chapter 9 and 1983: 218-220). The development of the till cliff and the Green Shiel area needs to be placed in the context of the early postglacial development of the island as a whole. Following the de-glaciation of the area, the relatively high areas of Pleistocene till would have experienced a certain amount of isostatic recovery; the remaining low-lying areas of the tombolo are largely early Holocene marine deposits. The combination of isostatic recovery and sedimentary deposition resulted in the formation of today's landsurfaces. These processes are identifiable on other parts of the tombolo. The Ouse which forms the modern day harbour adjacent to the village (see figure 3.2), comprises a raised beach feature, which serves as an embayment. The raised beach is backed by a lower marshy area which gives way to a low terrace (Galliers 1970: 13). This feature is essentially part of a storm beach which probably emerged during the early Holocene. However, we can be reasonably sure that it abuts the glacial clay till which forms the higher parts of the island which are obviously Pleistocene deposits. This feature, and the cliff-embayment area at Green Shiel must therefore be considered as the result of two principle processes: first, the isostatic recovery of both, Pleistocene till deposits (which would have also been eroded and shaped by the retreating ice), and Pleistocene sands and gravels, and second, early Holocene deposition of sediments as sea-levels rose and finally stabilised. Consequently it is apparent that the Green Shiel cliff and embayment are of late-Pleistocene/early Holocene origin, however, there is little doubt that this area has undergone a certain amount of subsequent alteration; most notably the deposition of aeolian sands up against the till cliff.

One of the primary reasons for excavating a trench up against the cliff was to examine the nature of the sediments that had been blown up against it, and to ascertain their relationship with those sediments around the Green Shiel settlement site considered previously.

The sediments that have built up against the cliff are dominated by a fine red sand (unit B) (see figure 3.14), similar in colour and texture to the red sand described above from the test pits. However, its particle size characteristics are slightly different (see below chapter 4).

Moving from the current land surface down through the central area of the section (see figure 3.14), the top turf layer (unit A: 7.5YR 4/2) overlies a c. 10cm thick deposit of light coloured sand (unit C: 10 YR 8/3). Below this unit the stratigraphy becomes slightly more complex. Towards the top of the cliff section the layer below the light top sand (unit C) is a mixture of surface till and clay wash (unit M: 7.5 YR 6/4) which lay directly on top of the clay cliff surface (unit O: 7.5 YR 6/). Further down the section, the dark sand (unit K: 7.5 YR 5/2) covers a buried soil (unit L: 7.5 YR 5/2) of 5-8cm
thickness; this in turn overlies a unit of red sand (unit B), which at its thickest is 40cm. Below this unit the band of clay wash (unit M), which is clearly derived from the top of the cliff, appears throughout the section as a sloping unit of about 12cm to 30cm thick. The final major unit, which directly overlies the cliff surface, is another deposit of red sand which is considered to have the same provenance as the red sand unit above (unit B). This is interrupted by a black lens of staining (unit N: 7.5 YR n 2/). At the foot of the cliff section the basal layer is a bleached sand containing stones and rocks (unit I), the same unit that underlies the whole of the Green Shiel area.

Plate 3.4: The excavation of the till cliff-line.
Figure 3.14: Section drawing from the excavation of the clay cliff at Green Shiel.
Although the base of the cliff is covered by over 1.5m of sediments, the top of the cliff line, as would be expected, is buried by less than 20cm of material. The elevation of the top of this section is 8.6m above sea level and 3-3.5m higher than the current elevation of the Green Shiel flat area. The relationship of the cliff to dune formation processes is discussed below (chapter 4).

Moving south (inland) from the top of the cliff section, the blown sand becomes thicker, and the till is here buried by the large dunes discussed earlier. However, away from the dunes in the flat areas between them, and in the ridge and furrow area, the clay land surface and the soil which developed on top of it can be traced.

**The Ridge and Furrow Area Stratigraphy**

*Introduction*

The modern characteristics of the ridge and furrow were considered earlier. In this section the stratigraphy and the topographical characteristics of the buried units are considered.

The modern land surface is about 12.5m-13m above sea level. The amplitude of the ridge and furrow is quite low, and consequently the accurate measurement of the distance between the centre points of two adjacent ridges or furrows is difficult. However, this width is c. 8m, with ridges and furrows of about 4m each. The tops of the ridges are roughly 8-10cm higher than the bottoms of the furrows.

Below the modern land surface the stratigraphy is quite simple. As figure 3.15 shows, the two trenches excavated in this area revealed very similar stratigraphical characteristics (see figure 3.7 for location of trenches). The modern land surface is formed by a grass turf (unit A1 7.5 YR 4/2) of c. 8-10cm thickness. Below this unit a thick deposit of light-coloured blown sand (unit B2: 10 YR 8/3) (see plate 3.5) overlies the buried soil (unit C1: 7.5 YR 5/2). There is, however, some variation in the thickness of this deposit across the ridge and furrow. In trench 1 (figure 3.15) the blown sand deposit is c. 50-54cm thick, while in trench 2, just to the south of trench 1 (figure 3.15), this same unit is between 25cm and 30cm thick. The variation in the thickness of the blown sand deposit that lay between the modern land surface and the buried soil is illustrated in figure 3.16. This shows quite clearly that the deposit is at its thickest towards the central area of the ridge and furrow: as deep as 1.2 metres in one area. This sand unit becomes narrower towards the edges of the area, especially
moving towards Nessend to the east.

Figure 3.15: Section drawings from ridge and furrow excavation trenches; see figure 3.7 for locations.

Plate 3.5: The ridge and furrow buried soil and overlying units.
Figure 3.16: Two and three dimensional representations of the thickness of blown sand between modern land surface and buried soil.
A potentially important characteristic of this blown sand unit is the fact that in both trenches there are a series of pedogenic bands. In trench 1 there are c. 20 of these bands of varying thickness. In trench 2 there are less than six that can be seen easily. These bands must represent relatively brief periods of stability during the phase or phases of sand encroachment in this part of the dune system. They will be considered below at greater length during the discussion of geomorphic processes in chapter 4.

Situated below the blown sand unit is the buried soil. This palaeosol also varies in thickness across the area. In the two excavated trenches the soil thickness varies between 8cm and 14cm. The elevation of the buried soil in this area is c. 12.1-12.30m above sea level. As the two-dimensional contour plot and the three-dimensional digital terrain model (figure 3.17) illustrate, the topography of the ridge and furrow buried soil possesses the same characteristics as the modern land surface: sloping gently uphill from west to east, and sloping down towards the north shore. There is no variation in the topographic characteristics of the buried soil. The average elevation of this area is between 11.5m and 12.5m above sea level. Therefore the buried soil is c. 7m higher than the elevation of the occupation levels of the Green Shiel settlement site, whereas today the ridge and furrow area is on average 7.5m higher than the Green Shiel flat.

Figure 3.17: (see caption below)
The similarity of the modern difference in elevation between the ridge and furrow and the Green Shiel flat with the difference between the buried soil and the occupation levels in the buildings is explained by the fact that even though the buried soil is lower than the modern land surface in the ridge and furrow area, there is little doubt that the flat around the settlement site was in fact higher at the time of occupation, or certainly when the site was constructed; therefore, "compensating" geomorphological processes, i.e. deflation in the flat and accretion over the ridge and furrow area, have ensured that the relative differences in height of these two areas have altered very little. The next stratigraphic unit in this sequence is the clay till which underlies the buried soil over the majority of this area; the elevation of this unit is between c. 8-14cm below the surface elevation of the buried soil (figure 3.18). There is, however, some important variation in the stratigraphic sequence in the ridge and furrow area. North of the currently visible ridge and furrow, in the area designated by a box labelled area "D" on figure 3.6, the stratigraphic sequence changes. The palaeosol and till become subdivided and the following sequence emerges: turf/sand/palaeosol/sand/till (rather than the sequence elsewhere of turf/sand/palaeosol/till). A test pit was excavated in this area and the section drawing illustrates this variation (figure 3.19). Figure 3.20 shows both a two-dimensional and three-dimensional plot of the thickness of the sand unit that is sandwiched by the palaeosol above, and the till below, in the area where this subdivision occurs. This unit reaches its maximum thickness in the northern part of the
area where it achieves a depth of c. 1m. Over the majority of the sub-divided area the unit is between 0.4m and 0.7m thick. In the south of this area the sub-dividing sand unit achieves a thickness of between 0.6m and 0.8m. Moving further south (inland) the sub-division disappears and the undivided sequence reappears.

Figure 3.18: Two-dimensional contour plot and three-dimensional digital terrain model of clay till surface across the ridge and furrow and Green Shiel environs viewed from the north west.
Figure 3.19: Section drawing from ridge & furrow pit illustrating the sub-division of the palaeosol sequence.

Figure 3.20 (below) should be compared with figure 3.16 (the depth of blown sand between the modern land surface and the buried soil). Both diagrams represent what could be described as low extensive dunes in the central ridge and furrow area. Figure 3.20 represents an event, or events, that took place before the period of stability that allowed the development of the buried soil, while figure 3.16 represents a similar low dune that developed on top of the buried soil, possibly when the main dune system developed. These processes are considered more fully in chapter 4 below.

To the south of the ridge and furrow and the dune ridge which abuts this southern edge, the buried soil disappears and the height of the till dips down from about 11m to just over 10m (see figure 3.18). Therefore, the buried soil developed on an elevated area of till which as a result of its relative height afforded some protection from sand inundation from the south and west. The significance of this to the history of the development of the dune system is considered below in chapter 4.
Figure 3.20: Two-dimensional contour plot and three-dimensional digital terrain model of the thickness of the sub-dividing sand unit which lay below the palaeosol and above the clay till in area "D" on figure 3.6.

The Slack Area
The final stratigraphic element of the Green Shiel environs which must be considered is the relationship of the dune slack to the ridge and furrow area and Green Shiel (see figure 3.6, area "C"). The buried soil emerges to the west of the ridge and furrow on a slope from beneath the blown sand unit (see figure 3.17) in the area of c. 800/700 on the two- and three-dimensional plots. In the slack area itself the excavation of a pit combined with an auger survey revealed that below the soil (which can be defined as a split-palaeosol in this area) the clay till was overlain by an average of 1.80m of blown sand. Tracing the extent of the till westwards became impossible due the limits of the auger extension rods.

We can assume that the elevation of the slack area has altered very little and this area has remained a stable feature throughout the history of the dune system. There is, however, no reason why this area may not have been covered by dunes which have subsequently disappeared. If the current slack surface did develop as a part of the original palaeosol then it must also be recognised as the ancient land surface. As noted earlier this land surface is currently c. 8.4m above sea level and would therefore have been at an elevation c. 2.5m above the settlement site.

General Discussion

This section has considered the nature of the sedimentary relationships in and around the Green Shiel environs which includes the ridge and furrow area. Much of this investigation has been concerned with observing basic stratigraphic principles in the interpretation of the relationships between the settlement occupation levels and the surrounding land surfaces. Unlike the majority of sites in other environment types, the problem has been complicated by the nature of the aeolian processes in a sand dune system, deflationary and accretionary processes having to be considered together. The aim of this part of the research was to develop an understanding of the topography of the Green Shiel area contemporary with the early medieval occupation of the settlement. Crucial to the reconstruction of the early medieval environment on the north shore of Lindisfarne is the reconstruction of the history of the dune system and the sub-dune topography. This type of geomorphological work is absolutely necessary in an environment that is subject to potentially rapid and extensive environmental change. In this environment type more than most, ecology, and therefore the availability of resources, is closely linked with the fluidity of such a geomorphic system.

Figure 3.21 summarises the principle stratigraphic relationships described in this chapter with the emphasis placed on the relationship between the Green Shiel settlement area and the following; the ridge and furrow area, the slack and the shoreline.
Figure 3.21: A representational diagram indicating the various stratigraphic relationships around the ridge and furrow, and slack area (not to scale). See figure 3.6 for the transect line represented by this diagram.
CHAPTER 4
ENVIRONMENTAL PROCESSES IN THE GREEN SHIEL ENVIRONS

Introduction

Chapter three considered the various stratigraphical relationships between the dunes, the sediments around Green Shiel, and the various built structures within the system; from these descriptions a broad relative chronology was derived. The aim of this chapter is to reveal the nature and characteristics of the environment contemporary with the early medieval settlement at Green Shiel, as well as before and after. The emphasis of this chapter is on the similarities and differences that exist between the present topography and geomorphological processes on the north shore of Lindisfarne, and those of the early medieval period. This chapter considers the nature and intensity of the range of environmental processes that characterise a coastal sand dune system, emphasising the extent to which these processes have varied throughout the historical period. Section 1 describes that range of processes which affect sand dune systems, and section 2 goes on to consider these processes from an historical perspective.

Dune Formation Process

Introduction

Much of the research into coastal dunes has been borrowed directly from research into desert dunes (Cooke & Warren 1973), and consequently studies of coastal dune systems have often failed to consider explicitly the processes peculiar to this environment type (i.e. linear systems with often extensive vegetation cover), assuming that direct comparisons can be made between these two very different environments. Although the principles of desert geomorphology inform any study of a coastal dune system, especially the study of aeolian sedimentation, the nature of the specific processes that give rise to stability and instability within a coastal dune system must be elucidated.
Sediment Sources

The important factors in any investigation of sedimentation is the nature of sediment source or supply and the mechanisms involved in its transportation and deposition.

There are two source areas for Lindisfarne: Goswick Sands to the north-west, and Holy Island sands to the south-west (see figure 4.1). An important question is the extent to which each source area contributes sediment to the Lindisfarne dune system.

The source material of the Lindisfarne dunes is wave re-worked sand from shoals which were originally derived from glacial drift (Bird 1990: 20). Some of the sediments that constitute today’s sand-flats may also have their origins as alluvial sediments washed down from the upland areas to the west immediately after the last glaciation. The major river system in this part of Northumberland today is the Tweed which discharges c. 14km up the coast, north-west of Lindisfarne.

Figure 4.1: Map of Lindisfarne and its sand-flats.

As mentioned above, there are two named sand-flats supplying Lindisfarne. First, Holy Island Sands, to the south and south-west of the tombolo, covers an area of c. 6km², if the course of South Low (a stream running south-eastwards from the mainland across
the sand-flats) is taken as the boundary with Fenham Flats to the south (see figure 4.1). For practical purposes Holy Island Sands and Fenham Flats should be considered as one system. The second sand flat is Goswick Sands, which also covers an area of about 6km² in a relatively narrow strip extending west-north-west from Lindisfarne towards Goswick on the mainland. However, the characteristics of Goswick sands are complicated by the fact that by the end of the nineteenth century the course of the Swinny Goat, once a freshwater stream running from the same mainland source as South Low, but turning to the north-east rather than to the south-east, began to alter. Today, (and probably since the 1950s), the Swinny Goat is a separate channel, disconnected from its mainland source and running close to the north shore of the Snook arm, disappearing into the North Sea just to the north of the Green Shiel area. How this change affected sediment supply is open to question. Darlington (1965: 75) observes that such a change resulted in Goswick Sands extending another mile to the east, implying an increase in the sediment source area, and therefore one must assume, an enhanced potential for sand-blow. However, it might be possible that the development of a channel close to the north shore of Lindisfarne has acted as a barrier to sand flow, thus potentially decreasing the amount of sand reaching this shore.

This development on Goswick Sands is only known about as the variation in the course of the Swinny Goat took place during the modern period when mapping was well developed. There is no reason to suppose that such variations have not taken place in previous centuries, both over Goswick Sands and Holy Island Sands.

In summary, it should be apparent that the sediment supply characteristics for the Lindisfarne dune system are complicated to a certain extent by the existence of two areas of sand-flats, split roughly into two by the Snook arm running from west to east. However, this situation does not preclude us from developing an understanding of the processes which have affected the dune system.

The Particle Size Analysis Of Sediments From Around Green Shiel and Its Environs

Introduction

In any study of sedimentary processes particle-size is one of the most fundamental sedimentary characteristics for the description and interpretation of any sedimentary unit. Therefore particle size studies are common in alluvial, colluvial and glacial geomorphological studies. Aeolian geomorphology has achieved a new popularity during the last ten to fifteen years. Prior to this, research into aeolian geomorphology
had been a minor discipline, dominated by a few committed specialists, most notably R.A. Bagnold (1941).

Aeolian landforms and surface properties are characterised by geomorphic processes which are primarily a function of wind velocity and direction. The sediments, and the soils, in these environments are formed primarily from particles transported and deposited by wind.

During the last few decades of research into aeolian environments there has been an emphasis on the study of deserts and the dune forms therein (Cooke & Warren 1973; Mabbutt 1977). Much of this work is pertinent to the study of coastal dunes, particularly research into the physics of sand particle transport. However, coastal dunes are very different environments from desert dune systems and therefore require a modified approach. Investigations into coastal dunes have continued to be largely informed by research carried out into desert sedimentary processes. Coastal geomorphologists investigating dune systems during last two decades have placed great importance on the early work of Bagnold, as well as subsequent particle-size research by Folk & Ward (1957).

The study of the particle size distributions from Lindisfarne employed the traditional classical statistical method which employs descriptive statistics. A more recent statistical method using log skew Laplace as developed by Fieller et al. was carefully considered (Fieller et al. 1984; Fieller & Flenley 1988; Fieller et al. 1992). However, for a number of practical reasons this form of statistical analysis could not be pursued.

The aim of the analysis is to assess the particle size characteristics of aeolian sediments from a number of different "environment types" in and around the Green Shiel settlement site. This data is then used to describe the nature, and consequently, the possible depositional environment, of the sediments on top of which the buildings at Green Shiel were built. To achieve this, sediments from the beach, the surrounding dunes, the ridge and furrow as well as samples from units immediately outside of the building, were collected in order to allow comparisons to be made between all of these environments.

An analysis of the sediments from the beneath the building walls and the occupation layers alone would have been meaningless, as it would have been based on the assumption that the grain-size distribution of any aeolian sediment is diagnostic without recourse to local supply and sources.
The Principles of Aeolian Transport

Before the methods and results of this work are covered, a brief discussion of the principles of aeolian transport is required. Note all measurements are given in phi (\(\phi\)); this is an expression of the particle size as the negative logarithm, to the base of two, of the diameter in millimetres. Therefore, the lower the phi, the larger the particle size.

One of the most important characteristics of any particle size distribution is the relative proportions of sediment moved under the three main modes of transport: suspension, saltation, and creep.

Saltation is a process whereby once a wind velocity reaches the fluid threshold velocity sand grains of a certain size are lifted away from the ground surface and transported in a series of jumps. The important characteristic of the saltation process is the movement of grains of a certain size range, usually about 3.32\(\phi\) to 1.7\(\phi\), or as large as 1.0\(\phi\) (fine sand-medium sand) (Pye & Tsoar 1990: 112) can be initiated when they are dislodged by other grains that are bouncing (saltating) along a surface, thus imparting a certain amount of kinetic energy to those grains with which they impact. Therefore, the initiation, and more importantly, the maintenance, of movement of saltating grains can be achieved at lower threshold velocity: the impact threshold velocity. It should be noted that in some environments c. 95% of sand transport is accounted for by the saltation of sediment within the 2.5\(\phi\) to 2.00\(\phi\) (fine sand) size classes. For this reason a consideration of any variances from this within a set of samples is worthy of consideration. Specifically, it is important to examine the proportions of material conveyed by the other modes of transport: creep (traction) and suspension.

The traction load usually consists of particles larger than about 2.00\(\phi\) to 1.0\(\phi\) (medium sand), although as has been noted above, part of this fraction can be transported as a part of the saltation load. The qualifying characteristic for a grain to be part of the traction load is that it never loses contact with the surface. The traction load, or "creep" element, is at its greatest when saltation becomes fully developed, and the larger grains, when impacted by the fully saltating smaller grains, are "pushed" forward. Particles larger than -1.0\(\phi\) (fine gravel) are only moved during the most intense storms, while grains smaller than 1.0\(\phi\) can be transported as creep prior to saltation (Pye & Tsoar 1990: 112).

The suspension load is constituted by particles which tend to be smaller than the 2.5\(\phi\) to 3.00\(\phi\) (fine sand) range. These particles are transported entirely through the air, with the smaller particles from this size range travelling great distances and contributing to loess deposits.
It should be noted that these boundaries vary with velocity, and the figures given tend to relate to "typical sandstorms", in particular, desert sandstorms.

The particles most easily entrained are those which fall into the 3.8φ to 3.0φ (fine sand) size range (Pye & Tsoar 1990: 92). Grains smaller than 4.0φ (fine sand) tend to be transported mainly in suspension and have very little impact on other grains, therefore having little influence in the saltation process, although the inverse is not true. Grains smaller than 4.0φ can be entrained as a result of the impact of larger grains.

**Methods**

A series of samples were collected from different locations: the beach, dunes, archaeological contexts, soil pits around Green Shiel, the ridge and furrow trenches as well as blown sand that had built up against the till cliff and the buildings.

Once in the laboratory, a c. 250 g sample was taken and passed through a series of steel sieves ranging from -1.0 φ to 4.5 φ at half phi intervals. The sieving system was a wet-sieve stack strapped to an electric vibrating unit. The sieving time for each sample was ten minutes. The sediment from each sieve was washed into ceramic crucibles and dried in an oven. Once dry, each size range was weighed. Using a computer graph package, each amount was entered into a table and then the cumulative percentages calculated. Line graphs of sieve size (in phi units) against cumulative percentage with interpolated curves were produced. Once the graphs were produced the next stage involved the calculation of the descriptive statistics. These statistics were calculated by taking percentile readings from the graphs and entering the values onto a spreadsheet package and the following statistics were calculated: the phi-median, phi-mean, phi-skewness, phi-sorting, and finally, phi-kurtosis.

Once these values had been calculated for all the samples, a number of bivariate plots of one statistic against another were produced. The aim was to look for groupings and assess the characteristics of the sediments from each environment type; the reasoning behind the production of these graphs is "...based on the fact that each process of transport and deposition tends to produce sediments with a characteristic range of particle size distributions' (Briggs 1977: 87). Briggs uses plots of phi mean against phi sorting and phi kurtosis against phi skewness. These types of bivariate plots were produced as well as one of phi mean against phi skewness.

The descriptive statistics were also entered onto the Minitab statistical software package where ANOVA (one way analysis of variance) was carried out on each statistic between each environment type.
Results

The Descriptive Statistics and Bivariate Plots

The descriptive statistics are employed as indicators of various characteristics of each sediment. The median is of little use with such descriptions and therefore the phi mean is usually employed as an estimate of central tendency. The measurement of skewness is useful as an indicator of any difference that exists between the median and the mean, and therefore the degree of non-symmetry. A distribution which is shown to have a positive skewness is one where the amounts of finer material are greater than would be expected in a log-normal distribution, while a distribution which is negatively skewed is one where the amounts of coarser material are greater than would be expected in a log-normal distribution. For example, it should be expected that samples taken from beach environments will have negatively skewed distributions; as such a sediment will often contain coarser material due to finer material having been "winnowed" out (King 1972: 172).

Phi sorting is an expression of the standard deviation, and as Briggs states, it is often correlated with the mean, with very fine, or very coarse, sediments having a high standard deviation, therefore being poorly sorted, and sediments with a lower standard deviation being well-sorted (1977: 85).

Finally, the measurement of kurtosis is a measurement of the "peakedness" of a distribution, therefore, it is related to the level of sorting (or standard deviation of a distribution); and the non-normality of a distribution. A sediment that has a low kurtosis possesses a flat, or platykurtic, particle size distribution, while a well-sorted distribution may have a high, or leptokurtic, distribution. In a dune system we might expect many of the sediments to be relatively well-sorted as a result of the efficiency of the wind in depositing a narrow range of grain sizes in different types of environment as entrainment of different grain sizes is a function of wind velocity. Hypothetically, we might expect a relatively coarse, poorly sorted sediment close to the sand source, and finer, well-sorted sediments as one moves progressively further away from the source.
The full results can be found in appendix 3.

The results will be considered by environment type: i.e. ridge and furrow, Green Shiel buildings, dunes, beach, and then a discussion of the other samples from the site environs. After these descriptions of the results, the nature of the aeolian processes associated with each environment type will be discussed.

Ridge and furrow

All of the samples from the ridge and furrow buried soil are fine, relatively well-sorted with approximately normal distributions. Of the four samples analysed, three tend to group quite closely on all of the bivariate plots (see figure 4.2, plots a,b & c). These sediments tend to be well-sorted to very well-sorted, with sorting values ranging from 0.30 to 0.37 Ø. (It should be noted however that the vast majority of all of the sediments examined fall into these categories. Therefore, it is the groupings of sediments within the group parameters that is important.) In the light of this observation it should be pointed out that the ridge and furrow samples tend to fall in the mid-region of sortedness for all sediments. These samples also tend to be leptokurtic, with one sample being extremely leptokurtic, thus implying a very well-sorted sediment, i.e. possessing a narrow range of grain sizes.

Most of this group are symmetrical, with skewness values ranging from -0.03Ø to -0.04Ø, with only one being very negatively skewed (-0.31Ø).

The mean sizes of these sediments also fall into a broadly similar range from 2.18Ø to 2.28Ø.
Figure 4.2a: Bivariate scatter gram of phi mean against phi skewness.

Figure 4.2b: bivariate scattergram of phi mean against phi sorting.
The Beach

The beach samples, like the previous groups, are generally well-sorted, fine sediments; part of the group is approximately normal, the rest is negatively skewed. The group as a whole is not as well-sorted as any of the other environment groups, but it still falls within the well-sorted and very well-sorted categories. The sorting values range from 0.44ø to 0.32ø with a mean of 0.37ø. There is no discernible difference between the samples collected from the low, mid and high tide zones, although those samples which are most negatively skewed are from the high tide area of the beach.

These samples also fall within a wide range of kurtosis categories, ranging from mesokurtic up to very leptokurtic; the values range from 1.069ø to 1.972ø with a mean of 1.366ø.

In terms of skewness these samples tended towards symmetry and negative skewness with one falling into the very negatively skewed category. These values ranged from -0.04ø to -0.316ø with a mean value of -0.129ø.

The mean value of particle sizes for the beach samples is 2.176ø, with a range from 2.09ø to 2.26ø.
The Dunes

The samples taken from the dunes tend to be medium-fine, well-sorted and negatively skewed sediments. More specifically, the samples taken from dune surfaces tend to fall within the very well-sorted category, with some in the well-sorted category. However, as the graphs and the measurements show, the dune samples, as a group, are not as well-sorted as those from the building (see the statistical tests below). The sorting values range from 0.38$\phi$ to 0.184$\phi$ with a mean of 0.308$\phi$.

The kurtosis values for this group of samples are slightly problematical in that they span three categories, although they do tend to group around the mid area; mesokurtosis, with a mean value of 1.0247$\phi$. The kurtosis values range from 0.75$\phi$ to 1.349$\phi$.

As a group, the samples tend to fall within the negatively skewed category, implying a coarse tail to the particle size distributions. Two of the nine samples are in fact symmetrical. The skewness values range from 0.06$\phi$ to -0.246$\phi$ with a mean value of -0.144$\phi$.

The mean particle sizes of the grains for this group range from 1.95$\phi$ to 2.21$\phi$ with a mean value of 2.076$\phi$.

The dune samples examined were collected from different locations on the dunes: from the base, the middle area, and the crest. On the whole the samples from the crest possess a smaller mean grain size and are slightly better sorted than those samples from lower down the dunes.

Green Shiel Building

The majority of this group are fine, very well-sorted sediments with approximately normal distributions. In fact this group are quite noticeably the best sorted of all of the categories with sorting values ranging from 0.315$\phi$ to 0.164$\phi$ and a mean sorting value of 0.244$\phi$. This characteristic, implying a narrow range of particle sizes, is also illustrated by the kurtosis values for these samples; all of them fall into the leptokurtic to extremely leptokurtic ranges with values from 1.36$\phi$ to 5.05$\phi$. This maximum value is not representative of the group as a whole: the mean value for these samples is 1.89$\phi$: very leptokurtic.

Most of these samples fall into the symmetrical to negatively skewed categories (0.00$\phi$ to -0.28$\phi$), with one being positively skewed (0.16$\phi$).
The mean particle size of these samples is 2.242ø ranging from 2.18ø to 2.31ø.

The Green Shiel Environs

In this section the particle size characteristics of the various sediments from around the Green Shiel site and the ridge and furrow are detailed.

Ridge and Furrow area

The modern soil (sample 50) and the sand directly beneath (sample 43) (that is the sediment above the palaeosol) possess similar characteristics, both being negatively skewed with values of -0.166ø and -0.154ø respectively, and both also being very well-sorted (0.262ø and 0.249ø). The narrow range of particle sizes for these two samples is also attested to by the fact that they fall into the leptokurtic and very leptokurtic categories. They also possess very similar mean particle sizes (2.18ø and 2.17ø).

Sample 25, the sand from below the palaeosol in the northern area of the ridge and furrow, is quite different. It has one of the highest mean particle sizes for all samples (2.44ø) and, it is also positively skewed, indicating a fine tail. It also just falls into the very well-sorted category with a sorting value of 0.33ø. However, it is also platykurtic, possibly implying a less wide range of particle sizes.

Cliff

The red sand which has drifted up against the till cliff is split into two units by a band of clay wash. Sample 8 from below the clay wash and abuts the clay, is a positively skewed (0.25ø), very well-sorted sediment (0.31ø) with a mean grain size of 2.42ø. The unit above the clay wash, sample 2, is almost identical in all its characteristics. Sample 11 is also from the red sand above the clay wash and possesses similar characteristics to the previous two sediments, whilst sample 12, the clay wash itself, is a well-sorted (0.43ø), but very negatively skewed (-0.33ø) sediment. This sediment also possesses a large fine tail. Sample 9, a band of pedogenesis a few centimetres below the modern land surface, is symmetrical (-0.22ø), very well-sorted (0.34ø) and extremely leptokurtic (3.08ø).
The Pits

A series of 12 pits were dug around the immediate Green Shiel area, the aim being to discover the sedimentary relationships that existed across the site, and also between the site environs and the buildings themselves (see above, chapter 3). Particle size analysis was carried out on just a few of these sediments in order to ascertain first, the existence of any pattern in characteristics of these sediments and second, the possible nature of the processes responsible for their deposition.

The sedimentary sequence across the site appears to be quite uniform with the modern topsoil usually being underlain by a deposit of red sand which varies in depth. Particle size analysis was carried out on a number of samples of this sediment across the site environs.

The following samples can be considered as part of the red, and mixed red, blown sand units mentioned above: samples 4, 5, 13, 30, 34, 35 and 37. This set of samples groups together quite clearly on the mean against skewness graph (figure 4.2, plot a) and is slightly split on the mean against sorting graph (figure 4.2, plot b).

All of these samples fall into the positively skewed category, ranging from 0.10\(\phi\) to 0.21\(\phi\). Five of the six samples fall into the very well-sorted category (ranging from 0.33\(\phi\) to 0.19\(\phi\)), whilst the other, sample 4, just falls into the well-sorted category (0.36\(\phi\)). Four of the samples fall into the leptokurtic category, ranging from 1.13\(\phi\) to 1.51\(\phi\); sample 34, is very leptokurtic (1.64\(\phi\)) and sample 5 is mesokurtic (1.06\(\phi\)).

The mean particle size of these samples ranges from 2.27\(\phi\) to 2.38\(\phi\).

Pit lower-coarse deposits

Just three samples from the lowest coarse deposits from the surrounding stratigraphy were tested for particle size distribution: samples 3, 26 and 33. As they do not group in any discernible way, the details of each sample will be given separately.

Sample 3 from the slit trench is a symmetrical (-0.02\(\phi\)), very well-sorted (0.33\(\phi\)) sediment with a kurtosis value of 1.20\(\phi\) (leptokurtic) and a mean particle grain size of 2.38\(\phi\). Sample 7 is from the slit trench. This sample is a symmetrical (-0.06\(\phi\)), well-sorted (0.40\(\phi\)) sediment, with a kurtosis value of 1.01\(\phi\) (leptokurtic) and a mean grain size of 2.00\(\phi\). Sample 26 from pit 8 is a very negatively skewed sediment (-0.65\(\phi\)), in fact, it is the most negatively skewed of any sediment studied. It is moderately well-
sorted (0.62φ) and is also very leptokurtic (2.86φ). This sample possesses a mean grain size of 2.00φ. The final sample, number 33, from pit 4, is a negatively skewed (-0.19φ) and very well-sorted (0.23φ) sediment. It is also very leptokurtic (2.49φ) with a mean grain size of 2.22φ.
Other sediments

The following samples are from a number of different contexts around the Green Shiel and ridge and furrow area and do not form a group or groups as such.

Sample 19, a sandy unit just below the top soil in pit 3, is a negatively skewed (-0.12φ) well-sorted (0.36φ) sample with a kurtosis value of 1.03φ (mesokurtic) and a mean grain size of 2.13φ. Sample 20 is derived from the same pit as the previous sample, but from below the clay band. It is a negatively skewed (-0.16φ) well-sorted (0.36φ) sediment, with a kurtosis value of 1.50φ (leptokurtic) and a mean grain size of 2.19φ. Sample 21 is a mixed bleached sand above the basal sediment in pit 2. It is a positively skewed (0.19φ) very well-sorted (0.24φ) sediment with a kurtosis value of 1.68φ and mean grain size of 2.31φ. Sample 31 is the sediment from beneath the dune slack soil. It is a very negatively skewed (-0.35φ) well-sorted (0.38φ) sand, with a kurtosis value of 1.00φ (mesokurtic) and a mean grain size of 2.02φ.

The Statistical Tests

In order to assess levels of similarity or dissimilarity between the samples from the different environment types: the ridge and furrow buried soil, the building (both archaeological contexts and sediment from directly beneath the building walls), the modern sand dunes, and the beach, forty analyses of variance tests (ANOVA, one way) were carried out on the different descriptive statistic values for each environment type. For example, the mean values of the grain size distributions of samples from the ridge and furrow were tested against those from the building, then the dunes, and finally the beach. These tests were repeated for all of the descriptive statistics for most environment permutations. The results of the tests then go some way towards illustrating the nature of the different sample groups by their similarity or dissimilarity with the other groups. Most importantly, it is possible to show to which environment type the Green Shiel building (archaeological) samples are most similar.

The analysis of variance test, otherwise known as the F ratio test, is a parametric test where the null hypothesis is that the samples tested all come from the same population. The test compares the within sample variance against the between sample variance: if the samples have been chosen at random from the same population, the within sample variance should be similar to the between sample variance. However, if the samples have been taken from different populations then there should be a relatively high level of variance between the samples.
The ANOVA results

The 0.01 significance level was chosen as the level at which the null hypothesis should be tested. Although the tests do give an idea of the levels of difference and similarity that exist between the sediment groups it is important to note that this test is not strictly a test of similarity, where the strength of a relationship is measured. The full Minitab output is in appendix 3a. One of the most useful parts of the output is the graphical representation of mean value and standard deviation of each group tested; this gives a clearer indication of the similarity or dissimilarity between the groups. The graphs discussed in the previous section (figure 4.2) give a clearer impression of the different characteristics of the various groups and the relative similarities between the various groups. Figure 4.3 is a matrix that indicates whether or not the null hypothesis for each ANOVA test was accepted or rejected.

Figure 4.3: Matrices indicating in which tests the null hypothesis was accepted or rejected: matrix A, left hand side represents the tests of skewness values, right hand side the test of mean values, matrix B, left hand side represents the tests of kurtosis values, the right hand side the sorting values.
Tests comparing the ridge and furrow with the Green Shiel building samples.
As the graphs show, there is very little overall difference between the ridge and furrow and the Green Shiel samples except in the degree of sortedness. Using all the ANOVA tests, except that comparing sortedness, the null hypotheses was accepted.

Tests comparing the ridge and furrow with the dunes.
This test shows that the particle size distributions from these environments possess characteristics of skewness and sortedness which are quite similar. All of the tests accepted the null hypothesis.

Tests comparing the ridge and furrow to the beach.
In all of these tests the null hypothesis was accepted, thus implying a level of statistical similarity between the ridge and furrow sediment particle size characteristics with those from the beach.

Tests comparing the Green Shiel buildings with the dunes
The null hypothesis of tests comparing skewness and kurtosis was accepted, while the tests comparing the means and levels of sorting rejected the null hypothesis. These differences indicated by the statistical tests are clearly shown on the graphs considered above (figure 4.2).

Tests comparing the Green Shiel buildings with the beach
The tests of the values of skewness, mean, and kurtosis all accepted the null hypothesis, while the test of the sorting values was rejected.

Tests comparing the dune and the beach
The null hypothesis is accepted in all of the tests, although it should be pointed out that the tests of the mean, kurtosis, and sorting values did produce relatively high "F" values.
Tests Comparing Red Blown Sand With Other Environment Groups

Anova one way was carried out comparing the red units from the test-pits with all of the other environment groups, once again using all four descriptive statistics.

Tests against the ridge and furrow
In these tests the null hypothesis was rejected for both the test of skewness and mean values, but the null hypothesis was accepted in the tests of kurtosis and sorting values.

Tests against Green Shiel buildings
Both the tests of skewness and mean values allowed the null hypothesis to be rejected, while the tests of kurtosis and sorting allowed the null hypothesis to be accepted.

Tests against dune samples
As with the previous test against the Green Shiel buildings, the tests of skewness and mean values allowed the null hypothesis to be rejected, and the tests of kurtosis and sorting allowed the null hypothesis to be accepted.

Tests against beach samples
In these tests the null hypothesis was rejected in the tests of skewness, mean and sorting values, while the test of the kurtosis values was accepted.

The Cumulative Curves and Discussion

This section comprises a discussion of the results considered thus far with a discussion of the cumulative curves.

The examination of the cumulative curves is not intended as a strictly quantifiable test, but rather the object is to gain an impression of the two extreme ends of each curve: the fine and coarse tails (figure 4.4). The envelope curves in figure 4.4 represent the maximum and minimum of all of the curves from the four main environments; they therefore represent the range of coarse to fine loads contained within each group of sediments. In the discussion of the principles of aeolian transport above, the size classes of grain transported by traction, saltation and suspension were examined in detail. This section specifically considers the relative sizes of the fine and coarse tails of the samples from the various environment groups: the coarse tail represents the coarse material transported as the traction, or creep, load which is made up of particles larger than the 1-2φ range. The fine material, or suspended load, is made up of particles smaller than the 2.5-3φ range. This examination compliments the measurements of
skewness and together they give an indication of the relative amounts transported as either the traction load, the saltated load, or finally, the suspended load.

The envelope curves in figure 4.4 serve to contrast the sediments from the Green Shiel buildings with the ridge and furrow, the beach and the dune sediments.

The Green Shiel buildings samples as a group are the best sorted of all environment groups, they also tend to be the most positively skewed with relatively small coarse tails, and relatively large fine tails. Despite being close to the sediment source, these samples do not possess a large traction element and were therefore not necessarily deposited by extreme winds. The fact that the majority of these samples are from units below the building walls indicates that the lack of a large traction load was not a result of the building walls acting as an obstacle.

As the skewness measurements and the envelope curves indicate, the ridge and furrow samples tend to have both relatively large coarse and a fine tails, implying that these sediments are constituted by relatively large amounts of material transported by creep over short distances, possibly during extreme windy/stormy conditions, as well as from suspended material that has been transported over greater distances, probably also
during high intensity storms. The environment group that possesses the most "similar" curves and skewness characteristics to the ridge and furrow is those from the beach environment. However, the beach sediment group does possess the largest coarse tail, and has a negligible small tail.

The dune sample group curve has slightly coarse tails, although there is very little material larger than 1.0ø. They also possess negligible fine tails; therefore the vast majority of the dune sediments is transported as part of the saltating load. The dune samples are midway between the beach and the building samples in terms of sorting, being statistically similar to the ridge and furrow in both sorting and skewness.

Examination of the bivariate plots indicates that the ridge and furrow samples are quite different as a group from the modern dune samples, although in each of the statistical tests the null hypothesis was accepted, thus implying that similar aeolian processes were responsible for the deposition of both of these sediments. The reason for this is probably that the sediments in the ridge and furrow palaeosol were deposited during intense storms which transported a wide range of particle sizes. This event, or process, probably pre-dates the early medieval period by some centuries, and possibly relates to an earlier stormy phase followed by a period of stability and pedogenesis. The blown sand samples above the palaeosol tend to be slightly better sorted and possess skewness values quite similar to those from the beach.

The red sand units from the pits around the Green Shiel area do not group with any of the other environment groups considered. They tend to possess a relatively fine mean particle size, finer than any of the other groups. They are also more positively skewed than the other groups, and as a group they possess a relatively large fine tail (see figure 4.4). In general these sediments are a relatively very fine well-sorted group with a low mean particle size; it is possible to argue that a large proportion of these sediments was transported by relatively low energy saltation and suspension.

The units sampled from the lower levels of the pits, usually identified as "beach" sediments, do not group on the graphs, and for this reason have not been discussed at any length. However, they do share certain important characteristics. They are all either symmetrical or negatively skewed with relatively coarse mean grain sizes. Also, examination of the particle size curves for these samples shows that they also possess coarse tails. Therefore, they can be identified as beach sands, with much of their fine proportion having been "winnowed" out at some point prior to burial.
General Discussion

The results considered above show a direct relationship between sediment source and the depositional environments. They show that each environment, from the beach moving to the dunes, the Green Shiel site and the cliff, possesses a particle size distribution which is largely derived from the environment shoreward of it (see figure 4.5). Therefore the beach is the main source and the finer particles removed from here constitute the landward sediments. Therefore we might consider that the Green Shiel particle size distributions may be indicative of a back-dune environment; however, they are better sorted than those sediments that have built up in the deflationary area around the settlement site. On the whole, the building samples tend to be the best sorted and possess relatively low mean particle sizes. There should therefore be no doubt that such sediments were transported and deposited by relatively weak aeolian forces and must therefore be a product of relatively low wind activity. There is certainly no evidence for severe sand encroachment during the early medieval period (see below). These points are considered extensively in the following sections on the processes in, and the history of, the Lindisfarne dune system and how these relate to the reconstruction of the early medieval environment.

Figure 4.5: Sketch (not to scale) of beach, dune and Green Shiel with corresponding typical grain-size curve.
Discussion of the Methods

Descriptive Statistics

There is undoubtedly a problem in employing a classical statistical test like analysis of variance on particle size data which possesses limited overall variance. There is little doubt that the majority of the sediments examined do fall into distinctive groups no matter which discriminating statistics are used in the bivariate plots. Despite the fact that there are clearly defined groupings on the bivariate plots, the statistical tests rarely implied any real differences between these groups. However, the statistical tests did indicate differences between the Green Shiel building sediments and the other groups in a number of tests. Also, there is little doubt that sorting is the most discriminating of all of the measurements employed in the tests. The tests also supported the contention held by many workers that kurtosis is a weak discriminant (Friedman 1961; Pye & Tsoar 1990). It is certainly true in this study that kurtosis is the weakest discriminant of the four measurements employed. Also, the fact that many of the kurtosis values almost contradicted the sorting values, when kurtosis was shown to be either mesokurtic or even platykurtic when the samples were well-sorted, implies that there is a problem in employing kurtosis values.

Sediment Transport in the Lindisfarne Dune System

The discussion of the particle size analysis included a description of the basic physics of sediment transportation under aeolian regimes. This section will build on that description and will consider the range of factors which influence sand transport with specific reference to the Lindisfarne dune system.

The key to sand transport is wind, specifically its magnitude and direction. One might expect that sand dunes would be more likely to develop in arid areas with relatively little vegetation cover and low soil moisture content; however, dunes can develop in any environment where adequate supplies of bare sand exist and wind force is strong enough to entrain it. Also, there might be an assumption that the extensive dunes of the world's desert regions are a product of the most intense aeolian forces on the face of the earth, but this is not the case. Wind energy is in fact highest on coastal areas and at the poles. Sand deposition in coastal locations can be ten times higher than those in mid-desert sand seas. This impressive rate of deposition is largely due to more intense coastal winds and greater sand supply (Pye & Tsoar 1990: 16). One of the most important characteristics of the relationship between wind and sand transportation is the cubic relationship that exists between wind velocity and sand transport. The relationship is such that for any increase in wind velocity there is a disproportionately
high increase in the quantity of sand transported. For example, if a wind of 50 km/hour is blowing, this should move 0.5 tonnes of sand per metre width of beach per hour; however, if the wind velocity were to increase by 16%, to 58 km/hour, the wind could transport one tonnes of sand per metre per hour, an increase of 100% (Pethick 1984: 133). Therefore, it should be considered that low frequency, high magnitude events, such as the storms of the sixteenth century (Gottschalk 1975; Lamb 1991), are more likely to initiate extensive dune development than high frequency, lower magnitude events.

Wind on Lindisfarne

It is reasonable to assume that dominant wind directions have altered little during the late Holocene and legitimate inferences of dominant wind directions can be made from modern data. There is however some historical data which allows us to refine and strengthen these assumptions (see below, this chapter). More importantly, there is a greater amount of data relating to the frequency of storms during the historic period which will be considered at length below.

The primary source for modern data is the meteorological office's records of wind direction and force, as measured at stations all around the country. The closest station to Lindisfarne is R.A.F. Boulmer c. 25km to the south of Lindisfarne (see figure 4.10 for location of Boulmer). Figure 4.6 is a wind rose based on data collected at Boulmer; the rose is based on hourly mean wind speeds for all months collected between 1979 and 1988. The diagram clearly indicates that the dominant winds are westerlies to south-westerlies. The highest wind force recorded during the 1979-88 period was 41-47 knots (Beaufort scale 9). Winds of this strength only emanate from the south-west. The wind rose shows that the majority of strong winds, greater than 27 knots, is south westerlies and westerlies. However winds of this magnitude can emanate from any direction (see figure 4.6). Despite the Boulmer wind rose and tabular data indicating that the majority of the majority of storm winds in this part of Northumbria during the 1980s tended to be south-westerlies and westerlies, historical records show that a much greater proportion of storm winds emanate from the west and north-west with many storms in the North Sea swinging from the south-west to west and then to the north (Lamb 1991: 25-30).
It is inferred from laboratory experiments that a wind force of 5 m/sec at 10cm above a flat sand surface is that which is required to maintain aeolian sand movement (Wishman 1990: 107). As wind force increases logarithmically with height, the threshold level for sand transport, i.e. the point at which it will become entrained (see above), corresponds to a wind force of 6-7 Beaufort (12-15 m/sec) at about 10m above the ground surface. Therefore it seems apparent that winds of the force necessary for sand transport during the recent past have predominantly emanated from the south-west to westerly direction. It should however be born in mind that these records are not for Lindisfarne itself, and the nature of a wind regime can vary over small areas of space. The situation on Lindisfarne is complicated by the fact that it is a tombolo jutting out into the North Sea. Therefore this locality must experience a slightly different wind regime to that recorded at Boulmer. An obvious indication of the characteristics of the locally dominant strong winds is the scrub vegetation dotted around the island.

**Tree Deformation**

All plants respond to wind stress in a number of ways. Many of the adaptations that take place are often similar to those that occur in response to drought (Grace 1977: 86). The most obvious affect that wind has on plants, especially trees and shrubs, is morphological. Trees and shrubs in exposed places tend to grow in a deformed manner: the mechanical stress caused by the wind, combined with salt spray in coastal localities, forces them to grow away from the direction of the dominant strong winds. Therefore, the measurement of the orientation of deformation is a useful indicator of locally dominant strong winds. It is unclear at what strength a wind can deform a tree or shrub, although this obviously varies with age and species. Another unknown variable
is the time of year at which the wind has its greatest effect: the stormiest months are during the autumn and winter; however, the majority of plants experience most growth during the spring and summer. Therefore we might assume that deformation is largely a product of strong spring and summer winds.

*Method*

The tree deformation survey on Lindisfarne was carried out mainly on *Corylus avellana* (Hazel) bushes, and *Salix repens* (creeping willow) around the island. The trees observed were not always clearly blown in one single direction, therefore the mid-point of their deformation was taken as representative of the dominant forces responsible for their deformation. A mirror compass was used to measure the angle of deformation by standing "leeward" the sample tree and measuring the direction from which the deforming wind had emanated. A total of 65 specimens were measured.

*Results and Conclusions*

The overall results are shown in table 4.1 (see figure 4.7). The clear majority of winds (60%) responsible for deformation emanate from between 331° and 350°, a north-north-westerly direction. About 28% emanate from 311°-330°, a north-westerly direction, whilst the majority of the remaining examples indicate that some winds emanate from the north.

<table>
<thead>
<tr>
<th>Angle of wind Direction</th>
<th>Percentage of all Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>280-310°</td>
<td>3.33%</td>
</tr>
<tr>
<td>311-330°</td>
<td>28.33%</td>
</tr>
<tr>
<td>331-350°</td>
<td>60.00%</td>
</tr>
<tr>
<td>351-10°</td>
<td>4.6%</td>
</tr>
<tr>
<td>11-20°</td>
<td>4.6%</td>
</tr>
</tbody>
</table>

Table 4.1: Breakdown of tree deformation angles.
Overall the modal measurement was $340^\circ$, but this does vary slightly around the island. Within the dune system itself the modal value was $15^\circ$ (north-north-east), while around the Green Shiel site and the ridge and furrow the modal values are $330^\circ$ and $340^\circ$ respectively. A Chi-square test on the frequencies of the various orientations clearly indicates that there is a very large difference between the expected and the actual distribution of these orientations (see appendix 3b for the statistic). This data clearly indicates that north-north-westerly winds are dominant locally. The relevance of these results for the history of dune development on the island is considered below.

However, it should be borne in mind that we cannot be sure if these inferred wind directions relate to the stormy winds which are necessary for extensive sand-blow and dune formation.

As well as winds of an adequate strength and sediment supply, there are other factors which influence dune development. One such factor is the level of moisture in the sand. There is no consensus on the influence of moisture levels on threshold level; some experiments in wind tunnels have shown that even low moisture levels of 2-3% can significantly increase threshold shear values and decrease transport (Goldsmith 1989: 4). Other case studies have shown that moisture contents of up to 14% have no effect on transport rates (Sherman & Hotta 1990: 178). This latter situation seems quite unlikely, although the impact of moisture content on threshold does vary and is dependant on other properties of a sediment, such as salts which can increase the fluid threshold velocity as these may act as a caking agent once dry (Pye & Tsoar 1990: 99). The majority of research does seem to indicate that increased moisture content in a sand does inhibit the amount of sand that can be transported (Pye & Tsoar 1990: 98).
Another environmental factor which has some impact on the level of sand transport is air temperature. Norrman argues that transport intensity is inversely proportional to air temperature (for a given wind) (1981: 124). This explains the efficiency of aeolian processes during the autumn and winter. However, the desiccation of certain sediments during periods of summer drought might also enhance potential transport rates, although such an effect may be negated by higher levels of relative humidity during the summer. Also, the fact that storms tend to attain their greatest intensity during the autumn and winter should be taken into consideration.

Another important factor which has a dramatic effect on the development of coastal dunes is vegetation. Usually no sand movement takes place once vegetation cover exceeds 30% (Pye & Tsoar 1990: 100). The importance of vegetation as a stabilising element within dune systems has been long appreciated, and dune grasses have been planted on European coasts since the Middle Ages (Ashton 1909: 130). The influence of vegetation on coastal dune form cannot be understated. Species such as *Ammophila arenaria* (Marram grass) and *Elymus farctus* (Sand couch) act as a very effective drag on the wind. Stands of this type of vegetation behave as false ground surfaces which leave a pool of still air behind them (Carter 1988: 311-314). The appearance of these "dead" areas within vegetation stands enhances the incrementation of sediments and eventually dunes develop. Species such as *Ammophila arenaria* (Marram grass) thrive on increased sedimentation (to a certain point) and grow in response to increased depth of sand.

**The Influence of Sea Level**

Bearing in mind the processes discussed above, this section will briefly consider the outline of a model for dune development which will incorporate one final but crucial influencing factor: sea level.

There are two basic models which consider the effect that relative sea level has on potential sand transport and dune development. The first model proposes that rising or high sea levels can lead to beach erosion, and subsequently a reworking of older dunes and the concomitant destruction of their vegetation. Such a scenario permits the development of transgressive dunes. This model therefore assumes that "...low sea level is associated with dune stability, weathering and pedogenesis" (Christiansen *et al.* 1990: 63).

The second model suggests that dune building takes place when sea level is low, or falling. Due to the lower sea level more sediment is exposed and is therefore available for landward migration.
It does seem more likely that as sea levels rise, dunes stabilise as less sand is available for transport. But as Pye and Tsoar argue, dunes can form during high and low sea level stands and marine transgressions and regressions (1990: 148). However, it has also been suggested that "...marine transgressions are responsible for initiating episodes of transgressive coastal dune development, whereas regressions lead to shoreline progradation and beach ridge construction. Rising sea levels cause shore face erosion and off-shore movement of sand" (Pye & Tsoar 1990: 151).

This second model seems to be accepted by the majority of workers (Carter & Wilson 1990: 30-31; Ritchie 1972: 33; Wishman 1990: 112) and its relevance to the Lindisfarne study will be considered below.

A History of the Lindisfarne Dune System

Introduction

Having considered the range of environmental factors that influence the development of a dune system, the following sections consider these factors in the context of the historical development of the Lindisfarne dune system, commencing with a description of the modern system. Understanding the chronological development of this system is a key to reconstructing the early medieval environment around Green Shiel. Therefore each of the environmental factors is considered in turn with the aim of understanding the ways in which they have altered over time and affected the development of the dune system. This section describes the morphological characteristics of the modern dunes, specifically the orientation of dune ridges and blow-outs. This is followed by a discussion of dune formation processes, especially the nature of the winds responsible for the development of the Lindisfarne dunes.

The terminology of dune morphology is relatively uncomplicated and universal: figure 4.8 illustrates the main forms in a plan view. In the majority of systems the building of dune ridges is the first stage of development; these can progressively move inland and at certain times, usually during storms, become blown out. A blow-out is usually caused by the removal of dune vegetation for one reason or another; the consequent destabilisation of the dune ridge increases the chances of blow-out formation. Where vegetation recolonizes the blow-out, the dune is then described as a parabolic form; the direction of the two "arms" indicates the direction from which the forming wind came (see figure 4.8). A parabolic dune can of course become destabilised itself and continue to move across the dune system.
The first characteristic of the Lindisfarne system that should be noted is the number of dune ridges and the orientation of blow-outs. Unlike many dune systems which are located along one coastal stretch and have a sediment derived from one direction, the Lindisfarne system is complicated by the fact that it faces two sand flats: to the north-west, Goswick Sands, and to the south-west, Holy Island Sands. In most systems dune ridges develop parallel to one another and the oldest dunes move progressively inland, and the flat areas between each ridge attain a higher level of ecological succession the older they are from slack, to scrub/pasture, to woodland (Ranwell 1972; Carter 1988). The Lindisfarne dune system does not achieve the ecological climax that is typical of many mainland systems; however, there are slack areas, and other areas which might be described as dune pasture.

Figure 4.8: The main dune morphological categories (after Bird 1984).
The description of the system will begin in the southern area, area "A" on figure 4.9. Most of the dune system in this area is characterised by groups of stabilised blow-outs with some possessing parabolic characteristics. Some of the parabolic dunes almost fall into the lunate category (Pye & Tsoar 1990: 206). The vast majority of the blow-outs and parabolic dunes possess typical "arms" which point upwind and are therefore indicative of the primary direction of the wind responsible for their development. 'The long axes of most coastal parabolic dunes lie almost parallel with the onshore wind resultant,...' (Pye & Tsoar 1990: 202). This is quite likely to change if the surrounding topography has the potential for significantly altering the dominant wind direction. In the south west area of the Lindisfarne dune system under consideration here, the arms of the blow-outs/parabolic dunes are oriented in a number of directions. This implies that these dune forms are the result of winds with varying dominant directions during different periods of development, or, winds that have varied in direction over a short period, during a single storm for example. In other words, if dating the establishment of these various dune forms were possible, it would be possible to ask whether all of the dunes that are oriented in the same direction formed during the same period, or whether dunes with different orientations also formed at the same time. Such investigations may be useful in gauging changing dominant wind direction and strength through time. The relationship between past storm-wind directions and blow-outs is considered below (this chapter).

Within area "A", the southernmost group, there are circa 11 blow outs, the majority of which are oriented between west and north-west; however, five of these blow-outs are oriented between a westerly and south-westerly direction (see figure 4.9). North-west of this group lies what will be referred to as the Green Shiel system (figure 4.9, area "B"). There is little doubt that this part of the dune system has only stabilised during the last thirty to forty years. However, we can be sure that dunes have developed, and subsequently disappeared or profoundly altered in shape during previous decades and probably centuries. As figure 4.9 and plate 3.1 (chapter 3) show, the four or five major blow-outs of the Green Shiel area run in a west-south-west to east-north-east line and are oriented north of the east-west line, two clearly facing north-west. The confident recognition of the orientation of these blow-outs is problematical as these dunes clearly are blow-outs rather than parabolic dunes with identifiable arms. In area "C" there are only two clearly identifiable blow-outs, both oriented to the west.
It is therefore apparent that most of the dunes in the Lindisfarne system are the product of winds emanating from a broadly westerly direction (between south-west and north-west), although one of the dunes in area "A" has been blown out from a north-north easterly direction. The orientation of all of the blow-outs is represented diagrammatically.
in figure 4.12 below. The orientation of these blow-outs is considered in relation to the historical development of the Lindisfarne dune system later in this chapter.

Sediment source and sea level

There is no suggestion that there has not been adequate sediment source for the Lindisfarne dunes during the late Holocene. Lindisfarne and the surrounding sand-flats must have assumed their current form during the early to mid Holocene, although the processes of isostasy and eustasy in this area are complicated by the fact that Northumbria is characterised as being part of a "hinge-line" between the south of Britain, which has experienced subsidence and relatively high eustatic sea-level rise, and the north, which has experienced isostatic uplift and relative sea-level fall. There is some evidence to suggest that the coastal area around Lindisfarne has been subjected to a subtle combination of both processes: uplift and sea-level rise, to the point where actual relative sea-level (taking 0m OD as the base line) has changed relatively little during the last 8,000 years (Plater & Shennan, 1993: 214-215). However, there is a discernible trend that can be inferred from the rather limited sea-level data that does exist for this poorly researched region.

Stratigraphic and palaeontological studies of borings from sites at Warkworth, Low Hauxley, Elwick, Lochhouses, Cowpen Marsh, and Alnmouth indicate that there has been a relative rise in sea-levels, albeit relatively small, in this region (figure 4.10). The diatom assemblage from the site closest to Lindisfarne, at Elwick, is characterised by a continual increase in the relative proportion of marine species. However, there seems to have been little or no sea level rise on this part of the Northumbrian coast since about 1000 BC (Plater & Shennan 1993: 214).
Figure 4.10: Location of sea-level data sites referred to in text and Sea-level trends for Elwick, Alnmouth and Warkworth in the north-east of England (after Plater & Shennan 1993).
It appears that Lindisfarne may have experienced a slight overall increase in sea-level by the mid-Holocene, and the major postglacial sea-level rise had taken place by the c. 3000 BP, and continued to a lesser extent after this period (Tooley 1978). As Plater and Shennan observe, we cannot be sure to what extent sand transport rates have been affected by sea level change in this area as the sea level changes that have taken place are relatively small. Also, the available data can not prove a clear correlation between reduced sea level rise and dune instability (Plater & Shennan 1993: 215). If sea-levels have been lower in the past, then it is possible that the amount of available sediment for transport has been greater, and the potential for dune development enhanced, providing the other necessary conditions existed. Whatever the exact conditions were, there is little doubt that extensive sand-flats have existed as a potential sediment supply for most of the Holocene. We can also be sure that there has been very little, or no, change in sea level since the medieval period.

**Climate Change and the Importance of Wind**

The widely accepted phenomenon of a climatic optimum during the Early Medieval period will be discussed later in this chapter. This section will discuss the timing and impact of the end of this optimum and the importance of climatic change during the so-called "Little Ice Age".

The Little Ice Age can be defined as a period which began during the mid-thirteenth century when climatic conditions began to deteriorate in some places, and continued up to the mid-nineteenth century, although many would argue that the main period of climatic deterioration was between AD 1550/90 and 1850 (Bell & Walker 1992: 140; Roberts 1989: 160). During this period average annual temperatures were somewhat lower than during the preceding centuries, and rainfall was higher, there was a renewed advance in all alpine glaciers and ice caps expanded (Grove 1988). During this period there was also increased flooding, and most importantly from the perspective of dune formation, increased storminess, both in terms of frequency and magnitude (Gottschalk 1975, 1977; Lamb 1982, ch. 11; Lamb 1988, chs. 8 & 9; 1991). The causes of the Little Ice Age are not entirely understood, and explanations include the entire range of factors usually considered as the causes of climatic change. One explanation is that the Earth's average temperature was reduced due to a reduction in solar radiation as a part of the Sun's cyclical activity. Another explanation considers that geomagnetic changes around the Earth affected tropospheric pressure which had an effect on weather systems. These changes may have effected an alteration in the wind/ocean relationship and warm water currents were moved polewards under cyclonic conditions and consequently cooled down. Some have argued that an increase in volcanic activity,
which would have reduced the level of solar radiation reaching the Earth's surface, may also have been responsible for the climatic changes that occurred during the medieval period (Grove 1988: 360-378). The effects of climatic change were largely felt in the northern hemisphere, and the changes had different characteristics all over this area, with some places benefiting from climate change while others suffered. In many mountainous regions, including those all over Europe, glaciers certainly advanced to an extent unknown for a number of centuries, in fact, glaciers that had all but entirely disappeared grew once again (Grove 1988: 4-5).

There is also evidence for the ice around East Greenland expanding about AD 1190-1200. By the middle of the thirteenth century AD the ice forced sailors to take routes between Iceland and southern Greenland that were further to the south. By the fifteenth century regular communication with Greenland ended due to the expansion of the ice. This state of affairs continued for about 300 years (Lamb 1988: 159). Archaeological investigations of sites in the north Atlantic area, including Svalbard in northeastern Iceland, clearly indicate that climatic deterioration during the Little Ice Age induced ecological stress to the extent that lamb mortality increased profoundly and other "famine" resources, such as seals, were increasingly exploited, and many areas were actually abandoned (Amorosi 1992: 132). One of the consequences of the so-called "neoglacialation" was the renewed uptake of water in the redeveloping glaciers, and a possible drop in sea-level, which in turn could well have exposed more extensive sand-flats in some areas, although this is unlikely to have been significant. Even if this was not the case, there is no doubt that one corollary of these climatic developments was the increase in cyclonic activity. As Lamb illustrates, there is much evidence to support the hypothesis that an "enhanced thermal gradient" existed between the northern Atlantic, around the Faroes and Iceland, and the regions around latitude 50°N during the Middle Ages. Such a gradient could have provided the "...energy base for the development of occasional storms in European longitudes of greater intensity than in warmer periods" (Lamb 1988: 125).

There is much evidence for an increase in storm frequency and intensity during the high Middle Ages, along with associated evidence of sand-blow and extensive dune formation. In fact, a number of accounts detail the complete submergence of entire villages and farms by dune systems which sometimes developed literally overnight (Willis 1986). Examples of such phenomena are considered below.

*The North Sea storms of the High Middle Ages*

The most useful historical study of storm events is that undertaken by Elisabeth Gottschalk (1971, 1975 & 1977), although Lamb has supplemented this work with his
own survey of storms in the North Sea area of the last 500 years (1991). Gottschalk's three volumed study covers the historical records relating to floods and storms, as well as dune formation in the Netherlands and elsewhere in northern Europe. It not only serves as a useful source of data on storm frequency, but also considers the nature of the historical data and some of the problems with it.

This work was largely based on documentary evidence for storm surges and floods in the Netherlands, but the author was also concerned to detail any evidence for sand blow on the Dutch coast.

The consideration of Gottschalk's work will focus on figure 4.11, a storm frequency curve for the Netherlands and northern Europe based on data covering the period from the beginning of the eleventh century through to the beginning of the eighteenth century. The graph (figure 4.11) is intended to illustrate both the variation in storm frequency within the Little Ice Age itself, and the overall trend of storm frequency. The interpolated curve represents the general trend over the entire period covered by the graph.

Figure 4.11: Storm frequency curve for the Netherlands and northern Europe for the eleventh to eighteenth centuries (based on data taken from Gottschalk 1971, 1975, 1977).
The first criticism that might be made of the data is that like any historical document reporting any phenomenon, an increase in frequency must in part be a function of the overall increase in the production of historical documents as time progresses: Gottschalk's data is derived from a wide range of written sources, from ship's logs to ecclesiastical manuscripts and the diaries and journals of people who were keen to record such phenomena. In every case Gottschalk was rigorous in checking the accuracy of any date, verifying an event with another source where possible. However, we must accept that the overall increase in the frequency of storm events through time is partly a product of the growth of the historical record. The total increase of storm events can not be attributed to this alone, because if this were the case then we would not necessarily see the variation that exists from the fifteenth century onwards. If frequency was directly related to position in time then we would not expect to see the dramatic peaks and troughs between 1450 and 1550 for example, but rather, a continually rising line. Also, we might not expect a downward trend after 1600 if the rate of reporting events was directly related to progress in time, although the rate of historical reporting can fluctuate with socio-economic and political factors.

The part of the curve which relates to the Little Ice Age indicates that the beginning of the increase in storm frequency is considered to be the thirteenth century. It seems that the Zuyder Zee had certainly developed by the middle of the thirteenth century, although it is known that the first inundation had taken place as early as AD 838. However, the frequency of storms during the thirteenth and into the first quarter of the fourteenth century is significantly higher: the intensity of the storms also increases. For example on the 23rd November 1334 a storm surge caused "considerable damage" to the coasts of most of Holland, Flanders and England (Gottschalk 1971: 327). By the end of the fourteenth century the frequency and intensity of storms was increasing. The graph (figure 4.11) indicates that this increase in storm activity continued up to the turn of the century. During this period there seems to have been a peak of storm surge activity, with particularly serious storm surges in 1404 and 1446 (Gottschalk 1975: 190). This evidence is tied to Brandon's (1971) work on abbey accounts from Sussex which cover the late 14th and 15th centuries. In Sussex also, during the first quarter of the fifteenth century, there was increased storm-tide height and frequency, as well as a greater number of catastrophic events (Gottschalk 1975: 190). During this period the combination of climatic deterioration and the Black Death (AD 1348-50), which may have partly been caused by climate change, resulted in a decrease in grain yields and the withdrawal from many so called "marginal" areas (Lamb 1977: 454-457; Parry 1978).

During the first half of the fifteenth century some of the storms damaged dune systems. Gottschalk states that the sand dunes in the area near Graft in North Holland and on Walcheren appear to have been eroding rather than developing (1975: 183). However,
in many cases, erosion of dunes must mean the inland deposition of sand, and therefore the extension of dune systems.

During the second half of the fifteenth century it is believed that the storm surges were not particularly catastrophic (Gottschalk 1975: 301). There were however "numerous" reports of blow-outs in Dutch dunes, and Gottschalk cites evidence for cultivated land on the island of Walcheren being made worthless as a result of sand inundation (1975: 302). The first quarter of the sixteenth century witnessed many storm surges although the second quarter was more peaceful, apart from the two hurricanes of 1530 and 1532 (Gottschalk 1975: 534). The second half of the sixteenth century saw much storm surge activity, and two of the surges were considered as "catastrophic", those of 1552 and 1570 (Gottschalk 1975: 817).

By the seventeenth century more reliable reports of storms which affect a number of places in northern Europe appear. For example, there is little doubt that on 27th March, 1606, most of northern Europe was struck by a severe gale (Gottschalk 1977: 16). There are relatively numerous reports of storms for this period. Admittedly this is probably partly due to the increase in record making. As Gottschalk comments of the first half of the seventeenth century, storm surges caused dune erosion along the North Sea coast of Holland and Zeeland and a number of fishing villages were threatened (1977: 157).

There is little doubt that storm frequency and intensity were increasing during the 13th and 14th centuries with a peak being reached during the sixteenth century. One example of a landform being radically altered during this period as a result of increased storm activity is the island of Heligoland. 50km out into the German Bight, this island is thought to have measured 60km across during the ninth century; by c. 1300 this had been reduced to 25km. It is believed that just one single storm could have been responsible for this loss. Today the island is only 1.5 km long.

It is apparent that there were many occasions during the fifteenth to seventeenth centuries when winds would have attained the necessary magnitude to initiate extensive sand-blow and either dune destruction or development. This section considers the evidence for dune development during this period. There is little doubt that one result of the severe storms of the late Middle Ages was the overwhelming of a number of coastal settlements by blown sand (Lamb 1982: 183).
Dune Development in the North Sea area

Most of the research into dune development and history has been carried out in the Netherlands where coastal geomorphology is recognised as being of national importance for a low-lying country susceptible to only slight changes in coastal processes. The British work that does exist will also be considered, but it is worth remarking that the Dutch work is in some ways just as relevant as some of the British work, as it is concerned with studying processes that have taken place in the North Sea which will have affected the Northumbrian coast as well.

The Dutch dune systems are considered to have developed during two distinct chronological periods and consequently the two types of dune are identified by the labels Older Dunes and Younger Dunes. The Older Dunes are known to have developed during the period from c. 2,200 BC to c. 1,500 BC and are typically ridge forms which run parallel to the modern coast (Jelgersma et al. 1970: 94-95). Many researchers believe that conditions for sand drift would have existed by the beginning of the Holocene due to a lowering of the sea level and the existence of strong dry winds (Wishman 1990: 111).

There is of course much variation in the chronology of dune development along the Dutch coast. Also, this early period was not characterised by continual sand-blow and dune development: there were periods of stability. In Britain the evidence that does exist for dune development indicates that some prehistoric dune development took place prior to this Dutch formation phase. An early period of sand-blow and possible dune development on Benbecula in the Outer Hebrides is dated to 3750 ± 170 BC (Tooley 1990: 84), while sand deposition at Northton on the Isle of Harris continued until 1531 ± 54 BC (Ritchie 1979: 116).

There is little doubt that in the Netherlands by the late first millennium BC there was an hiatus in dune development; aeolian sedimentation ceased in most places except for the westernmost parts of the Netherlands (Jelgersma 1970: 100). This period of dune stability lasted until the twelfth century, although there were brief periods of intermittent sand blow within this "quiet" phase.

The Younger Dunes of the Netherlands are thought to have formed during three separate phases. Phase I is thought to have begun between AD 800 and 1000 and ended between AD 1200 and 1300. Phase II is considered to have been the period between AD 1300 and 1600, and phase III is regarded as the period between AD 1750 and 1850 (Klijn 1990: 89).

Jelgersma et al. (1970) consider the first phases of later dune building to be the period AD 1100 to 1300; phase II AD 1400-1600; and the third phase AD 1700-1850. Phase I
is split into "A" and "B". Phase "A" is interpreted as the levelling of the older dunes and the formation of a precipitation ridge at the landward boundary. Phase "B" is interpreted as the consequent deposition of thin horizontal beds (Klijn 1990: 90). Extensive "parabilization" occurred during phase II while phase III was characterised by this process on a smaller scale.

There is plenty of evidence elsewhere in northern Europe for extensive dune development during the Little Ice Age. In Denmark for example, the last period of dune development took place between 1450 and 1750. Here, although there is a clear relationship between the increased storminess of the Little Ice Age and enhanced aeolian activity, it is also believed that human impact on dune systems was partly responsible for the formation of some systems where overgrazing and deforestation cleared the way for dune development (Christiansen et al. 1990: 63). It is likely that human impact of this nature aided dune development but was a secondary process.

The evidence for dune development in Britain during this period is sparse and is largely based on a few radiocarbon dates and inferences made from the research carried out elsewhere in Europe. The dearth of scientifically dated sites which possess evidence for dune development during the Little Ice Age is partly compensated for by written accounts which directly refer to extreme aeolian events which took place during this period. For example, the site of Forvie village on the east Aberdeenshire coast is known to have been covered by sand on the 18th August 1413 (Ritchie 1972: 33; Willis 1986: 11). Somewhat later, in 1694, the Culbin estate to the east of the Moray Firth was also covered by sand during a single storm. The event was so sudden that farm workers reportedly abandoned fields whilst in the middle of reaping, and the barley that they were harvesting was buried by the encroaching sand (Willis 1986: 39-40). Other evidence for the onset of sand-blow comes from a few sites where periods of stability, succeeded by blown sand, are radiocarbon dated to the twelfth century AD (Tooley 1990: 86). At Low Hauxley on the Northumbrian coast a dune slack, succeeded by blown-sand, is radiocarbon dated to AD 976 ± 50 (Frank 1982: 29) (see below, for a more extensive discussion of this site).

We can be sure that extensive dune development did occur in the British Isles throughout the Little Ice Age but we cannot be sure when the Lindisfarne system developed. As the previous discussion (see above, this chapter) showed, we do know that the dune system had developed to such an extent that its various elements were considered worthy of recording on Speed's map of 1610. Also, we must be careful to avoid the implication that the Lindisfarne system developed out of one single storm event as seems to have been the case at the Scottish sites mentioned above. If the Lindisfarne system had developed out of one extreme event, or over a short period of time during the later Middle Ages, we might expect such a dramatic development on a
small but very important island to have been recorded. It is argued that the Lindisfarne system developed at some time during the fifteenth century, or perhaps the early part of the sixteenth century; this period saw storm activity at its most intense. However, there is some evidence for sand encroachment from the stratigraphy of Lindisfarne Lough pollen core (see chapter 6 for the palynological analysis). A sandy matrix has been identified in the core between the two samples taken for radiocarbon determinations (see figure 6.4), consequently it is possible to estimate the sedimentation rate in the Lough between these two dates and from this the probable date for the deposition of the sandy unit. The estimated date for this event (or series of events) is the end of the eleventh century AD. This is clearly much earlier than the recognised stormy period of the Little Ice Age. It is possible that this sandy unit does not relate to a great dune building period, or it may relate to an earlier period of sand encroachment that provided much of the material for later dune development on the island. In either case, this event occurred long after the Green Shiel settlement had been abandoned.

There is of course no reason why the Lindisfarne system did not develop in stages. Also, the system may have had a history of instability with entire dune systems developing and then eroding, with the gradual movement of the system being from west to east over time. The fundamental characteristics of the modern system may have developed during the late medieval period. However, the dune system in some areas, around Green Shiel, and the central area of the ridge and furrow, may have been the last areas to be covered with stable dunes due to the fact that the buried ridge and furrow soil lies directly on top of a relatively high area of glacial till which slopes down towards the sediment sources to the north, south and west. The slopes of the till topography may have afforded a certain level of protection, although the slope to the south is a gentle one (see below, chapter 3). This does not preclude the early development of dunes elsewhere on the north shore of Lindisfarne. In fact the area of blown-sand which is situated between the till and the buried soil, in the northern area of the ridge and furrow (area "D", figure 4.9), must represent an early period of sand inundation prior to the development of the buried soil.

Wind Direction

This section will consider dune formation in relation to the evidence for wind direction during the Little Ice Age. As with the modern records, there are, unsurprisingly, no historical wind records for Lindisfarne itself. Therefore we are once again reliant on records from elsewhere.
Where possible, Gottschalk in her work on storms has detailed any accounts which consider the direction of stormy winds. In the few cases that such characteristics are reported there does appear to be a level of conformity. Wind directions during storms tended to vary between south-west and north west: "...after a short interval of calm the south-westerly gale blew up again and subsequently veered to the north. The dykes were smashed, so that extensive flooding occurred'. This is based on the report of Emo, Abbot of Wittewierum describing a storm which hit the coast of Gronigen near the Ems on 16th January, 1219 (Gottschalk 1971: 147). Menko of Wittewierum reported on two storm surges in 1248, one in November and the other in December. English and German sources also refer to storm surges. However, it is questionable whether all the regions around the North Sea were struck at the same time (Gottschalk 1971: 185). Again, it is made explicitly clear that the storm winds, certainly for the November storm, veered from the south-west, to the west, then to the north-west and to the north. During 1610 persistent gales for much of January were recorded (Gottschalk 1977: 39). Again, winds seem to have started coming from the south west and then later moved round to the north. Such patterns of storm development are well-recorded for the seventeenth century. The Culbin sands disaster of 1694, mentioned above, was caused by a storm, which during its early stages, was characterised by westerly winds; during the peak of this storm winds from between the north west and the north east moved enormous amounts of sand over the Culbin estate where dunes up to 30m in height now stand (Lamb 1991: 51-55).

Although events such as this did not necessarily effect the north east of England in the same manner as in the localities where the events were recorded, we can assume that the processes illustrated by these examples would have been common to the Northumbrian coast as well. Although we do not have such wind records for Lindisfarne, the orientation of the blow-outs does correspond with winds which emanate from between the south-west and the north-west (see discussion below).

For most of England the strongest winds tend to come from between the south and the west. This state is indicated by the wind rose from Boulmer considered earlier. However, in the North Sea area, and the coasts looking over it, the strongest winds tend to come from the northwest and the north as a result of the fetch over which their power can accumulate.

Although situated on the east coast of Britain, Lindisfarne's shoreline faces north and, in the area of the Snook arm, both north and south. Due to this relatively unusual coastal configuration the relationship between wind direction, dune development and blow-out formation, is potentially complex.
It is quite probable that much of the eastern half of the Lindisfarne dune system developed as a result of sand from the western part of the north shore being gradually transported eastwards. It is unlikely that the sandy coves at Sandham and Coves Haven have ever acted as primary sources of sediment: first, it is probable that neither of these areas ever possessed a large area of exposed sand, even at low tide; second, the narrowness of these beaches means that they lack the necessary extent to allow the wind to entrain large quantities of sand. In fact, the only part of the Lindisfarne system which has probably received much direct onshore sedimentation is the Snook arm, and the areas to the west and south of the Green Shiel area. The area around Green Shiel has probably received much of its sediment from Goswick Sands when north-westerlies have blown, while the area south of this has probably experienced sedimentation when south-westerlies transported material from Holy Island sands (see figure 4.1). This model is substantiated by the orientation of the blow-outs in these two areas. The blow-outs around Green Shiel are broadly oriented to the north-west, while some of those in area "A" (figure 4.9) are oriented to the south-west or west. However, many of the blow-outs in the south-west corner of area "A" are oriented between north-west and the north, with one even facing north-north-east. Although the orientation of blow-out/parabolic arms does give some indication of the wind direction which affected their development, the existence of parabolic dunes with arms of different lengths implies that the wind has hit the original dune at an acute angle and consequently any variation in wind direction results in the shortening of one of the arms (Enquist 1932: 39). Also, local variation in topography is important, but research carried out on a number of Danish and British sites has shown that "...wind regime...is the major factor in dune orientation, and the net effect of all other environmental factors...is not more than one of a few degrees" (Landsberg 1956: 187).

In all cases it is quite probable that much of the sediment in this main dune area is derived from sediment already blown on to the Snook to the west. Many researchers indicate that oblique winds, especially on narrow beaches, may transport more sediment to dunes than winds of an equivalent magnitude blowing directly onshore. This is due to the greater storm surge and wave activity associated with direct winds which will produce a smaller beach width, and consequently, sediment source (Davidson-Arnott & Law 1990: 200). It is probable that the central area of the dune system, including the ridge and furrow area, has been subjected to sedimentation from a variety of directions, but primarily winds between south-west and north-east. Westerlies would have been important in transporting sediment already within an unstable system eastwards. Of the 18 blow-outs that can be identified and plotted from areas "A", "B" and "C" on figure 4.9, about 35% are oriented in a north-westerly direction, and c. 20% in south-westerly direction, another 30% are oriented in a westerly to west-north-west direction, while the remaining dunes are oriented to the...
south-south-west, and the north-north-east. These orientations are represented in a diagram: figure 4.12. The blow-outs in both area "A" and area "C" may all be remnants of larger single blow-outs as tentatively outlined on figure 4.9; area "A" is broadly oriented west-south-west, and area "C" west-north-west.

Figure 4.12: Rose diagram indicating orientation of blow-outs in the Lindisfarne dune system.

In the Green Shiel area (area "B", figure 4.9) it is apparent that westerly to north-westerly winds have been very important for the recent development of the dunes. This is clear from the 1951 R.A.F. photograph of this area (plate 3.2) which shows that the dune system in the Green Shiel area at this time was unstable, with unvegetated blown-sand covering the Green Shiel flat, the cliff and petering out to the south and south-east on the edge of the ridge and furrow. Making inferences from the orientation of the blow-outs that have built up against the till cliff it is probable that these blow-outs must be the product of north westerly onshore winds. A north westerly direction for locally strong winds in recent times is attested by the tree deformation data discussed above (this chapter, figure 4.7). Such winds may have also been responsible for sand creep over the ridge and furrow area. However, it should be born in mind that such a wind may well have created a "stagnant" area in the lee of the cliff (the ridge and furrow area just to the south-west of the settlement), thus impeding the development of dunes or even sand blow in this area. Also, it should be noted that the greater the magnitude of such a wind the more pronounced the stagnant area (Landsberg 1956: 183).

The foredunes in the north-eastern area of Green Shiel (between the site and its sediment source) are relatively low and therefore lend further support to the argument
that this area is inherently unstable as high foredunes tend to be found on coasts which
are stable or slowly prograding (Pye 1983: 540). A stable large foredune does exist just
to the north-west of the site and appears almost as an island of stability on the 1951 air
photograph.

Discussion: The Instability of the Lindisfarne Dune System

We can be sure that the Lindisfarne dune system around Green Shiel has only achieved
its current relative stability since the 1960s. The system as a whole may have achieved
relative stability recently due to the planting of Ammophila arenaria (Marram grass),
the organised planting of which has only been practised since the 1970s (Davey, pers
comm).

The inherent instability of the Green Shiel area is attested to by written accounts from
the nineteenth century. In 1845 work on a trackway for the limestone extraction on the
north shore made use of stone from the Green Shiel settlement site. It was noted that
these ruins, having for centuries been overwhelmed with sand, which here shifts with
every high wind, were, during the last spring, uncovered, and again brought to light,
by the prevalence, for a considerable time, of strong easterly winds...' (Selby 1849:
159). It is not clear whether Selby is referring to winds blowing from or towards the
east, the latter being more common for strong winds (see above). In either case it is still
apparent that the dunes in the Green Shiel area were extremely unstable during the
nineteenth century.

The instability of the dune system during the nineteenth century is further attested by
M.D. Johnston in his account of the Berwickshire Naturalists' Club visit to Holy Island
in 1854. He comments on the area to the south of Coves Haven on the north shore
where he observed sand hills that had been `...blown up by the winter winds', he goes
on to comment how during previous visits he `...had found this space a bent-covered
warren'; this area in 1854 was `...perfectly bare of all herbage and all life' (1875: 32).

An 1837 edition of The Penny Magazine observed that of the c. 1000 acres available on
the island, over one half of this was, `...from the violence of the tempests, covered
with sand, and produces nothing but bents...' (Penny Magazine 1837: 283). Such
accounts are important as the relationship between storms and sand-blow is noted and
implies that the system, although established, is still unstable over much of its area
during the nineteenth century.

Although some of the commentators remarked that the area was useless as agricultural
land, the writer for the Penny Magazine said of the dune area; `...even this part,
however, is valuable as a rabbit warren' (1837: 283). The absence of rabbits during the early medieval period would have had a profound affect on the ecology of any dune system that did exist on Lindisfarne at this time. Whether the absence of this animal would have resulted in vegetation growth that would have increased dune stability is open to question.

Rabbits are probably the most important biotic influence after humans. Westhoff notes that the rabbit is often considered to have a destructive effect on dune vegetation. This is only true if the rabbit population becomes too dense and "over grazes" a dune area, thus destabilizing it and allowing increased sand drifting. However, rabbit populations of a certain size can stimulate an ecosystem and increase vegetation diversity (Westhoff 1989: 46-7). Decreased rabbit populations due to exposure to myxomatosis have resulted in the development of overgrown and "impoverished" dune areas. Before the impact of myxomatosis it is believed that the vegetation of many dune systems was a product of rabbit grazing. In fact Garson says specifically of the Lindisfarne system, `...the contemporary botanical assemblage on these slacks and dunes must necessarily consist of species with some resistance to rabbit grazing' and that a drop in the rabbit population results in a reduction in floral species diversity (1985: 207). This hypothesis is supported by work elsewhere. In one experiment on Jersey mowing was carried out in order to assess its effect on species diversity: Where mowing stopped there was a decline in species diversity. Except where rabbit grazing was intensive (Anderson & Romeril 1992: 231-2).

Although it is apparent that myxomatosis has had some impact on the rabbit population of Lindisfarne (usually of cyclical nature over periods of c. five years) the population is still thriving and there is little doubt that they have had an important impact on this dune ecosystem.

The establishment of a rabbit population in the dune area on Lindisfarne serves as another indication of when the dune system, or a part of it, could have developed. Revenue from a coneygarth is first recorded in the priory Rolls for the 14th/15th century, but the placing of rabbits in the dune system may have taken place before then, although the fecundity of the species could mean that the priory would not have had to wait too long for this enterprise to bear fruits.

The Early Medieval Warm Period

As with the Little Ice Age considered above, the causes of the preceding warm period are difficult to discern. This problem does not however detract from the wealth of evidence for a climatic amelioration, the duration of which is not agreed, but the full
range of possible duration falls between AD 700 and 1300. Evidence includes oxygen isotope records from near Greenland which show a sustained warmth after AD 800 building up to a climax around AD 1100 (Flohn & Fantechi 1984: 35). Over most of Europe the climax of this optimum is considered to have been the period between c. AD 1150 and 1300. During the tenth century anticyclonic activity was unusually common, with low rainfall, warm summers and cold winters being the result (Lamb 1982: 164). This trend was probably the consequence of sub-tropical anti-cyclones being displaced to the north. Lamb states that strong winds in the latitudes between 40° and 60° North were less prevalent (Lamb 1977: 440). As the storm frequency curve indicates (figure 4.11), there is little evidence for intense aeolian activity in the North Sea area during this period; in fact according to Gottschalk there is only one reliable record of a storm event for the entire period from AD 500 to 1000, that which took place on 26th December 838 (Gottschalk 1971: 40). However, a lack of documentary evidence does not preclude the occurrence of storms during this period. Although some researchers have dated a new transgression phase, which included the development of new dunes and the blocking of the mouth of the Rhine at Katwijk, to the middle of the 9th century, there is no convincing evidence for such a transgression, although it is quite possible that relatively minor events of this nature did take place at a local level, but certainly not to the same extent as during the Little Ice Age that followed (Gottschalk 1971: 40).

The evidence that exists at the moment indicates that there was relatively little storm activity during the early medieval period, and consequently very few areas were subjected to intensive sand encroachment and dune development. There is plenty of evidence, once again, much of it from work in the Netherlands, on the status of dune systems during this optimum. The most extensive work is that by Jelgersma et al. (1970) carried out over several sites on the Dutch coast. At two sites on the North Sea coast west of Amsterdam, radiocarbon dates from stable peat horizons below the Younger Dunes indicate that the stability phase (as represented by the peat horizon) lasted from about 1300 to c. 850 B.P. This phase varies along the Dutch coast, but all of the dates indicate that most dune systems in this region were stable during the early medieval period. Fortunately, one of the few British dune sites with a radiocarbon-dated stability horizon sandwiched by blown-sand is on the Northumbrian coast at Low Hauxley (Frank 1982) (location on figure 4.10). The slack deposit, which must have developed behind an already established dune ridge, is dated to 980 ± 50 BP (920-1030 AD). As Frank notes, this date gives a maximum age for the slack as the shell from which it was derived is a lag deposit (1982: 31). Not only is the date from the slack important as it is evidence for a stability phase along the Northumbrian coast during the early medieval period, but the history of this system as a whole might be considered as a useful contrast with the Lindisfarne system to the north. Research at the Low Hauxley site indicates that sand dunes had developed on the Northumbrian coast during the
prehistoric period, certainly by about 860 B. The site is located at the top of a beach; it comprises a peat sequence (with in situ tree stumps), covered by blown sand and then a slack horizon succeeded by more blown sand. The slack horizon represents an early medieval hiatus when sand dune development had stopped, the system having perhaps been eroded and stabilisation and slack development taking place. It is also worth noting that the slack horizon is 5.6m OD almost the same height as the Green Shiel occupation levels which are about 5.8m OD (see above, chapter 3). Both the Low Hauxley and the Green Shiel sites were located at the top of sandy beaches which had been, and would subsequently be, susceptible to sand encroachment and dune development. The data indicates that both sites, at very similar elevations, were relatively immune from extensive sand-blow and were therefore geomorphologically stable during the early medieval period.

Further evidence to support the hypothesis of relative stability in this area during the early medieval period comes from the biometric analyses of *Nucella lapillus* (the dogwhelk).

**Nucella Lapillus** (The Dogwhelk) as an Indicator of Shoreline Exposure

*Introduction*

Evidence for the climatic optimum, or more specifically, a less intense wave regime on the shoreline of Lindisfarne itself, exists in the form of variation in dog whelk (*Nucella lapillus*) morphology. The shell morphology of this marine gastropod is directly influenced by the intensity of wave action on the shore where it lives (Crothers 1978). In general terms *Nucella lapillus* tends to be shorter or squatter in exposed environments, that is the ratio of the total length to aperture is smaller, while in calmer, or less exposed environments the opposite is true: the shell tends to be longer with a larger total length to aperture ratio. It is important to note that this morphological relationship is considered to be independent of the overall size of the whelk, although the relationship does tend to be stronger in adults than in juveniles (Andrews et al. 1985: 74).

The aim of comparing the morphology of the modern population with that of the ancient one is to consider the possibility of the ancient shoreline having been subjected to a different level of exposure to that of today. The aim is not to assign a shoreline exposure rating (Andrews et al. 1985; Ballantine 1961), but to examine the relative difference in shoreline exposure as indicated by whelk morphology alone. The reasonable assumption that the sample from the archaeological context originally lived
on the shore adjacent to the settlement site, i.e. from the same place as the modern samples used for comparison, must be made in interpreting the site data. Today the dogwhelk inhabits all of the rocky shorelines around Lindisfarne: therefore it is concentrated on the northern and eastern shores, i.e. those shores that are most susceptible to wave action.

**Methods**

As many as possible complete examples (N=38) of *Nucella lapillus* from archaeological "occupation horizons" were extracted from the Green Shiel finds archive. The majority of these examples were retrieved during on site dry-sieving, with some retrieved during laboratory based wet-sieving, between 1986 and 1991. The modern population was sampled so that the ancient whelk morphology could be compared with that of today's. One sample, totalling 36 specimens, was collected in April 1990, and the another totalling 60 was collected in September 1990. The sample taken in April 1990 was restricted in size as the population was low. This was because migration up to the littoral zone was not complete.

Measurements of total height and aperture height of each individual were made (see figure 4.13) using a vernier callipers to the nearest 0.1mm. All of these measurements were entered into Minitab; the two modern populations were entered as separate samples. Once the data was entered onto Minitab, the ratio of total length to aperture height was calculated. A series of statistical tests was then carried out in order to test the difference between the samples. The parametric analysis of variance test (F ratio test) and the non-parametric Mann-Whitney test, were carried out with the following permutations for both tests: the archaeological sample tested against the modern sample collected in September 1990, the archaeological samples tested against the modern sample collected in April 1990, the archaeological sample tested against the two modern samples treated as one single sample, and finally, the two modern samples tested against one another.

![Figure 4.13: Drawing showing both "squat" and elongate examples of the marine gastropod *Nucella lapillus*. "T" = total height, "A" = aperture height.](image)
Results

(The full results of the statistical tests can be found in appendix 3d)

Although the ratio values from different studies around the British Isles can not be used as direct comparisons, as each population is subject to a different combination of processes, it is useful to point out that a ratio of c. 1.8 is considered to be indicative of sheltered shorelines, while those from more exposed areas tend to have ratios of c. 1.7-1.6 (Andrews et al. 1985: 79; Crothers 1978).

The archaeological sample from Green Shiel has a mean ratio value of 1.82 with a standard deviation of 0.142. The modern September sample has a mean ratio value of 1.62 and a standard deviation of 0.108, while the modern sample that had been collected in April had a mean of 1.66 and a standard deviation of 0.114. A graphical representation of these results can be found in figure 4.14.

![Graphical representation of the results.](image)

**Figure 4.14:** The means and standard deviations of the total height to aperture height ratios of all of the *Nucella lapillus* sample groups. A= the archaeological sample; B= the modern sample collected in April 1990; C= the modern sample collected in September 1990.

The analysis of variance test carried out comparing the archaeological sample with the two modern samples as separate samples shows that there is a significant difference (at a level of 0.01) between the archaeological sample and both of the modern samples. The archaeological specimens are significantly more elongate than those collected recently. A second test comparing the archaeological sample with the two modern samples was also carried out, but this time the two modern samples were treated as one; as should be expected, a clear significant difference was illustrated. The test comparing the two modern samples with one another showed that these samples were not statistically different from one another. However, the sample collected in April 1990 is slightly more elongate than that collected during September.
The Mann-Whitney test showed that the archaeological sample was significantly different from both of the modern samples at a 0.0000 level. It should be noted that the Minitab Mann-Whitney procedure automatically calculates the lowest significance value at which the test is significant (extreme difference is indicated by the 0.0000 value). The test comparing the two modern samples showed that this test was significant at 0.0001 level.

Discussion

It is argued that the limited size of the archaeological sample does not detract to any great extent from the statistical analysis detailed above; the analysis of variance test is based on comparing within-sample variation with between-sample variation, and the fact that the within-sample variance was so small compared with the between-sample variance indicates the relative homogeneity of the archaeological sample, even though the standard deviation of this sample was slightly higher than those of the modern samples. Also the relatively normal characteristics of all of the samples shows that they are representative of their populations.

The most important statistical tests are those which compare the archaeological sample with two modem samples treated as a single sample. The parametric analysis of variance clearly indicated that the between-sample variance was much greater than the within sample variance. This difference was confirmed by the non-parametric Mann-Whitney test. There can be no doubt that there is a significant difference between the archaeological sample and those alive today. One explanation is that the early medieval shoreline adjacent to Green Shiel was subject to less intensive wave action. This may have been the result of different wave-energy levels. One possible explanation is that relatively higher sea-levels would have resulted in wave energy being lost against a more extensive sea-bed. However, as the discussion above showed, sea-levels have been relatively constant during the last 1,000 years; also, the majority of waves on this type of shoreline are gravity waves, whose energy and amplitude is largely related to wind strength. Therefore it is fair to assume that lower exposure levels on the north shore of Lindisfarne were a product of reduced wind activity.

Note: the collection of modern control populations

The slight variation in the aperture/total length ratio between the two modern samples is an important phenomenon, and it should be taken into consideration in future studies of Nucella lapillus. A safe method would include measurements of samples taken at
different times of year over a number of years and the mean of all of these ratios taken as the control population. This may be necessary as we can never be sure at what time of year our archaeological samples were harvested.

**Early Medieval Stability**

There can be little doubt that early medieval Lindisfarne enjoyed a period of relative climatic amelioration and stability. The exact temporal extent of this period is almost impossible to deduce, but we can be sure that the period included the ninth century AD during which the settlement site at Green Shiel was inhabited. The period of stability indicated by the tenth to eleventh century AD date from Low Hauxley just to the south of Lindisfarne, and the range of evidence from the Netherlands, indicates that a climatic optimum with few major storms characterised much of the early medieval period, and lasted until the twelfth century.

The Green Shiel site was occupied at a time when the dune system was either entirely absent from all parts of the north shore, or, had previously developed in some areas but was stable during the early medieval period. Optimal climatic periods with warmer summers are not considered by many researchers to be a factor which increases the potential for sand-blow and dune formation. In contrast they allow stabilisation as floral communities flourish under such conditions (Wishman 1990: 112).

At the time of occupation the Green Shiel site and environs were very different. The settlement was located at the top of an extensive sand beach, adjacent to a wave-cut limestone platform. The now intervening dunes were absent. The dunes behind Green Shiel would also have been absent, but it is possible, even probable, that a dune system did exist on the Snook to the west of Green Shiel, and also in the area to the south of the ridge and furrow. The Green Shiel site was backed by a low cliff-line, on top of which a well-developed soil existed, which at this time was not threatened by extensive sand-blow. This field may have been accessible from a number of directions: the lower area at the western end of the ridge and furrow; the area which subsequently developed as the slack; or finally from the area just to the north-east of the settlement site where the soil would have extended almost up to the shoreline. The close proximity of the soil to the north shore is an indication, as much as any other evidence, of stability during this period, especially as in this area the soil developed on top of an earlier deposit of blown-sand which had previously covered the clay-till serving as the foundation for the soil elsewhere in the ridge and furrow area.

Even if sand-blow was not a serious threat during this period, one phenomenon which could have been a potential threat was inundation by the sea. It is unlikely that the
settlers would have built adjacent to the high-tide mark. But the possibility of rising sea-levels during the medieval optimum in combination with a high spring-tide and a storm, could potentially have lead to a transgression; as Gottschalk notes, 'it is generally believed that the construction of sea dykes began in Western Europe in about 1000 AD' (Gottschalk 1975: 819). This implies that the sea was certainly reaching, what was until this point, unprecedented levels. This kind of transgression seems unlikely in the Green Shiel area and there is no discernible evidence for the site ever having been inundated by the sea, and even if such evidence had ever existed the nature of the aeolian processes in this area would have removed any such traces. If such an event did take place it is unlikely to have occurred before the stormy period which begun during the fifteenth century.

Conclusion

This chapter has considered the range of environmental variables, both climatic, biotic and geomorphic, which effect sand-blow. It is apparent that a complex suite of factors such as sediment supply, wind, sea-level vegetation and faunal activity influence sand dune development.

In summary, the younger dunes in Britain and northern Europe developed during the high Middle Ages, a time of lower temperatures, higher winds and greater precipitation. This was preceded by a period of climatic stability with higher average summer temperatures and possibly lower winter temperatures. Most important in the Lindisfarne study is the fact that aeolian activity was appreciably lower; relatively little or no sand blow combined with an ameliorating climate to allow a level of stability in an otherwise unstable environment. The sand dune system on Lindisfarne probably existed in one form or another for much of the Holocene. Its early development took place in the area of the Snook to the west of the Green Shiel area. It must have gradually moved further east, covering the north shore of the island some time during the medieval period. Even since its stabilisation, the Lindisfarne dune system has failed to achieve a high level of ecological succession; even today there are no areas within the system that can be classed as dune pasture, let alone dune scrub or woodland. Also, the area around Green Shiel only appears to have stabilised since World War II. All of this points to the sand dune system being relatively young. We can be sure that during early medieval times the Green Shiel settlers had access to a viable agricultural soil as well as the full range of resources found in the littoral zone.
CHAPTER 5
THE INVESTIGATION OF THE PALAEOSOL

Introduction

This chapter considers the range of material extracted from the ridge and furrow buried soil. This includes work on the characteristics of the soil itself i.e. measurements of organic and calcium carbonate content, and micromorphological studies of soil thin-sections. The aim of the research detailed in this chapter, and the following chapter where the palaeoecological material from the buried soil is considered, is to highlight the potential of a range of techniques that might be employed in the study of a dune environment. The production of definitive results from two or three techniques studied in depth was never a possibility in an environment that allows only limited preservation of most ecofacts. This chapter and chapter 6 highlight the strengths and weaknesses of a wide variety of methods, some of which have produced meaningful results, others however, are shown to have certain drawbacks.

Soil Analyses from the Ridge and Furrow

Introduction

The buried soil in the ridge and furrow area covers an area of about 10 hectares located broadly between the two principle areas of dune hills (see figure 5.1). The palaeosol is a sealed record of previous land use. Despite the fact that the boundary between the palaeosol and the blown sand above it is relatively sharp, we cannot be sure that this soil has not been covered and re-exposed a number of times. Notwithstanding this, the study of this buried soil is of great importance as its rudimentary characteristics will have been maintained throughout its existence, although the characteristics of the soil, as measured today, are not necessarily the same as those when it was at the surface. There are two basic reasons for this. First, the soil was not buried directly after the abandonment of Green Shiel: the soil is not only a relic of early medieval exploitation, but also of any exploitation of the period up to the point when the palaeosol was last buried. The second reason is that post-burial processes have undoubtedly taken place.
Figure 5.1: Map of dune area showing location and extent of the buried soil.

Approaches and Methods

The topographical characteristics and extent of the buried soil were ascertained by auger survey and the three-dimensional recording of augered levels. The detailed description and analysis of this survey were covered in chapter 3, where all of the digital terrain model is discussed. It should be reiterated here that for much of its area, the buried soil
lies directly on top of glacial till, however; in the northernmost area, near the shoreline, the soil has formed on top of a sand unit which at some time covered the till in this area (see chapter 3).

Particle size analysis of the buried soil was also carried out and the results of this are considered in chapter 4. The organic content of the soil was measured using two methods: loss on ignition and wet oxidation. These tests were complimented by a reaction spot test for calcium carbonate content. Finally, the characteristics of the buried soil were examined in thin-section.

**Organic Content**

During the auger survey of the ridge and furrow, samples of the buried soil were taken from the chamber of the dutch auger and placed in numbered bags where the number referred to the location of the auger-hole which was subsequently located three-dimensionally using a total station electronic distance measurer. Thirty-eight of these samples were then used in the laboratory for the organic content and calcium carbonate tests. These thirty-eight samples were chosen to represent the entire area of the buried soil as surveyed.

**Loss on ignition**

The method employed was as detailed in Briggs (1977: 147-150).

Approximately 10gm of soil were dried at 105°C for 24 hours and cooled in a dessicator. A crucible was taken for each sample in the batch and its weight recorded as W1. The dried soil was placed in the weighed crucibles and then re-weighed and this weight recorded as W2. The batch of crucibles was placed in a furnace at c. 450°C for sixteen hours. Once this ignition process had been completed the crucible and its contents were weighed, this weight being recorded as W3. The amount of organic matter is therefore the loss of weight during ignition which is shown as a percentage of the original sample weight: Organic Matter % = (W2-W3/W2-W1).100.

The percentage values from this experiment were then entered onto the computer in a column adjacent to the samples two-dimensional co-ordinate in order to allow the values to be plotted spatially (see below).
**Wet oxidation**

For this method a variation of the Walkley-Black wet-oxidation method as detailed in Jackson (1958) was used. This method is based on the principle of the spontaneous heating by dilution of H$_2$SO$_4$ (Jackson 1958: 219).

After each soil sample had been ground with a pestle and mortar to under 2mm, a sample 0.5gm of soil was placed in a 400ml tall beaker. The amount of soil used is dependent on the expected organic matter present, as too much or too little organic matter results in the failure of titration.

Initially 10ml of potassium dichromate (K$_2$Cr$_2$O$_7$) was run into each beaker from a pipette; three soil samples and a blank were done in each batch. Following this 20ml of concentrated sulphuric acid (H$_2$SO$_4$) was added to each beaker, stirred, and then left to stand for thirty minutes. After this period the solutions were brought to approximately 200ml by adding 170ml of distilled water. Then 25ml of 0.5N ferrous ammonium sulphate was added. Finally the samples were titrated against 0.4N potassium permanganate (KMnO$_4$). The organic content of the soil is arrived at by subtracting the mean value of the titrated blanks from the amount of titrate used for each soil sample: this value is multiplied by 0.0012 and from this the percentage amount of carbon in the soil is calculated.

As with the loss on ignition results, the values for each sample were entered into the computer data file with the corresponding spatial co-ordinates.

**Calcium carbonate content**

This test was not designed to produce accurate assessments of the CaCO$_3$ content in the buried soil, but to discover if the expected inverse relationship between organic content and calcium carbonate did in fact exist. For this reason a straightforward spot-test was employed.

About 5gm of soil was taken from each sample and placed on a petrie dish where two or three drops of 10% hydrochloric acid solution were added. The level of reaction was then noted and the amount of calcium carbonate present was thus estimated from the degree of reaction (see table 5.1). The mid-points of the percentage ranges indicated by the degree of reaction were recorded as the actual estimated values.
CaCo₃ content | Reaction
--- | ---
<0.1% | None
0.1-0.5% | Faint Spitting Audible
0.5-1.0% | Spitting Audible
1.0-2.0% | Clearly Audible; Slight Reaction Visible
2.0-5.0% | Easily Audible and Visible
5.0-10.0% | Vigorous Effervescence

Table 5.1: Calcium carbonate spot-test reactions.

As with the organic content results, the estimated percentage figures were entered into the computer data file.

Presentation of data

Once all of the data from the organic content tests and the calcium carbonate test had been entered into the data file the results were viewed using UNIMAP. As with the digital terrain models (see chapter 3) the data file was imported into UNIMAP and the results of the three tests were treated as "Z"-values (third co-ordinates). Each of the three result columns were interpolated and two-dimensional contour plots produced, thus illustrating the spatial distribution of variance within the test results.

Results

The full list of results can be found in appendix 4.

As the interpolated plots show (figures 5.2a, b, & c), there is a clear trend in terms of the relative levels of organic content across the area examined. This trend is reflected in both organic matter tests, although as expected the wet oxidation method indicated lower levels of actual organic content compared with the loss on ignition test (see discussion below). The buried soil at the western end of the area immediately to the south of the
Green Shiel site possessed the lowest levels of organic content (see figures 5.2a & b). The level of organic content increases steadily eastwards across the area, with the highest levels occurring at the northernmost area of the visible ridges and furrows. The buried soil does of course extend northwards almost as far as the dunes above the modern shore line (see figure 5.1), but the levels of organic content decrease nearer to the north shore.
Figure 5.2: Organic content (wet and dry methods) and calcium carbonate content across the buried soil.
The highest percentage levels of organic content measured by the wet oxidation method were 1.24%, with three other values above 1.1%. The lowest levels indicated by this method are 0.15%, with three other values around 0.18%. The mean value was 0.51% with a standard deviation of 0.298%.

The loss on ignition tests continually estimated higher levels of organic content than the wet oxidation test. The highest level is 5.06%; 3.91% and 3.5% were the next greatest. The lowest values indicated by this test are 1.13%, followed by 1.18% and 1.2%. The mean for value for this test is 1.896%, while the standard deviation is 0.885%.

Calcium carbonate test results

As the spatial plot of the CaCo3 test results shows (figure 5.2c), the relative levels of calcium carbonate show a distribution which is broadly the inverse of the organic content distributions. The highest levels of calcium carbonate are at the westernmost end of the ridge area and decrease quite quickly towards the eastern area. The highest estimated mid-point value was 7.5%, which was recorded four times in total. The lowest estimated proportion of CaCo3 was 0.75%; this was recorded for eight samples. The mean value is 2.7632% and the standard deviation 2.11%.

Discussion

Although the two different organic content tests produce the same patterns in terms of the spatial distribution of relative organic content, there is obviously a large difference in the indications of actual organic content given by the different tests. It is well known that loss on ignition tests tend to over-estimate the amount of organic content in a sample because water held in the lattice structure of clay particles and carbonates may be lost using this method (Briggs 1977: 149). In the case of a sandy soil such as that on the north shore of Lindisfarne, it is the loss of water held in the carbonates which may result in an over estimation of organic content. Also, due to the lesser heating used in the wet oxidation technique, elementary carbon is not removed (Jackson 1958: 219). Figure 5.3 (below) is a plot of the two organic content tests plotted against one another for each sample. As the plot illustrates, overall there is a relatively constant difference between the two estimates. However, the coefficient of determination \( R^2 \) is 0.594; (a value of 1.0 means the fit is perfect) therefore 59% of variance in the dependent variable (the wet oxidation estimate) is accounted for by the regression. This graph reiterates the point made above: the loss on ignition tests continually give an estimate higher than the wet oxidation test.
It is interesting to consider if the outlying points on the plot (figure 5.3) share any characteristics. Points 1 and 2, which possess low wet oxidation estimates compared with their loss on ignition values, are located adjacent to one another in the ridge and furrow area. There is no obvious explanation as to why this anomaly should occur. Calcium carbonate content does not appear to be a factor as one has a CaCo₃ content of 7.5% and the other, 1.5%. The opposite trend is represented by points 3, 4 and 5 on figure 5.3. All of these samples have higher than expected wet oxidation values. Again, they are all located adjacent to one another at the easternmost end of the ridge and furrow. In this area the palaeosol is below the thinnest layer of sand, between 20 and 30cm. Also, these samples have a CaCo₃ content of 1.5% or 1%. Again, there is no straightforward explanation for this particular anomaly.

Figure 5.3: Scatter-plot of loss on ignition estimation of organic content against wet oxidation estimation. Regression value also indicated.

There is little doubt that more credence should be given to the organic content estimates derived from the wet oxidation tests. These tests indicate that the organic content of the soil was in fact very low: a maximum of just over 1%. It is quite common for soils to have organic contents at about the 1% level or less (Fitzpatrick 1986: 110) and such a low level should not necessarily be considered as indicative of a poor, potentially unproductive, soil. As mentioned earlier, a whole series of post-depositional processes may be responsible for the alteration of this palaeosol and current estimates of organic
content may not reflect its past organic content (Retallack 1990: 144). In fact the current estimates probably reflect the minimum organic content. It is quite probable that with the onset of the increased storminess of the sixteenth century and the formation of the major dune system, the then extant soil underwent some erosion: the turf layer may have died, consequently leaving an exposed soil susceptible to erosion. Therefore, the buried soil as it exists today may in fact be a fraction of the thickness of the original soil.

**Micromorphology**

*Introduction*

Micromorphology is an approach to the study of soils which compliments the traditional methods of soil analysis. Bullock *et al.* describe micromorphology as "...the branch of soil science that is concerned with the description, interpretation, and to an increasing extent, the measurement of components, features and fabrics in soils at a microscopic level, i.e. beyond that which can be readily seen with the naked eye" (1985: 4). This approach more than any other is considered by some to permit the consideration of soil processes as well as describe characteristics. Many micromorphological studies have recognised human impact on soil systems and not just "natural" processes (Courty *et al.* 1989: ch. 7).

*Methods*

In the field a series of pits and trenches were dug (figures 3.7/10). Once the trenches had been excavated the sections were cleaned up and drawn (figure 5.4). Each corner of each pit and trench was also located on the site grid three-dimensionally using the Electronic Distance Measurer. Once the drawings were completed samples for micromorphology were taken. These "Kubiena" samples were taken with open metal boxes about 5cm square. The top of each box was clearly marked and the sample location marked on the section drawing (figure 5.4).

Over the two main seasons of field-work some twenty Kubiena samples were taken from different units around Green Shiel and the ridge and furrow. Due to the sandy nature of the majority of the sediments some of the samples were unusable as the material crumbled. The majority of those taken from the ridge and furrow palaeosol maintained an adequate level of cohesiveness and five samples were selected for impregnation. Two of these samples were from the 1990 ridge and furrow trench (samples GSK11/90 and GSK12/90), and three were from the 1991 excavation: two
from the buried soil (samples GSK1/91 and GSK2/91) and one from the thickest band of later pedogenesis within the sand blow (GSK3/91) (see figure 5.4).

Figure 5.4: Section drawings of ridge and furrow trenches: location of samples taken from both trenches indicated.

The two samples from the 1990 trench were impregnated at Leicester using carbowax 6000, following the method detailed in Fitzpatrick (1984: 20-22). Initially this method seems very straightforward: enough carbowax to cover the Kubiena sample is placed in a beaker and melted in an oven at 70°C. Once this has melted the sample (still in its tin) is lowered into the melted wax. The temperature is lowered to 60°C and the sample left for one week in order to allow complete impregnation. After this period the sample is removed from the wax and left to cool down for 24 hours. The soil block is then removed from the tin. It was decided that the most efficient way to achieve this was to saw through one corner of the tin and then pull the sides of the tin carefully away from the soil block. The soil block can then be sawn and a thin section made. This part of the process was attempted in the University's geology department. The production of a thin section proved almost impossible as the inherent weakness and relative friability of the carbowax, combined with the sandy nature of the soil, meant that parts of the section broke away once grinding had reduced the section to about .5mm. Consequently this method was abandoned.

The three samples from the 1991 trench were sent to Queen Mary and Westfield College for impregnation and slide production. This process was entirely successful and slides ready for examination produced.
Method of examination

Each of the three slides was examined using both a low powered binocular microscope at magnifications of 10X to 40X, and a petrological microscope at magnifications of 40X to 400X under plain polarised light and cross polarised light. Each slide was studied following the method outlined in Bullock et al. (1985). The methods of examination and descriptive annotations detailed by Fitzpatrick (1984) and Kemp (1985) were also referred to.

Thin section descriptions

The thin sections are considered in stratigraphic order (from the base upwards) rather than sample number order (see Figure 5.5 and b/w plates).
Figure 5.5: Drawings of micromorphological thin-sections in stratigraphic order. Note the location on the thin-section slide of each drawing.
Thin-section GSK2.

(See Figure 5.5, drawings 2a & 2b and plates 5.1, 5.2, 5.3 & 5.4)

Structure: Estimation of groundmass relative proportions: coarse/fine=50:50. The coarse fraction is dominated by fine sand with smaller proportions of medium and some coarse.

It should be noted that although this structure dominates this thin-section, drawing 2b represents an anomaly in that a relatively large fragment of whinsill (see plate 5.2 (2500μm X 1500μm) is detailed.

Aggregates are absent to rare, with the fine material often forming a relatively concentrated coating around the sand grains and constituting an infilling finer matrix.

Generally poorly sorted, sub-rounded, sub-angular quartz, some calcite (shell) >1%.

Generally porphyric for much of this sample, but becoming more open-porphyric higher up the section (see figure 5.5, 2b).

Higher up this thin-section the coarse fraction becomes better sorted (see top of drawing 2b; figure 5.5, and plate 5.2). The coarse quartz material shows clear signs of irregular linear alteration.
Plate 5.1: photograph of GSK2. Frame width 6.7mm.

Plate 5.2: Thin-section GSK2 showing whinsill fragment in centre (XPL and gypsum plate). Frame width 6.7mm

Plate 5.3: Thin-section GSK2 showing speckled b-fabric (PPL). Frame width 3.35mm.
Groundmass (plasma): Large areas of speckled b-fabric (see plate 5.3).

Voids/Pores are rare in the majority of this section. But some are illustrated in figure 5, 2a/b (and see plates 5.1 & 5.2) where pseudo, zig-zag planar voids are shown in 2a, along with an atypical vugh running horizontally across much of the entire slide. This has an average width of 500μm. This feature may have been produced during the impregnation process.

Pedofeatures: Hypo-coatings of grains: iron and/or manganese; these vary locally. Most concentrated areas indicated by drawings 2a and 2b (figure 5.5).

Some faecal material does seem to be present. Although this material appears similar to mite faecal pellets, it does not occur within plant material as is the norm with such material; therefore the possibility of this faecal material belonging to beetle larvae is also a possibility (Fitzpatrick 1984: 171).

Organics: Coarse organics >1%. Most are dark brown and lignified and slightly decomposed, lignified and are probably derived from root material (see plate 5.4). There is also clear ferruginisation of some roots (Macphail pers com.).
Plate 5.5: photograph of GSK1, frame width 6.7mm.

Plate 5.6: photograph of GSK1, frame width 6.7mm.

Plate 5.7: photograph of GSK1, frame width 6.7mm.

Thin-section GSK1

(See figure 5.5: drawings 1a, 1b & 1c, and plates 5.5, 5.6 & 5.7)
Microstructure: Well-moderately sorted, sub-angular and sub-rounded with smooth surfaces. Generally porphyric with some vughs.

Coarse/fine ratio (estimate): 60:40.

Mineral content: Quartz dominant; >1% feldspar; >1% biotite.

5-10% calcium carbonate (marine shell).


Voids/Pores exist, but those that are present tend to be small chambers.

Organics: Coarse organics >1%: most are dark brown and lignified and slightly decomposed, and are probably derived from root material.

Pedofeatures: Hypo-coatings of grains; iron and/or manganese; these vary locally.

Infillings: Dust clay, with some infilling of channels by clay and coarser material. Some charcoal infillings in voids and mollusc esp.

Textural pedofeatures: dusty clay?

Excrement: some faecal pellets, possibly mites or beetle larvae (see above).

Minerals with fine coating of clay/humus. Pellicular grain structure or, intergrain micro-aggregate structure.

Coarse material dominant.

Cell residues and tissue residues. Total organics >1%.

Other features

Section of terrestrial mollusc; probably Cernuella virgata (see below, section 2).

Thin Section GSK3

(see figure 5.5, drawings 3a 3b, and plates 5.8 & 5.9).

Soil Structure: Single grain structure

Generally well-sorted with local areas only being moderately sorted (see figure 5.5, 3b and plate 5.9), sub-rounded, sub-angular. Coarse/fine=50:50.
Single to double spaced porphyric.

Groundmass (plasma): Dominated by b-fabric (as above).

Infillings: Dust clay, with some infilling of channels by clay and coarser material

Voids/pores are quite rare with some vughs.

Pedofeatures: Amorphous aggregations of material similar to that described previously. However, this material does not really exist as hypo-coatings (Bullock 1985: 101).

Organics: Coarse organics >1% Most are dark brown and lignified and slightly decomposed, and are probably derived from root material.

Plate 5.8: photograph of GSK3, frame width 6.7mm.

Plate 5.9: photograph of GSK3, frame width 6.7mm.

Summary and discussion
The discussion will consider all three thin-sections described above but will emphasise, when necessary, any differences that exist within and between the sections. Also, it should be remembered that sections GSK2 and GSK1 come from the main buried soil unit which lay directly on top of the till, while section GSK3 comes from the band of pedogenesis above this (see figure 5.4).

**Structure**

The sections are dominated by a well-sorted fine to medium sand, with less well-sorted areas towards the base of the unit. The structure is dominated by sub-rounded, sub-angular, quartz (with small quantities of feldspar and calcite, and larger (<1000µm) pieces of whinsill and siltstone (with mica) derived from till. The coarse fraction normally constitutes c. 50% of the section areas; the remaining proportion is dominated by the fine groundmass and voids. Throughout the unit, aggregates are absent to rare, although some "rounded lumps" of soil are present (Macphail *pers com*). Some panning is apparent at the bottom of samples GSK1 and GSK2. The presence of relatively large amounts of till in the lower sections is indicative of mouldboard ploughing (Macphail *pers com*).

**Groundmass**

The groundmass, or plasma, is largely characterised by areas of both speckled and undifferentiated b-fabric. Speckling of the matrix could possibly be indicative of weathering. The possibility of weathered geothite is implied by the colour of the matrix as this imparts a reddish-brown, reddish-yellow, or, brownish-yellow colour to the matrix (Fitzpatrick 1984: 191). Iron has clearly accumulated at the bottom of sample GSK2 (the lowest sample).

**Voids/pores**

These are relatively rare with the majority being classed as vughs or chambers. The one major anomaly is the vugh which runs horizontally across much of lower part of sample GSK2. Whether this is a "natural" pedogenic feature, or a "crack" which developed during the sampling or impregnation process, is difficult to discern.

**Infillings**

Dusty clay, clay along with some charcoal and coarser material are present as infillings.
Coatings

In the two samples from the buried-soil, hypo-coatings were identified. In some areas, especially in GSK2 (the sample from lowest point in the unit), the staining tends to be dark brown to brown: these colours are imparted by ferric hydroxide and/or colloidal organic matter; this `...is common in a number of soils which have incorporated organic matter or are in a relatively early stage of weathering' (Fitzpatrick 1984: 192) (these substances are isotropic when present in large amounts). Some of the coatings, or caps, are indicative of the precipitation out of secondary carbonate; this is clearly a post-burial alteration of the soil (Macphail pers com.).

Excrement

A relatively small number of faecal pellets are present in all of the sections; these have been tentatively identified as mite or beetle larvae excrement; there is also a possibility that they may be ant excrement.

Organics

Brown to dark brown lignified organics are present in all of the sections, and it is suggested that the material from the lower sections tends to be slightly more decomposed than that from higher up.

Conclusion

The ridge and furrow buried soil is undoubtedly a very important feature, not only because it contains a wide range of palaeoenvironmental evidence within its matrix, but also because of its close proximity to the Green Shiel site. All of the tests carried out on the Lindisfarne buried soil show that it is a very well-sorted, homogenous, structureless sandy soil, with a low organic content and high pH. The micromorphological study shows that there are relatively important differences between the lowest unit (sample GSK2) and those above. The heavier staining in a less well-sorted matrix does imply the earlier presence of a well-developed and stable soil, not subject to inundation by blown-sand. The ridge and furrow palaeosol seems at first to be a calcareous pararendzina type, but the fact that it developed directly on top of a drift substrate complicates the discussion; therefore a consideration of the hydrological regime is important. Even though the palaeosol is directly on top of a relatively impermeable clay till, it is probable that excess water drained laterally into the lower area to the west (today's slack). The buried soil is primarily a sandy soil with the typical characteristics that one would expect in such a soil. Relatively large particle sizes means that the soil should be relatively freely draining: the
field capacity was probably rarely reached due to lateral drainage, and therefore the available water was probably quite low and the soil prone to drought.

Sand grains have relatively small exposed surface areas in comparison with silts for example; therefore the part that such particles play in the chemical and physical processes within the soil would have been relatively small (Foth 1978: 27).

It would seem from the characteristics of the modern paleosol profile that the growth of many crops would in fact have been quite difficult as the soil has a maximum depth of about 10cm. Such a thin soil laying directly on top of impermeable till could well have prohibited downward root penetration. Of course it is quite likely that the original soil was thicker than the relic paleosol of today. In fact, today's paleosol could well be an "A" horizon which at one point had a more humic "O" horizon. There is no clear evidence for a thick homogenous layer at the top of the buried soil as one might expect from a ploughed soil. However, the presence of ridge and furrow, and Macphail's contention that the till found in the thinsections could well have been moved upwards into the soil matrix by a mouldboard plough, is a clear indication that ploughing has taken place. However, it does seem unlikely that this area has ever been successfully used for arable agriculture; the ridge and furrow may be representative of a short-lived attempt at crop husbandry in the area.

The thin-sections lack the classical characteristics that we might expect in a soil that had been trampled by grazing animals. Mechanical action on the soil from trampling and consequent puddling is not identifiable. However, it seems quite likely that if these characteristics had been present, they would have largely existed in the upper part of the soil profile which seems to have been eroded prior to burial. It is safe to assume that pre-burial erosion rather than truncation has taken place (i.e. a large part of the A horizon may have been blown away) and a certain amount of postdepositional reworking has taken place that has been responsible for the destruction of any typical diagnostic features that relate to much of the agricultural exploitation of the soil.

There is little doubt that some of biological activity has taken place since the soil was buried, however, this does not seem to be very extensive (Macphail pers comm.). A certain amount of faunal activity has also taken place. As the above descriptions show, the presence of mite faecal pellets confirms this. This means that much of the organic matter initially present in the soil has probably been ingested.

Potentially, one of the most important post-depositional factors has been root penetration from the modern vegetation as such roots are quite apparent during excavation. This type of biogenic reworking may have had a profound affect on some
of the palaeosol's characteristics. However, the roots that were identified during the examination of the thin sections tended to be small, and decomposed; there seemed to be little indication of massive reworking by modern root penetration.

The relatively coarse partical size of the soil means that water percolation through the profile may have been quite intense on ocassion, with the sudden down-washing and horizontal movement of soil materials taking place. The relative lack of voids could be due to this kind of saturation of the soil profile, although as was noted above (this chapter) the soil in this area would have been relatively free-draining as water would have moved laterally down to the slack to the west of the ridge and furrow area.

Taking these post-depositional processes into account, it is fair to assume that despite these post-burial alterations, the fundamental characteristics of the palaeosol are quite similar to those of the original soil, or at least the lower portion of the original A horizon.

Discussion and consideration of similar soils in relation to that on Lindisfarne

Although the buried soil from Lindisfarne would have developed under conditions in some ways different from those which characterise the modern dune system, some of the fundamental factors such as underlying topography, and source material, will have remained constant. In order to understand the nature of the Lindisfarne palaeosol, soils from the surrounding region, and from similar dune environments, are discussed below.

Soils in north Northumbria are formed mainly on greyish till derived from Palaeozoic mudstones, or on the reddish till which is derived from the Carboniferous beds in north Northumberland. The dune areas of Lindisfarne are part of the Sandwich association which includes the Formby series (Soil Survey of England and Wales 1983: 7).

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The soil survey of England and Wales notes that the Formby profiles are dominant on Lindisfarne (Jarvis 1984: 117). The Formby series can be considered as a useful comparison, as the Formby dune system (although on the north-west coast of Britain) is a well developed dune environment that has been investigated extensivly. A typical profile description is given as follows: 0-30cm - Ap, very dark greyish brown; 30-55cm - Bg, greyish brown, mottled, stoneless medium sand; single grain structure; 55-120cm - Cg, brown, mottled, stoneless medium sand, single grain structure. The Formby series are an element within the Blackwood association which "...is dominated by deep permeable sandy and coarse loamy soils in glaciofluvial drift' (Jarvis 1984: 116). The Soil Survey of England and Wales assess the land use of this soil series as being best for cereals,
potatoes and sugar beet with some areas providing short-term grassland and deciduous woodland (1983: 19).

The Formby series is of an 'inherently low fertility and is generally under permanent grassland': if any attempt at arable farming is made, they require careful management in terms of husbandry and manuring (Hall & Folland 1967: 47). An important characteristic of the Formby environment is a stable area in the lee of a dune ridge which is considered as representing a "biotic climax" and has been a managed pasture throughout living memory; 'The sward is dominated by sheep's fescue with common bent grass and sorrel (Rumex acetosa) becoming locally abundant' (Hall & Folland 1967: 48). Although too much emphasis should not be placed on the occurrence of one plant species, i.e. *Rumex acetosa*, it should be pointed out that this species is clearly dominant in the Lindisfarne samples, although the seeds identified from the buried soil are thought to be modern contaminants (see chapters 4 and 5).

As with the buried soil on the north shore of Lindisfarne, many of the soils in the Formby area have developed on till, and the soil characteristics detailed above are of course only a very general assessment and can in no way be taken as being entirely characteristic of the Lindisfarne soils, and especially not the buried ridge and furrow soil in the north of the island.

The other soil type which possesses similar characteristics to the soils on the main body of Lindisfarne is the Clifton series which is described as 'slowly permeable seasonally waterlogged reddish fine loamy over clayey, fine loamy and clayey soils associated with fine loamy over clayey soils with slowly permeable subsoils and slight seasonal waterlogging' (Soil Survey of England and Wales 1983: 16). In terms of land use this soil series is described as dairying grassland with the potential for crop growing in drier districts.

Other than the Lindisfarne study, there have been few purely pedologic studies of soils on coastal sand dunes. 'Dune soils are a rather neglected aspect of both pedological and dune research in the British Isles. Because of their limited agricultural value they are frequently regarded as an unimportant medium for the growth of plants and of little pedological interest' (Wilson 1992: 159).

The development of dune soils has been studied at a number of sites on the northern Irish coast; four stages of development, or profile characteristics, were observed over a range of sites, with only one site demonstrating all four stages of development.

Stage I is characterised by recently deposited or disturbed sand with no evidence for pedogenesis. Such soils lack vegetation cover and consist of just "C" horizon material (Wilson 1992: 155). Stage II sees the progression to pararendzinas as vegetation
colonisation and stabilisation take place ("A-C" horizon development). Such pararendzinas have developed at some of the northern Irish sites and other sites after about 15 years (Wilson 1992: 156). 'In England and Wales, sand-pararendzinas are the most extensive soils found on freely drained calcareous coastal dunes... In many cases they are thought to be over 100 years old and often considerably older (Jarvis 1984). Stage III is characterised by the procession of acidification and decalcification and the consequent development of a brown calcareous sand. The "A" horizon thickens and acidic conditions spread down through the profile with the upper boundary of the "C" horizon moving down the profile (Wilson 1992: 156). This progression to "Stage III" has never been achieved in the ridge and furrow area on the north shore of Lindisfarne. Stage IV is characterised by podzolisation. Obviously this does not occur in the ridge and furrow area on Lindisfarne, but it may do in time. The buried soil, and the narrow bands of pedogenesis above this, possess a pH of between 8 and 9. A pH level of 9 for the buried soil is quite common. This may be a product of the partial leaching of CaCO₃ and the clay till preventing its depletion down through the profile. In fact the assumption that calcium carbonate decreases down through a sandy profile is thrown into question by this and the results of an investigation of CaCO₃ depletion as an indicator of dune ages on Lindisfarne (Hand 1985). The ridge and furrow buried soil may have maintained or developed a high pH level due to CaCO₃ leaching losses being partly masked by continual inputs of shell from both land and marine mollusca. The subsequent leaching of calcium carbonate down through the blown-sand above the buried soil must have altered the chemical characteristics of that soil, as at Magilligan in Northern Ireland (Wilson & Bateman 1986).

Some workers have argued that the organic development of dune soils is very slow at first, organic content often remaining below 1% for c. 100 years; after this period organic accumulation seems to be appreciably faster (Wilson 1960; Ball & Williams 1974). It might be expected that soils which have developed for a long period of time would have high organic contents; this has been illustrated at a number of sites, notably at Southport where the organic content progressively increased with the age of the dune ridge, the organic content in the oldest dune area reaching a maximum of 25% (estimated by loss on ignition) (Salisbury 1925: 326-327). The Southport system was compared with that at Blakeney where there was an appreciably smaller amount of calcium in the sediments and organic content was lower. One might have expected that a soil developed directly on top of clay till, as is the case on Lindisfarne, which has to be the first soil established (assuming that the soil has never been eroded down to the till itself), would possess a relatively high organic content. However, this does not appear to be the case in this instance.
Other work on modern dune soil development has also shown that such soils can develop relatively high organic levels in young foredunes quite quickly. Part of the research at Magilligan Point in Northern Ireland showed that in the younger fore dunes and secondary dunes pedogenic development was limited; the soil is described as 10YR 6/3, 6/4, with an organic content of <0.7%, pH values of above 7.5 and CaCO3 of 10-20%. However, in the more stabilised foredunes organic matter ranged from 3.5 to 9.5%, with pH values from 7.0 to 7.5 %, and CaCO3 was c. 10% (Carter & Wilson 1990: 150)

At Newborough Warren on Anglesey, as on Lindisfarne, there is evidence for a stabilised land surface directly on top of glacial till; 'There seems little doubt that this buried sand was deposited well after the last glaciation, as the clay was evidently well vegetated before the sand was blown in', (Ranwell 1959: 573-4). Ranwell goes on to note that this buried soil represents a stabilised surface within a pre-existing dune system which was of a quality that permitted croft settlement and agriculture up to the sand blow of the fourteenth century.

An extensive analysis of dune soils was also carried out on the South Haven peninsula in Dorset; here, most of the samples were taken from the surface. Samples were taken from a series of ridges with an age range of approximately 0-50 yrs to 240-350 years (Wilson 1960: 350-1). In broad terms, the older the dune ridge, the higher the organic content, and the lower the pH. The mean organic content measurement for the youngest ridge was 0.21% (range 0.13-0.35%) while the pH levels ranged from 5.0 to 7. The mean organic content of the oldest ridge was 12.67% (range 2.64-31.71%), while the pH levels ranged from 3.6 to 4.5. The younger ridges were, as expected, dominated by a plant cover of *Agropyron junceiform* and *Ammophila arenaria*; there was a steady succession to the older areas which were dominated by *Calluna* (Wilson 1960: 352). This final succession stage is one which has never been attained in recent history in the Lindisfarne dunes. Although the pollen diagram indicates the existence of *Calluna* on the island, it must be recognised that much, if not, all of this pollen may have been transported from the mainland (see chapter 6).

An example of an archaeological investigation into a buried dune soil comes from Lodbjerg, on the west coast of Jutland. The field soil developed initially on till, but this was subsequently covered by a layer of blown sand during the later Neolithic. Extensive pedogenesis took place on top of this. Much of this soil was not covered again by blown sand until the Viking period (Liversage 1985: 56).

The soil under investigation was a dark grey sandy soil (Liversage *et al* 1985: 56). The soil developed from an "O" horizon into an Ap horizon. In some areas, where the "O" horizon remained undisturbed, subsequent periods of sand blow and stability are
preserved. One important period of stability is C\textsuperscript{14} dated to AD 995 and AD 695-770 (Liversage et al. 1985: 57).

One sample taken from the site had a loss on ignition determination of 24.10% (much higher than any of the other samples). The other 11 samples tested by loss on ignition yielded results of between 0.7% to 3.5%, very similar to the range found on Lindisfarne.

The authors of this report argue that the period of cultivation was substantial as the organic matter that would have been present in the "O" horizon had been destroyed and an homogeneous Ap horizon developed in its place.

The micromorphological analysis of this soil yielded the following information. The soil lacked structure, it was well-sorted with loosely packed sand grains, and slightly coated with dark polymorphic organic matter (Liversage et al. 1985: 76). Lower down the profile the polymorphic matter was replaced by monomorphic organic matter.

The Ap horizon of the cultivated profile contained the same coarse fraction as above and polymorphic organic matter was very uncommon. The fine fraction of this sample consisted of `... dusty, yellowish-brown silty clay areas, forming small aggregates between and around sand grains' (Liversage et al. 1985: 76).

After more than 30 years mean organic matter content had increased to >7%. This increase developed through the following stages: 12 years, 1%; 15 years >2%; 21 years >4%.

According to Cruickshank, many dune soils are characterised by very high sand contents with relatively low humic and clay contents. Such soils do however possess relatively strong colours in spite of this as the sand grains require relatively little humus or clay to cover their surfaces; thus the strong colours but low organic content (Cruickshank 1980: 23). As a result of the low levels of clay and humus the capacity of such soils to hold exchangeable cations is quite low. However, many of the studies cited above show that dune soils often develop high organic contents over relatively short periods of time, and there is little doubt that these soils would easily support pastoral, and perhaps even some forms of arable, agriculture.

**General conclusion**

The palaeosol is as important as any artefactual material, or architectural information gained from the Green Shiel site itself. The ridge and furrow area is as much a part of the Green Shiel site as the buildings themselves. For this reason its thorough investigation was essential. Despite the obvious post-burial processes that must have affected the
palaeosol, the analyses of the soil illustrated in this chapter have produced some useful conclusions.

The organic content and calcium carbonate analyses yielded basic and essential information about the palaeosol. As expected, organic content was higher towards the eastern end of the area examined, while calcium carbonate content was lower, thus illustrating the point that the impoverishment, and eventual burial of the soil started at the western end of the area (supporting the hypothesis that the dune systems encroached eastwards from the Snook, see chapter 4). The micromorphological study showed that despite having developed directly ontop of impermeable clay till, the palaeosol would have been relatively free-draining in its upper levels, although drainage at the bottom (the soil/till interface) may have been poor. Consequently, it is unlikely that this area would have been subject to the flooding that is quite common in many slack pasture areas.

Despite the fact that the assessment of organic content and the micromorphological investigations indicated that the palaeosol is quite impoverished in some respects, it is important to take post-burial processes into account. As noted in the discussion of the thin-sections, it is quite likely that the uppermost level of the A horizon was arroded away prior to burial. Therefore the organic content assessment may be too low. However, inspite of this it is clear from the assessments of organic content that the palaeosol was a viable medium, if not for crops, then certainly for pasture. The micromorphological study has shown that the soil was probably tilled using a mouldboard plough, however, we can not be sure of the date of this activity. Therefore it is impossible to show whether the area was being used for arable or pasture at the time when Green Shiel was occupied. However, the micromoromorphology does give us a very clear idea of the potential of this soil.

Finally, this chapter has shown that the palaeosol would have been important resource for the occupants of the Green Shiel settlement. Once again, it has been shown that this feature, as with the settlement as a whole, can not be understood without recourse to a series of analytical techniques. As well as orthodox chemical analyses, micromorphology was used to develop an understanding of what is a very important environmental and archaeological artefact.
CHAPTER 6

PALAEOECOLOGICAL STUDIES OF MATERIAL FROM THE PALAEOSOL

Introduction

This chapter details the analyses of various forms of ecological material from the ridge and furrow palaeosol. As mentioned in the previous chapter, the aim was not to produce definitive analyses of the various materials examined, but rather to test a wide range of techniques, and thus assess the potential of each technique in this very poor environment. All of the techniques employed are described whether or not they produced useful results.

The Analysis of Fungal Spores and Pollen from the Ridge and Furrow.

Introduction

Although the ecological information yielded by microfossil forms other than pollen, i.e. fungal spores, is often limited, investigations into such assemblages are still very useful. Much information can be yielded from comparisons of spore correlations with other ecological data, especially pollen (van Geel 1986: 497).

The relative lack of research into this area of palaeoecology means that there are no identification keys as such, and up until now (1992) workers in this field have been reliant on their own type-fossil assemblages, or the series of papers produced in Amsterdam by van Geel et al (1978, 1980a & b, 1981, 1982, 1983, 1984a & b and 1986). At the time of writing Gerraint Coles and Ciera Clarke are developing a comprehensive identification key (Coles pers comm.).

Methods

Fungal spores and pollen were extracted as a sub-sample from phytolith preparations; following the destruction of calcium carbonates with a 10% Hydrochloric acid mixture, the destruction of organic material by acetolysis and finally the separation of the microfossils with sodium-polytungstate with a specific gravity of 2.3.
Pollen and fungal-spore sub-samples were stained with aqueous safranin, moved into absolute ethyl alcohol via tertiary butyl alcohol and then finally had silicone oil added and then mounted.

As many spores as possible were identified in Leicester using the following sources (Van Geel 1978, Pals et al. 1980, van der Wiel 1982, Van Geel et al. 1981, and Van Geel et al. 1983). Not all of the Lindisfarne examples could be identified using these publications, so photographs of the unidentified examples were sent to Gerraint Coles in the Department of Archaeology at the University of Edinburgh. Full written details of Coles' assessment are not available, but discussions concerning the material have taken place and the results of this are included below.
Results of pollen analysis

The pollen analysis is based on the examination of four samples from the ridge and furrow buried soil, numbers 11, 12, 14 and 22 (see caption for table 6.2 for the exact provenance). Sample 22 contained some pollen but it was too degraded for identification. All of the samples examined contained low concentrations of pollen and non-pollen microfossils (fungal-spores discussed below, this chapter). Much of this pollen was both abraded and degraded. This is clearly indicative of movement within a sandy matrix and ingestion by micro-fauna.

Samples 11 and 14 both contained enough pollen to permit reasonable counts; sample 12 although included in table 6.2 only contained 4 land pollen grains. Samples 11 and 14 contain broadly the same spectrum of species, although Pinus comprises almost 9% of sample 11 and 5.5% of sample 14. Table 6.2 shows the species in order of frequency.

<table>
<thead>
<tr>
<th>Species</th>
<th>Sample 11 (%)</th>
<th>Sample 12 (%)</th>
<th>Sample 14 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lactuceae type</td>
<td>89</td>
<td>2</td>
<td>17</td>
</tr>
<tr>
<td>Cyperaceae</td>
<td>21</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Pinus</td>
<td>11</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Gramineae</td>
<td>1</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Coryloid</td>
<td>1</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Ulmus</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Alnus</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Anthemis type</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cirsium</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Chenopodiaceae</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ranunculaceae</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rubiaceae</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Caryophyllaceae</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>128</td>
<td>4</td>
<td>36</td>
</tr>
<tr>
<td><strong>Other spores</strong></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Filicailes undiff.</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>NPM type 1</td>
<td>150</td>
<td>3</td>
<td>28</td>
</tr>
<tr>
<td>NPM type 2</td>
<td>3</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>


The non-tree types present are all those that we might expect on waste ground or rough pasture with a basic soil. The pine element is problematical and may be due to long-distance travel; this is not surprising due to the very open nature of this area. Alternatively, this
component could represent post-reafforestation pine which may have become incorporated into the soil prior to burial, or after partial burial. It is also possible that some of this pollen may have been washed down from the post-burial land surface. This type of problem is quite typical of sand dune environments and characterises the extreme problems of investigating micro-, and even macro-, fossil assemblages from this type of sediment.

Conclusion

As should be expected, pollen does not survive very well in this environment. The combination of, a high pH, abrasion and the stresses put on pollen grains by continual wetting and evaporation, have all contributed to the impoverished status of this assemblage. However, what is surprising is the differences between sample 11 and the other samples in terms of the quantities present. The relatively large quantity in sample 11 may be the result of this sample point being located directly beneath a plant, or the sample point having slightly different microenvironment that gave rise to enhanced preservation. The former does seem the more likely. Despite this, it is apparent that pollen analysis in this type of environment is problematical and extended work on this material would not produce much useful data.

Results of the Fungal Spore Analysis

As the palaeoecological significance of many fungal spores is open to question, and the fact that many are not identifiable, due to the present state of knowledge, observations on the existence only (not percentages or absolute numbers) of identified spore types are used. The ecological information is based on the ecological preferences as indicated by van Geel (1986).

Type 55: occurs in eutrophic to mesotrophic conditions.

Type 140 Ascospore c. 38X22 μm.: occurs under eutrophic wet conditions.

Type 351.c occurs frequently during periods of human habitation.

As well as these, spores associated with animal dung have also been identified by Coles and Clarke (pers comm..). It should also be noted that the most common non-pollen microfossil (NPM type 1 in table 6.2) has not been successfully identified.

Conclusion
Despite the time and effort expended for the analysis of fungal spores, the results are undeniably disappointing. There does not seem to be the same problem of poor survivability as there is with pollen (see below, this section), but the problem lies with the current state of knowledge and the fact that the most common spore in the Lindisfarne samples can not be identified. Despite this, some limited inferences from the spores identified by referring to van Geel's publications, and by Ciera Clarke and Gerraint Coles, can be made. The palaeosol may have been waterlogged for certain periods, although this seems unlikely in the light of the soil characteristics and the local topography. The palaeosol possibly possessed a high nutrient status and the presence of cattle dung is indicated one spore type. However, evidence of this quality can not be used to either establish or confirm a hypothesis, but the fact that it does not contradict any other hypothesis developed during the environmental and archaeological investigations of the area is of some importance.

The Analysis of Phytoliths from Lindisfarne.

Introduction

The analysis of opal phytoliths for palaeoecological reconstruction is a relatively new and under-exploited technique, and for this reason a brief outline of the history of phytolith research, and what phytoliths are, follows.

It should be stressed that due to the relative novelty of the technique, little reference material is available, and relatively few British case studies exist. Therefore it should be recognised that this study is at least in part an exploration of the technique, and its potential.

History

Phytoliths were first recognised as microscopic floral fossils during the mid-nineteenth century. Early work into this type of material was pioneered by Christian Ehrenberg, a German doctor, whose book on the subject was published in 1854 (Powers 1992: 16-18).

The initial phase of ecological research into phytoliths took place during the period from 1955 to c. 1975, while the modern period of archaeological phytolith research is considered to have begun in about 1971 (Piperno 1988: 2).

In the British context, the early development of the phytolith studies is typified in two papers by F. Smithson: 'Grass opal in British soils' (1958) and 'Opal sponge spicules in soils' (1959). In these papers Smithson sampled a number of grassland soils and extracted
the phytoliths therein; sponge spicules were also considered as part of this early work. These silica bodies are derived from freshwater and marine sponges and are often found in soils. Research into sponge spicules is not extensive, and they are not considered in this work.

Smithson's early research (1958) into phytolith assemblages included the analysis of samples from three different localities: rough enclosed cattle and sheep pasture c. 90m above sea level; rough open pasture c. 920m above sea level; and finally rough enclosed pasture for ponies at about 107m above sea level. This research did not really attempt to consider the differences between phytolith assemblages from different sites in any rigorous fashion, but it did show that large numbers of distinct morphotypes were present in a range of soil types.

In 1971 Rovner published on the potential of phytoliths for palaeoecological reconstruction and a method which might be used to extract phytoliths from sediments. This method and the variations used by myself are detailed below.

Despite the explicit acceptance of the widely held notions of redundancy and multiplicity within plant phytolith research, some workers have argued that these concepts have been too readily accepted, and argue that phytolith morphology is in fact often idiosyncratic to plant family and even species. Rovner and Russ (1992), for example, argue that employing image analysis allows the identification of distinctive morphotypes amongst phytoliths which had previously been regarded as too similar to allow any differentiation. It would seem therefore that the future of phytolith studies as a powerful palaeoecological tool is ensured, but there is little doubt that more basic research and the development of reference collections are necessary.

The Occurrence of Phytoliths

Opal phytoliths are produced in many plants which take up monosilicic acid Si(OH)4. These silica bodies serve to give plants rigidity and strength; their quantities vary from species to species, and even within species as the chemical characteristics of the soil influences phytolith production. It has been argued that this process will only occur in soils with pH levels between 2 and 9 (Piperno 1988: 13). This is not surprising as the majority of plants will not grow outside of this range. It is also assumed by some workers that opal phytoliths are either damaged or destroyed by dissolution in sediments with a pH approaching 9 or above. However, some case studies have shown that this is not necessarily the case (Powers & Gilbertson 1987: 529-30). In their study of phytoliths from calcareous shell sands from the Hebrides and other western coasts, pH values ranged between 7.5 and 9.8.
The occurrence of phytoliths in plants is not uniform; some plants produce large quantities of silica while others produce little or no phytolith material. Another important point is that almost any part of a plant can produce phytolith material including roots, rhizomes, leaves, stems and seeds.

**The Identification and Interpretation of Phytoliths**

The first point that should be made is that the majority of phytoliths are not identifiable to species, or in many cases, family. Unlike pollen, there is usually no direct relationship between morphology and species or family, and numbers of different species may produce morphologically similar phytoliths. Also, a single plant species produces more than one phytolith shape; some plants produce four or five different phytolith shapes each. However, it is true that families and subfamilies do produce phytolith shapes which are unique, and as Piperno asserts, there is little reason to assume that this state of affairs has changed during the recent evolution of plants (Piperno 1988: 39). Consequently, phytolith analysis does allow us to infer the nature of general vegetation patterns in the past, usually at a family or sub-family level.

There are two approaches to phytolith classification: one is taxonomic classification where the researcher assumes a direct relationship between phytolith morphology and plant family or species; the second is the non-taxonomic approach where there is no assumption that directly relates morphology to species. With the non-taxonomic approach it is the characteristics or structure of the phytolith assemblage which is important: the numbers and proportions of different morphotypes within a sample. In graphical terms, the "signature" of an assemblage is more important than the individual phytolith types which constitute that assemblage. This is especially the case as ecologically dissimilar plants can produce morphologically similar phytoliths. In Britain, more so than in the United States where phytolith studies are well established, the lack of reference collections from different types of environments means that the palaeoecological information yielded by this microfossil comes largely from the comparison of archaeological assemblages with modern day assemblages from similar environments. In the United States it is more common to be able to identify the phytolith assemblage to a set of families, or sometimes even a set of species. Relatively little comparable work has been carried out in Britain. In recent years the subject has undergone a certain revival largely due to the research of Powers *et al* (1987, 1989). Prior to this, British phytolith work was largely represented by the studies undertaken by Smithson (1958) and then Parry and Smithson (1964 & 66). In Britain, it is the differences and similarities between phytolith suites which has been highlighted, and any work carried out in this field is an important contribution to a body of knowledge in a nascent technique.
Powers has devised a greatly simplified identification key which has grouped together morphologically similar phytoliths under new morphotypes (See figure 6.6) (Powers, Padmore & Gilberston 1989). The key is largely based on previous more complex keys (Parry & Smithson, 1964, 1966; Pearsall 1989). The more refined modern keys are quick and relatively simple to use. The non-taxonomic keys divide morphotypes into groups which are diagnostic of tribes or sub-tribes of grasses, such as the Chloridoid and Festucoid tribes. As detailed above, this means that the identification of a single morphotype is not necessarily indicative of a certain family, let alone species.

Figure 6.6: Phytolith identification key (after Powers et al., 1989).

One might assume as a result of these provisos that the analysis of phytolith assemblages is a labour intensive and relatively unrewarding technique in terms of the quantity and quality of palaeoecological information returned. However, there are a number of important advantages that phytoliths have over pollen: first, phytoliths often survive in environments where pollen does not; and secondly, the greater part of any phytolith assemblage is a relatively autochthonous deposit, and despite the contention above that pollen is a more rigorous method for the identification of types, families and sometimes species, this is not always true. Grass pollen, for example, is usually unidentifiable below family level, whereas certain phytoliths are morphologically diverse to the extent that more refined
Identification is possible. This would seem to be the case with the sedge family for example (Mulholland & Rapp 1992: 3; Ollendorf 1992).

Methods

Extraction from soils and sediments

The method detailed by Rovner (1971), and followed by many other practitioners, requires the dissolution of any carbonates in the sediment, and destruction of any organic content, through an acetylation (wet oxidation) process. The next stage, the separation of the phytoliths from the rest of the sediment, involves the use of a heavy liquid, such as tetrabromomethane or nitro-benzene-bromoform. Such liquids are potentially quite dangerous, and for this reason this study employed sodium polytungstate. Once the phytoliths (and spores and pollen) had been separated from the rest of the sediment it was decanted into new test-tubes and washed five or six times with distilled water to ensure that all of the sodium polytungstate had been removed. Once this part of the process had been completed the decanted material was washed in tertiary butyl alcohol before finally being placed in absolute ethyl alcohol.

Extraction from animal faeces

Modern comparative material retrieved from sheep and rabbit faeces was extracted using a different technique to that detailed above. This technique is based on that developed by Powers and Gilbertson (1987). For animal faeces the technique demands that a small amount of material (c. 5 gm) in a crucible is placed in a muffle furnace for 8 hours at c. 650 °C where all organic material is burnt off leaving a residue which should be rich in phytoliths.

Slide preparation

After the separated residues from the soil samples had been placed in ethyl alcohol a small quantity of this liquid was extracted using a pipette and then mounted onto a slide using three drops of styrolite, a mounting medium that requires no heating. A cover slip was placed over this and the slide left to dry for about one week.
The same slide preparation technique was employed for both the sediment and the ashed samples.

The problems with these methods are discussed below.

**Methodological observations**

Much time was spent experimenting with variations of the methods outlined above. The variation of the Rovner (1971) method was the most useful for retrieving material from sedimentary contexts. The Powers and Gilbertson (1987) method was experimented with when attempting to extract phytoliths from the sedimentary contexts as well as those from the faecal samples. In both instances the burning off of any organic material present by covering it with methanol and igniting proved unsuccessful. First, the organic material present was never entirely removed, despite multiple ignitions, and second, despite the contention of the method's architects, tapping the crucible containing the residue after burning onto a slide never yielded enough phytolith material that could be readily observed. This was quite likely a function of the dearth of the material in the archaeological sediments in the first place. However, this method also proved unsuccessful for the extraction of phytoliths from the faecal samples. With these samples the organic content of the faeces was never destroyed and it was therefore decided to ash these samples in a muffle furnace.

**Counting**

As the occurrence of phytoliths in all of the archaeological samples was so low, the idea of a minimum count (200 is used by many practitioners) was redundant from the outset as this was never attained on a single slide with an archaeological sediment. Each slide was scanned at .5mm transects from top to bottom, and the various morphotypes recorded on a counting sheet based on the Powers key (see figure 6.6). For most of the archaeological samples, two slides were viewed.

**Results**

The results of the analysis of phytolith assemblages are not considered in the same way as other types of ecofactual data: i.e. there is no discussion of the ecological preferences of individual species, but rather discussions of the characteristics of the suites of phytoliths within each sample, considering the dominant and "unusual" morphotypes as well as the differences between each of the archaeological assemblages and modern example
assemblages. The results are displayed in three graphical formats (figure 6.8): the first is a breakdown of the frequency of each morphotype in each sample assemblage; the second is a percentage breakdown of the same. Chi-square tests were also carried out on the samples, and these will be explained in detail below.

Quantities by sample

The actual morphotype frequencies for each sample were not obtained, as a tracer pill with a known quantity of "exotic" pollen was not used. A spike such as this could have been used to calculate absolute counts of phytoliths per unit volume of sediment. However, the actual numbers counted are tallied in table 6.3a. Although these totals are not actual frequencies per unit mass of sediment, they do give some indication of the relative quantities present in each sample, the most obvious characteristic being the low counts in the archaeological samples, while the modern faeces samples yielded much higher quantities of phytolith material, as one would expect.
<table>
<thead>
<tr>
<th>Sample number</th>
<th>Provenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample 1</td>
<td>Ridge and Furrow Palaeosol, 1990 Trench.</td>
</tr>
<tr>
<td>Sample 2</td>
<td>Ridge and Furrow Palaeosol, 1991 Trench.</td>
</tr>
<tr>
<td>Sample 3</td>
<td>Ridge and Furrow Palaeosol, Sample point 12</td>
</tr>
<tr>
<td>Sample 4</td>
<td>Ridge and Furrow Palaeosol, Modern Top-Soil</td>
</tr>
<tr>
<td>Sample 5</td>
<td>Ridge and Furrow Palaeosol, 1990 Trench.</td>
</tr>
<tr>
<td>Sample 6</td>
<td>Ridge and Furrow 'Top Band', 1990 Trench</td>
</tr>
<tr>
<td>Sample 7</td>
<td>Rabbit Faeces: Ridge and Furrow Sample</td>
</tr>
<tr>
<td>Sample 8</td>
<td>Rabbit Faeces: Slack Sample</td>
</tr>
<tr>
<td>Sample 9</td>
<td>Sheep Faeces; Island Pasture</td>
</tr>
</tbody>
</table>

Table 6.3: Sample numbers and their provenance.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smooth Rods</td>
<td>72</td>
<td>44</td>
<td>89</td>
<td>252</td>
<td>19</td>
<td>54</td>
<td>105</td>
<td>92</td>
<td>168</td>
<td>895</td>
</tr>
<tr>
<td>Fine Wavy</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Coarse Wavy</td>
<td>29</td>
<td>9</td>
<td>10</td>
<td>46</td>
<td>9</td>
<td>12</td>
<td>18</td>
<td>13</td>
<td>11</td>
<td>157</td>
</tr>
<tr>
<td>Fine Spiny</td>
<td>2</td>
<td>7</td>
<td>3</td>
<td>6</td>
<td>0</td>
<td>3</td>
<td>15</td>
<td>8</td>
<td>28</td>
<td>72</td>
</tr>
<tr>
<td>Coarse Spiny</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>74</td>
<td>78</td>
</tr>
<tr>
<td>Sinuous Rod</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>39</td>
<td>39</td>
</tr>
<tr>
<td>Trapezoids</td>
<td>10</td>
<td>9</td>
<td>22</td>
<td>54</td>
<td>12</td>
<td>25</td>
<td>134</td>
<td>46</td>
<td>140</td>
<td>452</td>
</tr>
<tr>
<td>Trichomes</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>183</td>
<td>53</td>
<td>21</td>
<td>258</td>
<td></td>
</tr>
<tr>
<td>Short Smooth</td>
<td>28</td>
<td>19</td>
<td>25</td>
<td>16</td>
<td>10</td>
<td>8</td>
<td>10</td>
<td>5</td>
<td>0</td>
<td>121</td>
</tr>
<tr>
<td>Long Smooth</td>
<td>1</td>
<td>0</td>
<td>6</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>1</td>
<td>27</td>
</tr>
<tr>
<td>Totals</td>
<td>141</td>
<td>90</td>
<td>150</td>
<td>375</td>
<td>51</td>
<td>103</td>
<td>466</td>
<td>217</td>
<td>482</td>
<td>2075</td>
</tr>
<tr>
<td>Diatoms</td>
<td>5</td>
<td>5</td>
<td>28</td>
<td>35</td>
<td>80</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td></td>
<td>203</td>
</tr>
<tr>
<td>Diatoms/phytoliths</td>
<td>0.035</td>
<td>0.456</td>
<td>0.033</td>
<td>0.075</td>
<td>0.686</td>
<td>0.777</td>
<td>0.009</td>
<td>0.005</td>
<td>0.008</td>
<td>0.098</td>
</tr>
</tbody>
</table>

Table 6.3a: Quantities of each phytolith morphotype by sample.

The chi-square tests are designed to discover how similar or dissimilar the phytolith assemblages from each sample are (see table 6.3 for each sample's provenance). A low chi-square value shows that the samples in question have similar distributions, i.e. the relative proportions of morphotypes within one sample have a similar distribution to those in the other samples in the contingency table for that test. In the majority of the tests any categories which contained values of 2 or less in 50% or more of the samples being tested
were excluded from the test. Also, "0" values in categories which were necessary for the test were replaced with "1s".

Rather than list the results of each test in the main text, a summary table (table 6.4) is followed by comments and interpretation. The chi-square tests are considered and related to the sample graphs (figure 6.8) when necessary. In the final section of the results the breakdown of morphotype quantities by sample is considered. Full interpretation and discussion follow in a separate section.

**Chi-square and graphical results**

(see appendix 4a for full results)

The null hypothesis for the chi-square test is as follows:

Hₐ there is no difference between the samples.

H₁ there is a difference between the samples.

The chosen significance level is 0.01.

The chi-square tests were carried out in a sequence which initially tested samples that were assumed to be similar to one another (e.g. the samples from the palaeosol): and then moved on to test these against samples with different provenances; (e.g. those from the top soil, and the animal faeces). The aim of this system of testing is to test whether or not there is any consistency within the ancient assemblages, and then discover if there is any statistical similarity between these and the other samples.
Table 6.4: Simplified breakdown of chi-square test results (full results in appendix 4a.)

<table>
<thead>
<tr>
<th>Test No</th>
<th>Description of Test</th>
<th>Samples Tested</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Trench 1 Palaeosol samples</td>
<td>s1/s5</td>
<td>H0</td>
</tr>
<tr>
<td>2</td>
<td>Trench 1 Palaeosol samples against trench 2 sample</td>
<td>s1+s5/s2</td>
<td>H0</td>
</tr>
<tr>
<td>3</td>
<td>Trench 1 Palaeosol samples and trench 2 sample against sample point 12.</td>
<td>s1+s5/s2/s3</td>
<td>H0</td>
</tr>
<tr>
<td>4</td>
<td>Trench 1 palaeosol samples and Sample point 12 against ridge &amp; furrow &quot;Top Band&quot;.</td>
<td>s1+s5+s3/s6</td>
<td>H0</td>
</tr>
<tr>
<td>5</td>
<td>All palaeosol samples against the modern Top Soil sample.</td>
<td>s1+s5+s2+s3/s4</td>
<td>H1</td>
</tr>
<tr>
<td>6</td>
<td>The two rabbit faeces samples against one another</td>
<td>s7/s8</td>
<td>H1</td>
</tr>
<tr>
<td>7</td>
<td>All palaeosol samples against the &quot;Top Band&quot; sample and the top soil against the two rabbit faeces samples.</td>
<td>s1+s2+s3+s5/s4/s6/s7+s8</td>
<td>H1</td>
</tr>
<tr>
<td>8</td>
<td>As above, but also against the sheep faeces sample.</td>
<td>s1+s2+s3+s5/s6/s7+s8/s9</td>
<td>H1</td>
</tr>
</tbody>
</table>

Discussion of test results

Test 1:

As expected, these samples (both from trench 1) do possess similar distributions, although there is some difference between them; sample 1 possesses fine spiny rods while sample 5 has coarse spiny rods.

Test 2:

This test indicates that all of the samples from the palaeosol from the central ridge and furrow area possess similar distributions. However, there are some small differences which can be seen on the graphs for these samples (figure 6.8).

Test 3:

This test shows that all of these palaeosol samples have broadly similar distributions of morphotypes, but that similarity is not very strong. In fact sample 3 from the easternmost end of the ridge and furrow contains one coarse spiny rod (not included in the chi-square test as
such low values are not permitted in the test), a morphotype that does not occur in any of the other palaeosol samples. This sample also differed from the others in that it possesses the greatest proportion of smooth rods and the lowest proportion of coarse wavy rods.

Test 4:
This test showed that the distribution of morphotypes from the eastern most sample point (sample 3) was very similar to the sample from the "top band", the thickest dark band within the blown sand above the palaeosol, which must represent a brief period of pedogenesis.

Test 5
This test showed a large dissimilarity between the distributions within all of the palaeosol assemblages when compared with the distribution in the sample from the modern top soil (sample 4).

Test 6:
Despite the two samples being derived from similar sources, i.e. rabbit faeces, there is some difference between the two morphotype distributions. Sample 7 from the ridge and furrow area has a lower proportion of smooth rods than sample 8, from the dune slack to the west of the ridge and furrow, whilst sample 8 has lower proportions of trapezoids and trichomes.

Test 7
This test shows conclusively that the samples from the band of pedogenesis, the modern top soil and the samples from the rabbit faeces, have highly dissimilar distributions. This is most obvious when the graphs are examined. The rabbit sample distributions are largely constituted by relatively large numbers of trapezoids and trichomes, a morphotype which is almost non-existent in the palaeosol samples. Other than this the rabbit sample distributions are not too dissimilar from the palaeosol samples. These characteristics will be considered further in the discussion below.

Test 8:
This test of all of the samples, including the sheep faeces sample from island pasture, is clearly the most different. This sample contained relatively large numbers of coarse spiny rods and sinuous rods, morphotypes which were either almost or entirely absent from every other sample.
Other Observations

As can be seen in table 6.3, the number of diatoms present was also recorded (these were in such poor state of preservation they were not identifiable to species). One interesting observation is that regarding the different diatom to phytolith ratios for each sample. The most obvious characteristic is that the faeces samples contain negligible numbers of diatoms, while the highest diatom to phytolith ratios are found in samples 6, 5, and 2, 5 & 2 being from the main buried soil and sample 6 from the "top band" of later pedogenesis.
The modern top soil sample (No. 4) had one of the lowest ratios. It is possible that diatoms found their way into the buried soil as aeolian deposits, the source of which was the sea or the beach. The lack of a sand dune barrier therefore meant that there was nothing to prevent this transport occurring with relative ease, whereas the opposite is true of more recent times.

Finally, it does seem possible that we might be able to identify phytolith assemblages that are in some sense unique to different animals. However, far more work needs to be carried out here, with larger numbers of samples being examined, and multivariate statistical analyses of these carried out. Such research might be useful in answering taphonomic questions; the phytolith suites from faecal material might be indicative of disturbance by certain mamals.

**Discussion**

The morphotype distributions of the samples retrieved from different spatial locations across the ridge and furrow palaeosol share similar graphical "signatures" (figure 6.7) and are statistically similar. It can therefore be inferred that this represents evidence for broadly similar vegetation cover across the ridge and furrow as a whole. As detailed above, one can not infer species composition from this data, but what it does show is that this area was at some stage definitely grassland of some description, thus supporting the contention inferred from other ecological data that the ridge and furrow was in fact rough pasture. Other phytolith work carried out in coastal dunes and grazed machair in the north west of Britain shows that assemblages from unvegetated blown sands tend to be dominated by smooth rods, and irregular and amorphous morphotypes. More diverse assemblages tend to be retrieved from samples taken from grazed and ungrazed vegetated machair (Powers et al. 1989: 36-7). Such assemblages contain smooth rods and the more amorphous morphotypes, but they also contain numbers of trapezoids. Spiny and wavy rods in Powers' case study only emerged as a common element in the modern samples of cattle and sheep faeces examined. This was not necessarily the case with the Lindisfarne samples. In this study spiny and wavy rods appeared in nearly all samples, with sample 1 from the palaeosol having the second largest number of coarse wavy rods out of all samples examined. However, coarse spiny rods were almost confined to the sheep faeces sample, as were sinuous rods.

The modern assemblages are apparently significantly dissimilar to the archaeological ones to the extent where one might argue that they are indicative of different types of grassland. This may in fact be the case, but while it is obviously possible to show what kind of grassland the faecal samples are derived from, this is not the case with those from the
palaeosol. In fact it may not be correct to assume that the samples do represent two very different grassland ecologies. The first reason is related to the fact that phytolith morphology is not related directly to plant species and that in addition to this we must consider a very complex taphonomic problem. First, the ways in which post-depositional processes affect phytolith assemblages, as it is possible that certain silica bodies are completely or partially dissolved at high pH levels. Secondly, different animals may eat different parts of different plants and consequently affect the distribution of phytoliths in the archaeological record, and more obviously, their faeces which are examined as modern comparative material may contain phytolith assemblages which are skewed in terms of the morphotypes contained therein. This last point is crucial when considering the differences between the rabbit faecal samples and those from the sheep. The graphs for these samples show that trichomes are an important element in both rabbit samples, whilst they are a relatively minor element in the sheep sample. Coarse spiny rods are an important proportion of the sheep samples, but almost non-existent in the rabbit samples. One might infer from these disparities that the two types of grassland from which the samples were taken are very different, but this is not necessarily the case, although there is little doubt that the dune area is not as ecologically rich as the island sheep pasture exploited today. In the light of this it is clear that future research must consider the processes behind these differences which exist in phytolith assemblages whose environmental origins are not necessarily that different. There should be little doubt that phytolith assemblages often possess 'signatures', i.e. reoccurring distributions, which are specific to different animals. Such signatures may be identifiable in archaeological contexts and thus provide a new source of data which can confirm or question interpretations of other floral and faunal data.
Bulk Sieving and Paraffin Flotation for Molluscs and Seeds

Introduction

The bulk-sieving and flotation of the buried soil from the ridge and furrow were undertaken in order to retrieve both molluscs and seeds as well as any other macrofossils which could give an insight into the palaeoecology of the ridge and furrow area.

While it was realised that any seeds recovered from the palaeosol might turn out to be intrusive, it was decided that the recovery of this material should be pursued just in case anything important was missed.

The molluscan analysis includes material retrieved from the Green Shiel settlement. The samples from the settlement had been extracted and identified by other workers, notably Pete Boyer. In the light of this extensive programme it was decided that further sieving and identification of material would be too time-consuming, and would probably not yield much new information. Therefore the data from the contexts identified as occupation levels in building "C" was compared with the material retrieved from the buried soil.

As with the previous studies considered so far in this chapter, three different locations across the ridge and furrow were sampled (see figure 6.1) and the 1991 trench was split in two: the ridge, and the furrow, therefore, in effect there were four different sampling locations.

Parallel programs of wet sieving and paraffin flotation were adopted in order to assess any variation in yield of seeds especially from the two different methods.

Methods

Bulk wet-sieving.

Initially samples were air-dried on large plastic trays; once dry, quantities of about 1 Kg were weighed and placed in a bucket. A nest of sieves comprising the following mesh sizes was used: 4750 μm, 2000 μm, 1000 μm, 500 μm, 355 μm and 250 μm. Initially the material which floated was passed through the nest of sieves. Once material had ceased floating the residue from each sieve was placed in a sealable plastic bag. The remaining sediment in the bucket was then passed through the nest of sieves, but with two smallest mesh sizes removed (355 μm and 250 μm) as the particle size distribution of the sediment would have resulted in a large proportion of the sand element being trapped in the smaller
sieves, thus greatly reducing the efficiency of the method. Again, the residue from each sieve was stored in sealable plastic bags for subsequent sorting. Any large molluscs spotted during sieving were placed into plastic sample tubes.

Once the sieving of the samples had been completed, the material from each sieve was sorted under a binocular microscope at 10X magnification. The material retrieved was then divided into groups, i.e. molluscs, seeds and miscellaneous, and then placed in test-tubes ready for identification.

Paraffin flotation

Damp samples of c. 1.5 Kg were weighed and placed in a bucket. The sample was then covered with paraffin and mixed to ensure that all of the material was well covered. Excess paraffin was then decanted for subsequent reclamation. The paraffin-impregnated sample was then covered with water and left to stand for about one half-hour. After this period of time a constant flow of water was passed through the material in the bucket whilst the sediment therein was agitated by hand. The floating residue was then passed through two sieves (355 \textmu m and 250 \textmu m). Once no further material appeared to be floating, the residue trapped in the two sieves was washed in tepol and luke-warm water in order to remove the paraffin. Once the paraffin had been removed, the residue was soaked with alcohol and decanted into plastic bottles for storage.

The sediment remaining in the bucket was again covered with water and left to stand and the flotation process repeated. This part of the method was repeated three times in total for the first sample. When it was realised that the second and third flotations yielded very little, or no extra material, it was decided that repeat flotations would not be used on subsequent samples.

Once the flotations were considered to be complete, the sediment remaining in the bucket was washed through a 1 mm and a 500 \textmu m sieve.

The retrieved material was then sorted under a binocular microscope and divided into seeds and molluscs and miscellaneous material as before.
Results

As expected, in the light of the results of spore, pollen and phytolith analyses, the material retrieved from sieving and flotation was quite limited both in terms of seeds and mollusca. The results and discussion sections below are divided into two: the seeds and the molluscs.

The Seeds

For a full numerical breakdown see table 6.5, and the graphical presentation, see figure 6.8.

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Provenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample 1</td>
<td>Ridge &amp; Furrow palaeosol, Trench 1</td>
</tr>
<tr>
<td>Sample 2</td>
<td>Ridge &amp; Furrow Palaeosol, Trench 2; ridge</td>
</tr>
<tr>
<td>Sample 3</td>
<td>Ridge &amp; Furrow Palaeosol, Trench 2; furrow</td>
</tr>
<tr>
<td>Sample 4</td>
<td>Ridge &amp; Furrow Palaeosol, Pit &quot;C&quot;</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Species</th>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Sample 3</th>
<th>Sample 4</th>
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</thead>
<tbody>
<tr>
<td>Rumex acetosa</td>
<td>99</td>
<td>164</td>
<td>13</td>
<td>6</td>
</tr>
<tr>
<td>Carex arenaria</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>21</td>
</tr>
<tr>
<td>Potentilla sp.</td>
<td>9</td>
<td>5</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Viola sp.</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>Cirsium vulgare</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Reseda luteola</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Selaginella selinoides</td>
<td>7</td>
<td>7</td>
<td>0</td>
<td>70</td>
</tr>
</tbody>
</table>

| Total                 | 120      | 184      | 14       | 106      |
| Sample weight Kg      | 8.28     | 48.95    | 10.32    | 2.55     |
| Seeds per unit mass   | 14.50    | 3.76     | 1.36     | 41.57    |

<table>
<thead>
<tr>
<th>Species</th>
<th>Sample 1 %</th>
<th>Sample 2 %</th>
<th>Sample 3 %</th>
<th>Sample 4 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rumex acetosa</td>
<td>82.50%</td>
<td>89.13%</td>
<td>92.86%</td>
<td>5.66%</td>
</tr>
<tr>
<td>Carex arenaria</td>
<td>0.83%</td>
<td>1.63%</td>
<td>0.00%</td>
<td>19.81%</td>
</tr>
<tr>
<td>Potentilla sp.</td>
<td>7.50%</td>
<td>2.72%</td>
<td>7.14%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Viola sp.</td>
<td>3.33%</td>
<td>0.54%</td>
<td>0.00%</td>
<td>7.55%</td>
</tr>
<tr>
<td>Cirsium vulgare</td>
<td>0.00%</td>
<td>1.09%</td>
<td>0.00%</td>
<td>0.94%</td>
</tr>
<tr>
<td>Reseda luteola</td>
<td>0.00%</td>
<td>1.09%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Selaginella selinoides</td>
<td>5.83%</td>
<td>3.80%</td>
<td>0.00%</td>
<td>66.04%</td>
</tr>
</tbody>
</table>

Table 6.5: Numbers and percentages of seeds retrieved from buried soil. Sample provenance given above.
The seed assemblage was dominated by *Rumex acetosa* (Common sorrel). From the total amount sieved 70.1 Kg, 282 *Rumex* seeds were counted. A number of other species were identified as well, but these occurred in relatively small numbers.

The first were seeds from the *Viola* family. These seeds proved difficult to identify down to species but are probably from *Viola tricolor* (Wild pansy). A number of seeds from *Carex arenaria* (Sand sedge) were also present. *Potentilla* was also represented in the sample; as with *Viola*, it proved impossible to identify down to species level, although the seeds were most probably from *Potentilla anglica* (Trailing tormentil) with a possibility of *Potentilla erecta* (Tormentil). A total of three seeds of *Cirsium vulgare* (Spear thistle) were also retrieved from the buried soil, whilst two seeds from *Reseda luteola* (Wild mignonette) were identified. Finally, a relatively large number of spores, 84 in total, from the clubmoss, *Selaginella selaginoides* (Lesser clubmoss) were counted.

One other seed from the *Juncus* family was retrieved, but as this seed germinated once it had been retrieved and placed in a water-filled test-tube, it has not been included in the final counts, nor in the ecological discussion below. It might be assumed that because this seed was clearly viable it was in fact modern and therefore "contaminating" the deposit. This is partially supported by the fact that this seed type only appeared once. However, there is much evidence to suggest that certain seeds can survive buried for many centuries. For
example Odum showed that seeds of *Spergula arvensis* (Corn spurrey) can remain viable for up to 1700 years (1965: 65). It is possible that the entire assemblage is a contaminating deposit: this is considered in the conclusion to this section.

**Discussion**

The discussion will initially detail the individual ecologies of each of the species identified and then go on to consider the broader ecological implications for the buried soil. Even though the seed assemblage is dominated by *Rumex* (Sorrel), which accounted c.90% in the 1991 trenches (samples 2 and 3), the ecologies of the other plants will be discussed just as extensively.

The most common species of plant found in the assemblage was *Rumex acetosa* (Common sorrel), a perennial plant which is very common in the British Isles. This species can be expected as a component in basic or neutral grassland, often inhabiting marine shingle locations (Lousley & Kent 1981: 110). Blamey and Grey-Wilson also state that it is a typical meadow plant (1989: 68). This plant is sometimes as an indicator of old grassland (Fitter 1987: 31).

The next most common species is *Carex arenaria* (Sand sedge), a sedge which one would often expect in dune areas or other sandy environments. Specifically this plant tends to inhabit the transition area between sand dunes and dune slack.

*Potentilla anglica* (*erecta c.f.*) (Trailing tormentil/Tormentil) is a low creeping perennial which one would expect to find in many grassland areas, often on field boundaries at low altitudes (Blamey & Grey-Wilson 1989: 188). Usually this species prefers moist to dry soil of an intermediate pH, but tending to avoid extremely calcareous soils. *Potentilla erecta* (Tormentil) especially is found on cultivated land.

*Viola tricolor* (Wild pansy) is an annual or short-lived perennial plant usually found in rough grassland, disturbed areas and on cultivated land. More pertinent to this investigation, one would also expect to find it in dune areas and dry rough grassland close to the sea, especially on shores of the North Sea (Blamey & Grey-Wilson 1989: 252).

*Cirsium vulgare* (Spear thistle) is another common species which one would expect to find on disturbed land, grassland and in cultivated fields. It prefers fertile base-rich soils that are moist to dry.

The final species of plant identified from seeds was that of *Reseda luteola* (Wild mignonette). This plant also inhabits disturbed calcareous soils and is often found in sandy areas and around field margins.
As detailed in the results above, a large number spores from *Selaginella selaginoides* (Lesser clubmoss) were identified. This plant tends to prefer damp habitats in grassland and dune areas. Specifically, this species is found in very calcareous dune slack areas in moist hollows where there is not too much tall vegetation; this plant also grows within the most stabilised dune areas, including sand dune pasture (Page 1988: 120-123).

**General Discussion**

The ecological characteristics of the area implied by the seed evidence is unsurprising, although the possibility that the seeds examined do not relate to the early medieval palaeoecology is a serious possibility (see below). Soil moisture seems to have varied from damp to moist or even perhaps dry in some of the more freely-draining areas in the northern parts of the ridge and furrow adjacent to the shoreline (see discussion of geomorphology and stratigraphy, chapter 3). The majority of the species considered prefer a neutral to basic soil and flourish in areas with little or no shade.

Together, the species of plant investigated are indicative of rough, possibly unmanaged pasture. The most common species in the assemblage, *Rumex acetosa*, implies that much of the ridge and furrow area could have been a nutrient-rich pasture (Hanf 1983: 403). Areas closer to the shoreline and sand supply could have been less rich and occupied by *Carex* and *Viola*.

There is some evidence for spatial variation over the ridge and furrow area as a whole; an interesting feature is the *Carex* element of the samples from the main trenches and the pit in the northern area of the ridge and furrow closest to the shoreline (sample 4). Whereas the trench assemblages are dominated by *Rumex acetosa*, 82.5% in the 1990 trench and 89.4% in the 1991 trench, the *Rumex* sample from pit "C" (sample 4) was only 5.7% of the total assemblage, whilst *Selaginella selaginoides* and *Carex arenaria* respectively dominated this assemblage. Also, the highest proportion within a sample of *Viola tricolor* was also retrieved from this sample.

This variation supports what one would expect to find, in that the area of the ridge and furrow closest to the shore is dominated by a sand-loving species. However, the very high proportion of *Selaginella* in this area is slightly confusing in that this moss tends to occupy damp or wet soils, a characteristic which would have been less likely in this northern part of the ridge and furrow as the palaeosol lies on top of blown sand rather than the clay till as elsewhere. Therefore this soil should have been freely draining, very low slack. But, *Selaginella* also occupies shifting unstable sediments and may therefore have been more successful on the less stabilised sediments closer to the shoreline. This ecological variation is supported by the molluscan evidence below.

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The Accelerator date

Once all of the seeds had been identified and quantified, a large number of seeds were sent as a single sample for accelerator dating at Oxford. The date estimated with the accelerator showed that the seeds post-date AD 1950 (OxA-3912). In hindsight this date is not surprising as the seeds are probably intrusive. Rumex seeds are relatively small, c. 2.5mm long. Such seeds are mobile, especially in sediments with a relatively large particle size. Today, earthworms are active in the ridge and furrow soil, and may have been more so in the past. Some worms will line burrows with small stones of between 2 and 5mm in diameter (Keppax 1977: 226). Rumex seeds clearly fall within this size range. Therefore, in the light of the accelerator date, we can be sure that some, if not all, of the seeds are intrusive. However, there is a further problem in that the main species represented in the buried assemblage, Rumex acetosa (Common sorrel), is absent or very rare in the ridge and furrow area today. Today this area is covered by a thick turf and is populated by Cirsium vulgare (Spear thistle), Epipactis palustris (Marsh helleborine), Potentilla arenaria (Grey Cinquefoil), Lotus corniculatus (Common bird's-foot trefoil), Echium vulgare (Viper's bugloss) and Carex species. In fact in Darlington's extensive vegetation survey of the Lindisfarne dune and mud-flats no Rumex species were recorded at all (1965). There are a number of possible explanations for this seemingly contradictory evidence. First, the Rumex seeds may be of some antiquity and somehow became contaminated with carbon and a post-1950 date was indicated by the accelerator. Second, the seeds are modern, but were derived from temporary or intermittent Rumex populations which did not exist at the time of Darlington's survey in 1964, and do not exist in this area today.

The Analysis of the Terrestrial Mollusca from the Ridge and Furrow Buried Soil

Methods

The sieving methods were as detailed above for the extraction of seeds; mollusca were retrieved from both wet-sieved and paraffin-floated samples. Material captured on the sieves was then sorted under a binocular microscope at 10X magnification. Once the mollusca had been divided into species groups, examples of each group were taken to Leicestershire's central museum where the extensive molluscan reference collection was consulted. Once this had been completed the quantification and the production of graphs were undertaken.
As the material is not from a vertical stratigraphic sequence, the usual type of molluscan diagram was not produced; instead, pie-charts illustrating the species proportions from the different spatial locations across the ridge and furrow were produced. Some molluscan material retrieved from the Green Shiel settlement site was also considered in order to assess any spatial variation.

This material had been retrieved by flotation and wet-sieving prior to this research. Complete records were available (Boyer 1987). Due to the nature of the taphonomic processes in and around Green Shiel, which undoubtedly result in the mixing of sediments, especially those close to the surface, the molluscan assemblages were placed into two broad stratigraphic groups. First, the relatively recent or "upper" deposits, and second, the secure "archaeological" deposits retrieved from layers where firm coin evidence was available. However, despite this coin evidence, it may still be possible that the molluscan assemblages were partially mixed as a result of aeolian processes.

Results

The results of the earlier molluscan analysis of material from building "C" at Green Shiel are considered first. The material from this area was derived from floated and wet-sieved deposits. As with the dune system as a whole, the sediments sieved yielded relatively little in terms of molluscs per unit mass. A total of 23.5 Kg of sand from the upper deposits (sample "B") was sieved and yielded a total of 21 molluscs whilst a total of 35.3 Kg of material from the archaeological deposits (sample "A") within the building yielded 56 specimens (see figure 6.9).
Molluscs from Green Shiel, Building C

The lower archaeological deposit, sample "A", was dominated by *Discus rotundatus* which constituted 53.6% (30) of the assemblage, *Oxychilus alliarius* 21.4% (12) and *Trichia hispida* 8.9% (5). The rest of the assemblage was constituted by *Zonitoides nitidus* 5.4% (3), *Cochlicopa sp.* 5.4% (3), *Cepea sp.* 3.6% (2), and finally *Oxychilus cellarius* 1.8% (1).

The upper deposits, sample "B", were also dominated by *Discus rotundatus* 38.1% (8), but the rest of the assemblage was constituted by a greater range of species even if in lower quantities (see table 2).

From the total of 70.1 Kg of soil sieved from the ridge & furrow palaeosol c.680 terrestrial molluscs were retrieved; however, the majority of these were juveniles and consequently the identifications of these were not necessarily as "safe" as the adult specimens.

The most noticeable and important characteristic of the molluscs retrieved from the palaeosol is the fact that the assemblages are dominated by *Cernuella virgata*, with *Pupilla muscorum* appearing in much smaller quantities (see table 6.6 and figure 6.10). All of the assemblages from the central area of the ridge and furrow are dominated by *Cernuella virgata* with adults of this species constituting up to 23.2% (41) in sample 3, whilst the juvenile of this species comprise 76.3% (135). The only other species to appear in the palaeosol assemblages is *Pupilla muscorum*: 0.6% (1) in sample 3. These
proportions are broadly reflected in the other two central ridge and furrow samples. An interesting anomaly occurs in sample 4, from the northern area of the ridge and furrow. Here the relative proportions are reversed with *Pupilla muscorum* constituting 85.7% (12) of this sample, while both adult and juvenile *Cernuella virgata* only make up 7% (1). Despite this observation, it is realised that these quantities are far too small, and realistic inferences can not be made from such poor data.

<table>
<thead>
<tr>
<th>Species</th>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Sample 3</th>
<th>Sample 4</th>
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</thead>
<tbody>
<tr>
<td><em>Cernuella virgata</em></td>
<td>58</td>
<td>58</td>
<td>41</td>
<td>1</td>
</tr>
<tr>
<td><em>Cernuella virgata</em> (juv)</td>
<td>75</td>
<td>309</td>
<td>135</td>
<td>1</td>
</tr>
<tr>
<td><em>Pupilla muscorum</em></td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td><em>Cernuella virgata</em></td>
<td>36.1%</td>
<td>15.7%</td>
<td>23.2%</td>
<td>7.1%</td>
</tr>
<tr>
<td><em>Cernuella virgata</em> (juv)</td>
<td>61.5%</td>
<td>83.6%</td>
<td>76.27%</td>
<td>7.1%</td>
</tr>
<tr>
<td><em>Pupilla muscorum</em></td>
<td>2.46%</td>
<td>0.8%</td>
<td>0.6%</td>
<td>85.7%</td>
</tr>
</tbody>
</table>

Table 6.6: Total numbers and percentages of molluscs from the ridge and furrow samples.
Figure 6.10: Pie charts showing the proportions of molluscs present in the ridge and furrow samples.

Discussion of Molluscan Evidence

Green Shiel, House "C" assemblages

The archaeological assemblage (sample "A") from the house appears indicative of a shaded, moist, or even wooded, environment due to the fact that Discus rotundatus dominates the assemblage (see figure 6.9). Other species present, including Oxychilus alliarius and cellarius, are also shade/moist loving, towards catholic species, and might support such a contention, whilst the presence of the more catholic to open species Cepea and Trichia hispida, should certainly cast some doubt over any hypothesis proposing woodland cover in this area, although similar types of assemblage from comparable localities have been used to support such hypotheses within prehistoric contexts (Spencer 1975: 96-103).
it should be born in mind that *Discus rotundatus* is an especially successful species, and therefore too much importance can be attached to its relative presence.

It is more likely that the Green Shiel assemblage is indicative of local habitats in and around the settlement buildings that offered ideal environments for shade-loving mollusca. Such species may have found their way onto the settlement via human transportation of vegetative material for roofing for example, and subsequently found acceptable niches within building walls. This interpretation is partly supported by the existence of *Oxychilus cellarius* in the assemblage, a species which is characteristic of wall debris (Evans 1972: 188); in fact the assemblage may be indicative of a collapsing, disused building. However, the appearance of *Oxychilus allarius*, considered by some as a synanthropic species, in the same assemblage may cast some doubt on the contemporaneity of this molluscan population with the occupation of the buildings. Sample "B" from the near surface deposits of building "C" shows more diversity and may be indicative of either a slightly more open environment, or the arrival and successful colonisation of the area by new species. This assemblage is still dominated by *Discus rotundatus* 38.1% (8), therefore implying the existence of shaded niches, probably within the tumble of the buildings. However, the appearance of *Zonitoides nitidus* 4.8% (1) might be taken as an increase in shaded niches. It certainly shows that there were some areas that were relatively moist or wet. The area around Green Shiel today is periodically covered by pools of standing water during the winter and spring after heavy rain. A possible increase in the availability of moist or damp niches is also implied by the appearance of the catholic species *Aegopinella nitidula* and *Vitrina pelucida*. However, both of these species are quite common in sand dune areas. The existence of *Trichia striolata*, another catholic species, implies a disturbed habitat or "man-made habitats" (Evans 1972: 176). Other species present in the building assemblages are *Euconulus fulvus* and *Cochlicopa* sp.. *Euconulus fulvus* often inhabits wooded areas, especially leaf-litter; however, it is sometimes found in more open environments and should therefore be considered as a catholic species (Evans 1972: 186). *Cochlicopa* (lubrica or lubriclla) is also a catholic species: therefore we can only make general inferences from this part of the assemblage. It seems that the Green Shiel buildings themselves offered a microhabitat which offered the shade required by some of the species described above. However, an open environment in the area around Green Shiel is implied by the remaining species in this assemblage: *Vallonia costata* and *Helicella itala*. These are common species within open sand dune systems, but neither are recorded as existing on Lindisfarne today and have certainly not been observed whilst undertaking fieldwork during the last few years. However, *Vallonia costata* is recorded as inhabiting the coast where Lindisfarne joins the mainland (Kerney 1976: 81 & 150), and it is quite feasible that such species do move from the mainland, along the arm of the tombolo onto the main body of the island itself. *Helicella itala* is considered to be in decline over much of southern England (Preece
1980: 20), and it seems quite possible that this decline is being mirrored in other parts of the country as well.

The ridge and furrow assemblages

Before moving on to interpret the ridge and furrow assemblage, the possibility of contamination from the sand overlying the palaeosol must be considered. It is important to note that this species is not present in the Lindisfarne dune system in large numbers today. This contention is supported by the fact the "Upper deposits" (B) from the Green Shiel settlement, which include very recent and modern mixed sediments, do not contain one single example of *Cernuella virgata*. The fact that the ridge and furrow assemblage does not include any of the species which dominate the dune system today also supports the belief that the palaeosol assemblage is not comprised of contaminants.

As detailed above, the assemblage from the ridge and furrow palaeosol is dominated by *Cernuella virgata*, a species which is relatively common in open grassland and dune habitats. Today it is more common south of a line drawn between the coasts of north Wales and north Yorkshire. North of this line, the distribution tends to be confined to coastal areas in Britain. This species would appear to be entirely absent from northern Europe and Scandinavia. Therefore, it would be fair to argue that *Cernuella virgata* is a relatively thermophilous species, and that the relative abundance of *Cernuella virgata* in the ridge and furrow palaeosol could be partly due to the more favourable environment of the early medieval climatic optimum. However, it is impossible to really test such an hypothesis based on the occurrence of one species, especially as the other species present, *Pupilla muscorum*, is found all over Scandinavia today albeit only in coastal habitats north of the same geographical line as described for *Cernuella virgata*.

The existence of only *Cernuella virgata* and *Pupilla muscorum* within the palaeosol must imply that much of this area of ridge and furrow was relatively well exposed short grassland offering little opportunity for shade.

An important spatial variation in the palaeosol assemblage occurs within sample 4 from test pit "C" in the northern area of the ridge and furrow (location on figure 6.1). Here *Pupilla muscorum* constitutes 85.7% (12) of the assemblage. This might be taken as implying a more exposed area, probably a sandy area: the transition between the field and the upper beach. However, once again, the small quantities involved in this discussion means that any conclusion can not be entirely substantiated and defended. However, the reversal of species proportions demonstrated in the seed evidence (with ecologies corresponding to those of the molluscs) does give this interpretation a little more weight.
General Discussion

Taking a more synecological approach to the assemblages allows us to question any interpretation which places emphasis on the so-called shade-loving or woodland species, and consequently infer the existence of woodland in the locality. Rather, we should consider the assemblage as a whole and consider environmental factors other than those which concentrate on simple shade and openness factors.

As Cain argues, often it is levels of cold and dampness that have more influence than the various types of vegetation on molluscan communities (1983: 601). For example a snail fauna found in wet coolish open conditions may not be that dissimilar to a fauna observed in a drier, warmer shaded locality. Therefore we need to consider not only vegetation cover, but other climatic factors as well.

The assemblages from the Green Shiel environs indicate a relatively open area with smaller microhabitats offering shelter for the shade-loving species. The evidence also suggests the possibility of very wet areas in and around the settlement site, areas which would not necessarily be uncommon within a sand dune system with dune hollows and areas of slack which could contain trough-, or pond-, like microhabitats.

It should also be noted that the palaeosol and settlement assemblages are mutually exclusive in terms of species membership: Cernuella virgata and Pupilla muscorum are found only within the palaeosol, whilst none of the species present in the settlement assemblages appear within the palaeosol.

Possibly just as important as the species present within the assemblages is the difference in species diversity or richness between the settlement site and the palaeosol. Thirteen different species have been found within the settlement buildings, whilst only two were found in the ridge and furrow. This phenomenon cannot be explained by the quantities sieved from each area, as far more material from the palaeosol (over 70Kg) was sieved than from the settlement case study.

The palaeosol is not so early that introduced species had not had time to colonise the area; Cernuella virgata is considered to be post-Iron Age, probably a medieval introduction. However, the fact that Lindisfarne is not a full island means that ideas relating island biogeography and ecology, and the possibility of limited richness as a result of relative remoteness, do not fully apply (see Gorman 1979: chapter 3). The low diversity in the ridge and furrow assemblage might be explained by a lack of microhabitats offering niches for a wider range of species, or the assemblage may represent the inability of other species to compete with Cernuella virgata. It is also important to remember that the buried-soil
assemblage could represent a very small chronological period and the dominance of *Cernuella virgata* in the death assemblage is not representative of the state of the entire population of molluscs, but only indicates which species was dominant over the ridge and furrow area just before a major storm and consequent sand-blow. It is however unlikely that the population dynamics of molluscs in this area were such that the dominant species changed with any regularity.

**Note on the beetle evidence**

Remains of a limited number of beetles were retrieved from the samples sieved. From the main ridge and furrow area, samples 1-3 produced three head cases and a thorax. One head case and thorax was retrieved from sample 4 (ridge and furrow pit "C"). After consulting an entomologist from Leicestershire Museum Service it was decided that the identification of these examples down to species level would not be an efficient use of time due to the dearth of the material and the ecological information that could be obtained. However, identification to family was possible and the broad ecological information inferred from this is outlined below.

Two of the specimens, one from sample 1 and the other from sample 2, were from the *Curculionidae* (Weevil) family. This family generally feeds on plant material and can be expected in the rough pasture described above. Another plant eating family, *Cerambycidae*, was tentatively identified as was a member of the *Tenebrionidae* [sub-families: *Lagriidae/Alleculidae*]. This family is sometimes associated with decaying wood and plants. One example of a beetle from the *Dyschirius* family was found in sample 4 from the northern ridge and furrow pit "C". This family can be expected on bare damp mud and sand. This is not surprising as this is the area defined above as the transition zone between the ridge and furrow and the beach.

**General summary and conclusion**

This chapter has discussed the range of palaeoecological material retrieved from the ridge and furrow palaeosol, as well as the terrestrial molluscs from Green Shiel itself. As stated at the beginning of this chapter, a broad range of environmental data types were examined. The poor survivability of much of the material examined demands that all potential sources of information are considered, as no single ecofact type can yield results of a quality that will permit an hypothesis to stand by itself.
These studies have shown that pollen certainly does survive, but much of it is abraded, and we can not be sure if that which does survive is representative of the ridge and palaeosol's flora. Fungal spores seem to survive well, but the lack of reliable identification keys is problematical. However, those spores that have been identified do support to a certain extent the contention that the area was used as pasture. But, as stated above, this data is not of a quality that allows the development of strong hypotheses to this effect.

The study of the phytolith material supports the contention that the palaeosol had supported grassland of some sorts, although the identification of species composition is not possible. The investigation revealed that much work needs to be carried out on comparative material, and complex taphonomic problems must be considered.

The existence of relatively open, short grassland is attested to by the molluscan material. The palaeosol assemblage is clearly dominated by *Cernuella virgata*, a species often found in such habitats. The molluscan assemblage also indicates that there was some difference in microhabitats between the Green Shiel site itself and the ridge and furrow area.

The interpretation of the seed evidence is problematical due to the modern accelerator date (see above). We must be aware of the likelihood of these seeds being intrusive, not just because of the accelerator date, but because it would be quite surprising if seeds were preserved in a non-carbonised form in such an environment. But the fact that *Rumex* is absent today (and has been for some time) from the ridge and furrow area does imply that there have been some important vegetational changes in this area during the past. It was for this reason that a full analysis of the seeds was undertaken. Even if the seed assemblage does not represent the ecology of the area contemporary with the inhabitation of Green Shiel, it may well highlight some important recent ecological changes.

Although none of the techniques in isolation allow a definitive reconstruction of the palaeosol's ecology, it is quite likely that the area supported open, rough pasture of some description. The palaeoecological evidence has to be considered in conjunction with the soil analyses detailed in the preceding chapter. Combined, they do give us some insight into the potential of the soil and its probable uses.
Introduction

This chapter considers the range of palynological evidence for the early medieval period in the north-east of England and compares it with the diagram from the Lough on Lindisfarne. It should be made clear at this point that the original work for this diagram was carried out by Sarah Crane (1992). Subsequent sampling for radiocarbon dates and the reinterpretation of the diagram was carried out by myself.

An important aim of this work is to consider the similarity of vegetational changes across the region during the early medieval period, and thus consider whether the Lindisfarne diagram represents a sequence of activity which is peculiar in that region during this period.

In order to appreciate the process of landscape evolution and "manipulation" it is necessary to consider the periods prior to and after the one in which we are interested. The location of the pollen diagrams considered in this chapter can be found in figure 7.1.

The Historical Background

During the Iron Age much of Northumbria seems to have been largely dominated by forest, with some increase in "cultural" pollen types as time progressed (Turner 1979: 286). The landscape in the region had dramatically changed by the end of the Roman period, 'with some of the pollen diagrams showing tree pollen percentages as low as those of today' (Turner 1979: 286). However, it should be pointed out that a greater level of continuity from the Roman period is seen in the southernmost part of this region (below the Wear), with arable activity maintaining Roman levels into the early medieval period (Fenton-Thomas 1992). The region's woodland was not all cleared at the same time; it should be remembered that we are dealing with a period of about 400 years. By the end of the Roman period the pollen diagrams of the region are dominated by the pollen of grasses, pasture plants and arable including barley, wheat and hemp.
In the following section the few pollen diagrams which possess radiocarbon dates for the historical period in the north-east of England will be described. Figure 7.2 indicates the various tree/shrub/herb ratios for each diagram where there is a radiocarbon date, i.e. Fellend Moss, Steng Moss and Camp Hill Moss. The graphs below this give more detail for the dated points for each of the diagrams. The figure, and the description below, both place emphasis on the early medieval period; however, as the trends either side of this period are just as important most of the historical period is considered as well.
Figure 7.2: Radiocarbon dated zones from pollen diagrams in the north-east of England showing the different tree/shrub/herb ratios for each date. Detail of each dated point is given in the bar charts (N.B. these pollen values calculated as percentages of total tree pollen).

Diagram Descriptions

In most of the original published descriptions of the following diagrams, dates are given in their uncorrected form. Consequently it was decided that these dates should be calibrated using the University of Washington radiocarbon calibration program, 1987, rev. 2.0, which was also used by the Belfast laboratory to calibrate the date from Lindisfarne Lough. The calibrated ranges are given in brackets after the published dates. The ranges of each date are shown on figure 7.2. In a discussion of ecological changes in the historical period, where the date ranges under discussion tend to be shorter, and reference to specific historic events, or processes, is made, some consideration of the problems of radiocarbon dating is useful. The most obvious problem is that of calibrating on a part of the curve which has a "wiggle".

The most obvious potential error in dating a pollen diagram is the dating of intrusive modern root matter or some other organic matter, such as a piece of wood, which might in fact be older than the surrounding sedimentary matrix. In the case of the Lindisfarne Lough samples large, fresh-looking roots were removed before packaging the sample for dating. As well as this type of sampling problem, the most important problem for the archaeologist working in the historical period is the relationship between the calibrated date and dates of historical events. As Aitken illustrates, there is a tendency for dates between 500 BC and 1300 AD to be overestimated, but by no more than 150
yearts (1990: 98). This consisant overestimation is clearly refelected in the dates discussed below, where the radiocarbon ages for dates prior to 1300 AD are all older than the calibrated ranges.

Fellend Moss (NY 679658 200m OD)

Fellend Moss is located in the south-west of Northumberland, just to the south of Hadrian's Wall, and is the most distant site from Lindisfarne considered in this section.

The first radiocarbon date considered on this diagram, a.d.2 ± 45 (86 BC-AD 77) (SRR 876), marks the beginning of an extensive clearance phase. The next date, a.d.620 ±40 (AD 649-762) (SRR 875), marks the subsequent period of forest regeneration which is best indicated by the rise in Betula. Between this date and the next, a.d. 1005 ± 40 (AD 1021-1156) (SRR 874), there is a phase of overall regeneration followed by clearance once again. The regeneration is especially reflected in the Quercus, Alnus and Corylus curves. The date of a.d. 1005 ± 40 (AD 1021-1156) is marked by sudden and short-lived increase in Gramineae, Cereals and Plantago and weeds of disturbance such as Rumex. However, there is also a similar increase in Corylus at this point as well. After this date there is another period of forest regeneration during which Quercus, Alnus, and to a lesser extent, Betula, all increase. During this period there is a marked drop in Gramineae and Plantago, and cereals disappear entirely for some time. This period of regeneration starts to wain by the final date of a.d.1516 ± 45 (AD 1428-1469). This date marks the beginning of the final phase of forest clearance.

Steng Moss (NY 965913 305m O.D.)

This site is located in central Northumberland about 50Km to the south-west of Lindisfarne.

A radiocarbon date of 20 ± 60 b.c (90 BC-AD 74) (Q 1520) is marked by the beginning of an extensive period of clearance, although the tree and shrub species (Betula, Quercus, Alnus and Corylus) remain an important component for most of this period. There is a coincident increase in Gramineae, Plantago and some weeds. However, the increase in cereal pollen is relatively minor. This trend continues until the next zone which is marked by a radiocarbon date of a.d. 460 ± 60 (AD 438-640). This date marks the beginning of a phase of regeneration. Betula is initially the most important component in this regeneration, but there is also a steady rise in Quercus and Alnus.
There is also an intermittent increase in *Corylus*. Gramineae and *Plantago* are relatively small components during this phase, with cereals disappearing entirely for much of this period. Towards the end of this period, perhaps during the seventh or eighth centuries, a new period of clearance is apparent, the maximum of which is most marked at a.d. 865 ± 35 (AD 896-993) (SRR 1041). At this point there is a sudden and marked reduction of *Betula*, although this clearance is not immediately reflected in *Quercus*, *Alnus* and *Corylus*. The clearance is matched by a sudden increase in Gramineae, *Plantago*, and weeds, along with the dramatic reappearance of cereals. Following this date, there is another period of continued regeneration with Gramineae and *Plantago* falling to levels of below 20 and 5 percent respectively (as % total tree pollen). Cereal pollen is entirely absent at certain points during this final phase, which ends with the beginning of what must be the later medieval final clearance.
Camp Hill Moss (NU 102263 213m OD)

Camp Hill Moss is located in the north eastern part of Northumberland, and is the nearest site to Lindisfarne: only c. 15 Km to the south.

There is one radiocarbon date for this diagram which falls within the historical period. The date, a.d. 1310 ± 80 (AD 1278-1405) (HAR 1948), is also considered to be too late (Davies & Turner 1979: 801). The date as it stands marks the beginning of an extensive clearance phase after a long period of Betula, Alnus and Coryloid dominance. The period after the date is one where Gramineae, Plantago and cereal pollen become dominant. The authors contend that this phase must in fact relate to the much earlier Roman impact on the landscape (see discussion below, this chapter).

Broad Moss (NU 02323111)

Broad is located in the eastern part of the Cheviot hills at 306m. This diagram shows a similar pattern of clearance succeeded by regeneration, but there are no radiocarbon dates for this diagram so it is of little direct relevance to this study.

Summary

In the historical period the Fellend Moss diagram clearly shows a period of post-Roman forest regeneration, the beginning of which is dated to AD 649-762. Just prior to the next date of AD 1021-1156, there is a period of clearance followed once again by a period of regeneration. The final phase of clearance begins during the early part of the sixteenth century. These phases of clearance and regeneration are indicated by fluctuations in the following tree species: Betula, Alnus, Corylus (which shows the greatest level of variation), and Quercus (Davis & Turner 1979: 788). The brief period of early medieval clearance is mirrored by a rise in Gramineae, Plantago, Cyperaceae and Calluna at AD 1021-1156. During this period there is only a small rise in cereal pollen and some pasture weeds.

At Steng Moss a similar sequence to that indicated by the Fellend Moss diagram is apparent. By AD 438-640 forest regeneration has taken place; between this date and AD 896-993 there is a brief period of forest clearance with the following species reflecting this trend most clearly: Betula, Quercus, Alnus, and Corylus. During this early medieval clearance there is the expected corresponding increase in Gramineae, Plantago, cereals and arable weeds, along with weeds associated with pasture such as Rumex acetosa (Davis & Turner 1979: 792).
The early medieval period is difficult to identify in the Camp Hill Moss diagram as it occurs between two radiocarbon dates with about 2000 years difference, the earlier date being 720± 70 b (899 BC-796 BC) (HAR 1947) and the latter date is a.d. 1310 ± 80 (AD 1278 - 1405). The authors of the report consider the second radiocarbon date to be too recent as the start of intensive land use at around this time indicated by this diagram is considered to be too late as it does not reflect the expected Roman impact in the area. However, there are of course a number of other possible explanations for such an anomaly. The most likely in this case is that there was a hiatus in peat growth between the date of 720 ±70 b and the date with which we are concerned (AD 1278-1405). At the point where clearance begins, and just prior to the point from which the sample for the radiocarbon determination was taken, there is a marked change in the peat profile from *Eriophorum/Sphagnum* peat with dense concentrations of pieces of *Betula* to, *Eriophorum/Sphagnum* peat with *Paludella squarrosa*.. If this difference in the stratigraphy does represent a hiatus in development, the radiocarbon date of a.d. 1310 ±80 (AD 1278-1405) might represent a late medieval clearance, although we might expect regeneration to be the norm during the thirteenth and fourteenth centuries in many places.

A hiatus, or reduction of growth rate, in such diagrams during this period might be explained by reduced precipitation during the early medieval climatic optimum, with growth recommencing during the wetter periods of the Little Ice Age. Whatever explanation we accept, care must be taken if any emphasis is to be placed on the Camp Hill Moss diagram.

The site at Hallowell Moss (NZ 251439) just outside Durham (Donaldson & Turner 1977) is worth comparison with the other sites considered in this study even though it is almost 100 Km to the south of Lindisfarne. Unlike those that have been considered from Northumberland itself this site is on the lowland and may in some respects be more representative than the upland sites considered so far. (N.B. this diagram is not summarised in figure 7.2 due to its distance from Lindisfarne.)

The main period of clearance in this area seems to coincide with the establishment of the Romans in the region. Clearance seems to have continued well into the post-Roman period: `...from the time the Romans left until about AD 600, farming continued as before under conditions of continued stability and a thriving economy' (Donaldson & Turner 1977: 30). The early medieval period on this diagram is dated by two radiocarbon dates (sampled from within 2cm of one another) which are inverted, the younger determination (a.d. 595 ± 50) (SRR 413) being below the older (a.d. 428 ±65) (SRR 412). Using the Washington calibration programme these two dates were taken and a weighted average calculated which was then calibrated. A date range of AD 600 to 652 was produced. At this point regeneration of the forest begins; the high
proportions of Betula and Coryloid species during this period indicate the emergence of a relatively open woodland, probably as the result of management. This trend seems to have continued throughout most of the middle ages, contrasting the ninth to early eleventh century clearance indicated clearly in the Northumbrian diagrams at Steng Moss and Fellend Moss.

In north-eastern England the medieval period overall seems to be characterised in these diagrams as a period of gradual clearance with some intermittent phases of woodland regeneration. After c. AD 400 the cleared landscape seems to have been maintained for a reasonable length of time; in some places regeneration took place as late as a.d. 595 ± 50 (Hallowell Moss) (Donaldson and Turner 1977: 30) and a.d. 780 ± 50 (lab number not available) at Bolton Fell in Cumbria (Barber 1981: 115). Following this period of regeneration, a period of clearance is identified in the majority of the diagrams for the region (although this is not the case with the Hallowell Moss diagram). The period of clearance varies from site to site but covers the period from the ninth century to the thirteenth. This phase is then succeeded in most areas by another period of regeneration which coincides with the Black Death (AD 1350 onwards).

The type of agriculture that was being practised in the region is hinted at by the changing proportions of anthropogenic indicators. In the majority of cases woodland is replaced by species predominantly associated with pastoral activity. Large increases in Plantago lanceolata, Rumex; and Calluna for example are apparent in most of the clearance phases. That is not to say that cereals and associated plants are absent during these phases, and that we should infer that crop production was a secondary concern, but rather it is apparent that pastoral activity could well have been the dominant farming practice during these phases of intermittent clearance. However, we should also be aware that it is often dangerous to make inferences regarding the level of pastoral activity as certain indicator species, especially Plantago lanceolata, produce relatively large amounts of pollen which travel further than pollen grains of cereal and associated arable weeds (Edwards 1979: 256).

The Lindisfarne Diagram

The Problems of Island Pollen Diagrams and Vegetational Histories

The pollen input processes in any environment are unique in each and every case, but islands are subject to a set of processes which are very different to those which affect the pollen input on mainland sites.
The most obvious distinction that can be made between island and mainland sites in terms of pollen components is that the terrestrial catchment area is clearly demarcated, and aerial components are less important if the island is some distance from the mainland. However, this does not mean that islands are isolated from mainland pollen components. For example, it was inferred from palynological work carried out on the Scilly Isles, located some 55Km off the tip of Cornwall, that the relatively low levels of *Alnus* and *Pinus* did not necessarily indicate the previous existence of these species on the islands, but the appearance of these in the record was a result of long-distance transportation (Dimbleby *et al.* 1981: 132). This problem has also been recognised in work carried out in the Orkney Islands (Moar 1969: 203). Here, a surface sample of sphagnum peat was taken, and the pollen from this compared with the modern local and regional flora. This work indicated that a certain amount of pollen from the Scottish mainland is included in the Orkney records. *Pinus* pollen especially is considered to have been transported over a "considerable distance" (Moar 1969: 206-7). The same problem was also observed in the analysis of the Mesolithic vegetational history of Oronsay where part of the *Pinus* input is considered to have been derived from mainland Scotland and/or Ireland (Andrews *et al.* 1987: 61 & 69).

Island sites do have some advantages over mainland sites when the emphasis is on the vegetational reconstruction of a relatively restricted space: e.g. an area of farmland around an archaeological site, or a small island. While extra-local components can make a significant contribution to the total pollen on some mainland sites, this problem is reduced to a certain extent on islands as they are buffered by the sea. As Jones *et al.* (1990: 31) argue, islands which are some distance from a mainland body are rarely in receipt of pollen rain from beyond the island itself, while there is little doubt that pollen cores from islands adjacent to mainland areas do contain a long-distance mainland component; this is true of islands such as Orkney and Shetland, and obviously Lindisfarne.

One of the most important factors affecting pollen sources is the size and nature of the site. The Lough on Lindisfarne is about 300 metres long and 180 metres wide. Being located on a small island, the Lough is not fed by any catchments carrying extra-local pollen. Therefore it is fair to say that the pollen input into the Lough is one that has largely been constituted by extra-local pollen-rain (extra-local taken to be 30m+). There will also have been an element of wind-transported pollen from the mainland. Finally, a long-distance component, washed out of the atmosphere by rain, will also have entered the Lough. However, the relatively small size of the Lough means that the majority of the pollen would be composed of the extra-local component, and a small trunk-space component (Moore *et al.* 1991: 14), with a small amount of pollen arriving as a secondary water transported component which would be dominated by pollen from the
island's catchment area, although the Lough on Lindisfarne does not possess a catchment area as such. Therefore there we can assume that the diagram is largely representative of the island, and to a great extent, the area around the Lough itself.

The moss polster provides us with a useful record of modern pollen rain on the island. It allows a consideration of the nature of extra-local pollen rain through a comparison of the flora on the island today with the species found by the pollen in the polster. It should be pointed out that a numerical approach has not been taken, i.e. the calculation of $R$ values): rather, a more qualitative consideration of presence and absence is deemed to be just as appropriate for this study.

The most important characteristic of the moss polster is the complete absence of *Betula* which is reflected in the pollen curve for this species as well; it disappears early on in the final zone. Despite the fact that *Betula* produces relatively large quantities of pollen, with a relatively low settling velocity, and is present in the uppermost parts of the regional diagrams and is still quite common today in the north-east, it does not appear in the moss polster. This might be considered as evidence for a relatively low regional pollen-rain onto the island. However, there is a relatively high level of *Pinus* in the moss polster which is derived from the mainland, especially from relatively new plantations. The nearest plantation to Lindisfarne at Kyloe Wood c. 10Km to the southwest of the island (see figure 7.3) is dominated by conifers and must contribute the largest amount of extra-local pollen to the island's pollen rain today. It is also likely that the *Quercus* pollen in the polster is also derived from Kyloe, although this species constitutes only a small proportion of the plantation (Hale Associates). The source of the *Ulmus* pollen is unclear as this species is absent from Kyloe wood, and therefore it must be derived from somewhere else on the mainland. There is also little doubt that *Alnus* pollen is also an extra-local component, with some probably emanating from Kyloe Wood where there is a small number of this species, but much of the pollen found in the polster, as well as the Lough record itself, must come from the wider region.
The Lindisfarne pollen diagram is based on the analysis of samples taken from a core of 1.17m of reed peat taken from the middle of the Lough on the eastern side of the island (see figure 7.4). The reed peat overlies a grey/white sand and is also interrupted at 86-92 cm by a leafy deposit within a sandy matrix.

The diagram (figure 7.5) has been divided into three zones, the first part of zone 2 having been dated to AD 657-785 (UB-3585). While reafforestation is reflected in the
moss pollster which was taken from the dune slack on the north shore of Lindisfarne, the top diagram itself shows very little pine and this must be taken to mean that the diagram pre-dates the reafforestation which occurred at the turn of the century in the Kyloie Hills to the south-west of Lindisfarne (Brown et al., in press).

Figure 7.5: The Lindisfarne pollen diagram. Percentage values are exclusive of aquatics and are calculated as the percentage of total land-pollen. The moss-pollster is the single thick line at the very top of the diagram.

Description of the zones

The land pollen

Zone 1 is dominated by Coryloid species, which in this case is mostly hazel. At the very bottom of the diagram Coryloid is at its highest constituting 55% of the total land pollen. Throughout this zone there is a steady but marked drop in Coryloid to about 40%, Betula remains at a roughly constant 13%. Ulmus appears as less than 1% at the bottom of the zone, while Quercus reaches a level of below 5% at one point in zone 1. Alnus attains a level of over 5% and seems to be gradually rising towards zone 2. Cereals are present throughout the diagram, but only at a level of less than 5% in zone 1, while Gramineae reaches a level of 13%. Plantago lanceolata rises steadily from about 2% to about 5% towards the top of this first zone, while Rumex is present as less than 1%.

Zone 2 is marked by fluctuations in Betula which is as high as 13% at the start of zone 2, but is reduced to a level of less than 5% about half-way up the zone and then rises again to a level of about 10% just before the very top of this zone. Pinus and Quercus both appear as blips at the top of zone 2 at less than 5% each. Zone 2 sees fluctuations in the Coryloid curve with a drop from 40% down to a low of 30% then back up to a short-lived peak of 40% before starting a steady and sustained fall towards the
boundary with zone 3. The fluctuations in *Betula* and *Coryloid* are reflected to some extent by the Gramineae curve, with reductions in trees and shrubs being mirrored by an increase in grasses, and to a certain extent *Cyperaceae*. Grasses achieve an overall increase during the period covered by zone 2 from about 13% to 20%. However, this increase is not mirrored in the cereal pollen which actually appears as less than 1% for a part of zone 2. *Calluna, Compositae (liguliflorae), Plantago lanceolata, Plantago media/major* and *Rumex* all increase as a proportion of total land pollen during this period.

Zone 3 sees the most dramatic changes in the diagram. *Betula* entirely disappears, although *Alnus* remains stable, contributing a constant 8-10% throughout most of the zone, but it certainly experiences a slight overall reduction between the bottom and the top of the zone. *Coryloid* is reduced to under 10% TLP, although there are clear fluctuations in this curve. This reduction in *Betula* and *Coryloid* is matched by an increase in Gramineae which constitutes between 40% and 50% of TLP towards the top of this zone. There is also an overall increase in *Cyperaceae*, although this curve does experience a relatively high level of fluctuation. There is marked overall increase in cereal pollen, although only at a level of just over 5% of TLP. There is an overall decrease in *Compositae (liguliflorae)* and *Plantago media/major* which disappears towards the top of the diagram. There is an overall increase in *Plantago lanceolata*, a high peak of 15% being attained at one point. *Rumex* experiences an overall, if unsteady, increase.

The aquatics

The most interesting aquatic on the Lindisfarne diagram is *Myriophyllum spicatum* (Water-milfoil) as any reduction in this species is probably indicative of periods of drying-out in the Lough. There is one such period at the zone 1 zone 2 boundary, then a continuous period indicated by the reduction, and then almost complete absence, of this plant in zone 3. It is apparent from air-photographs from the 1950s onwards, and observations today, that there has been an increased tendency towards seasonal drying-out. It seems clear that as this process has developed, fringing vegetation in the form of *Cyperaceae* has increased as would be expected; concomitant rise in this family can be seen in the diagram.

*Discussion*

The land pollen
Zone 1 probably reflects a relatively open hazel/birch woodland which could well date to the post-Roman period. Although these curves appear to dominate the diagram, it should be pointed out that the total tree-pollen constitutes less than 25% of TLP, and shrubs about 40% for most of this period. Also, a large proportion of the tree-pollen figure is made up of *Alnus* pollen which is probably a mainland component (see discussion below). Both grasses and cereals are present during this period, implying the existence of limited arable agriculture.

Zone 2 is the most important zone in the context of this research as its beginning is firmly dated to the early medieval period. The radiocarbon date of AD 657-785 (UB-3585) just post-dates the establishment of the early monastic community in AD 635. Although the date is about 150 years earlier than the occupation of the Green Shiel site, which is dated by nineteen coin finds (see Chapter 2), it is possible to relate the trends apparent in this zone to the period contemporary with the occupation of Green Shiel.

Zone 2 is characterised by a gradual clearance of the Birch wood on the island, and a fluctuating *Coryloid* (probably Hazel) level which may represent woodland management. It is quite possible that coppicing was being practised in order to supply hazel withies for a range of structure types (Brown *et al.* in press). There seems to be a sustained, but low level, of crop production during this period, although there is a slight reduction in its contribution to TLP during the later part of zone 2. Whether this represents an actual decrease in arable on the island, or is a direct function of the relative increase in *Coryloid* is unclear. The slight overall increase in Grasses may be indicative of clearance for either arable or pasture, while the increases in *Compositae*, *Rumex* and the *Plantago* species can be seen as indicative of the emergence of pasture during this period (Behre 1981). Overall, the main vegetation of the early medieval period on Lindisfarne can be characterised as areas of open managed woodland, with a reasonable proportion of the island given over to grass/pasture, and a few relatively small arable fields (see chapter 7). Much of the scrub-woodland was possibly located between the Lough and the Green Shiel area, as the few hazel hedges that are left on the island today are located behind the dune field to the north west. Although there was a gradual trend towards the opening up of the island's landscape, there is little doubt that any newly cleared land was used as pasture rather than arable. This trend is continued to a large extent in the period covered by zone 3, the top part of the diagram. The beginning of zone 3 is dated to AD 1270-1395 (UB 3646). During this period *Betula* disappears entirely, and the Hazel and Alder counts that appear in this part of the diagram must partly reflect input from the mainland (see below). The apparent increase in cereal pollen must once again partly be a product of the decline in *Coryloid* and to a lesser extent, *Betula*. The obvious and dramatic increase in grasses and to some extent, *Cyperaceae*, as well as the increase in *Plantago* species, supports the contention that the
almost entirely open landscape (very similar to that of today) was dominated by pasture, except for the northernmost area of the island which must have been covered by the extensive dune system sometime during this final period. Whether the relatively sudden decrease in *Betula* and Hazel can be attributed to the development of a dune system within a short period of time is open to question, but the dates of these two events could quite feasibly coincide.

Although the vegetational history of Lindisfarne appears at first sight to reflect a typical trend of overall clearance with varying levels of fluctuation, it should pointed out that even during the earliest part of the vegetational history reflected in the diagram, woodland was never a major component; the greatest variation has probably been in the proportion of scrub to open grassland or pasture.

Today, Lindisfarne is characterised by an open, farming landscape. There are relatively few large trees on the island, and those that do exist are concentrated in and around the village. The most common tree species is *Acer pseudoplatanus* (Sycamore). Bushes present today on the island include *Crataegus monogyna* (Hawthorn), which is a common hedging-plant, and *Sambucus nigra* (Common elder). A diverse range of grasses and flowers exists across the main body of the island, and a full list of these can be found in appendix 5.

Within the dune system a range of grasses and shrubs flourish. As one would expect *Ammophila arenaria* (Marram grass) is ubiquitous across the dunes, while many other grass species are also present, including *Parnassia palustris* (Grass of Parnassus), *Spartina anglica* (Common cordgrass), and *townsendii* (Townsend's cordgrass). *Agropyron repens* (Common couch) and *junceiforme* (Sand couch), are also important sand fixing grasses in this area. *Salix repens* (Creeping willow) also exists across the dune system.

Today's flora is one which has its origins in the late medieval period when the little managed woodland that did exist on the island appears to have been exhausted and agriculture may have been extended over a greater part of the island. The development of the extensive dune system on the north shore at some point during this period would also have had a profound impact on the ecology of the island; perhaps reducing variability on this part of the island, but ultimately giving rise to a new and diverse dune flora.
The Lindisfarne Diagram in its Regional Context

As shown earlier, the diagrams from around the north-east of England all show a period of regeneration some time after the Roman occupation had ended. This is not reflected in the Lindisfarne diagram: despite the fact that it covers the period when regeneration takes place elsewhere (between the fifth and tenth centuries AD), the early medieval period on Lindisfarne is characterised by the continued clearance of the island's trees, as the initial clearance phase on Lindisfarne must have taken place some time before the beginning of this diagram. A trend of overall clearance from the beginning of the diagram is indicated, especially in the Coryloid curve. We cannot be sure if this clearance phase follows on from a period of regeneration, as the diagram cannot go much further back than the fifth century AD.

Cereals are continually present in this diagram, while cereals and associated arable indicators fluctuate during this period in the regional diagrams, and completely disappear in some places.

After the early medieval period the regional pollen diagrams from north Northumberland follow similar patterns, although the same trends occur at different times (as indicated by the radiocarbon determinations). In the majority of cases a relatively brief period of clearance is succeeded by another phase of regeneration and ultimately the final phase of clearance in the medieval period. This pattern is not reflected on Lindisfarne where the trend is one of continuous clearance with some fluctuation in zone 2, followed by definite and extensive clearance during the thirteenth and fourteenth centuries. It is possible that mainland regeneration might account for some of the Betula, Alnus and Coryloid recorded from the Lough. It should however be born in mind that certain tree species relatively common on the mainland such as Quercus and Fraxinus are almost or entirely absent from the Lindisfarne record. Also, certain types of arable pollen which appear in the mainland diagrams are entirely absent from the Lindisfarne record, one of the most important being Cannabis which is present only in very small quantities in the later medieval zones of the Fellend Moss and Camp Hill Moss diagrams, and towards the top of the undated Broad Moss diagram.

The Lindisfarne diagram represents a continuous trend of clearance within a region which obviously witnessed quite profound variations during the post-Roman and Medieval periods. It should be noted that regeneration over relatively short time-spans could not necessarily have been as successful on Lindisfarne as on the mainland as colonisation on a tombolo cannot be as efficient as on the mainland. Therefore we must accept that periods of reduced human activity on Lindisfarne may not be reflected in the pollen diagram, and consequently a more finely resolved sampling of the core may be useful.
Conclusion

The Lindisfarne pollen diagram undeniably provides an exceptional vegetation history: well-dated diagrams for well defined localities covering the historic period are a rare phenomenon. It reveals significant changes in the island's vegetation which must largely be a product of human management, although the sudden reduction in trees and shrubs at the start of zone 3 may be related to the inundation of the north shore by blown sand during the late medieval period.

The late date for the inception of peat growth in the Lough is indicative perhaps of digging out of the Lough by the early monastic community: the Lough could have been artificially created, dug out of a natural depression (see chapter 2) with the outflow being controlled in some way (Brown et al. in press). Whatever process lay behind the formation of the Lough, the pollen record contained within it serves as a useful indicator of activity on the island at the time that the Green Shiel site was occupied (see chapter 7).
CHAPTER 8
THE EARLY MEDIEVAL ENVIRONMENT AND ECONOMY OF GREEN SHIEL

Introduction

This chapter brings together the main results and conclusions of the previous chapters which have dealt with the characteristics of the palaeoenvironment of Lindisfarne. This chapter will also include a discussion of two major facets of the Green Shiel sites: the early medieval environment, and the economic/subsistence strategies pursued at the site during the early medieval period. This discussion will detail the nature of the economic context of Northumbria, specifically the area known as Islandshire, within which Green Shiel operated. An underlying assumption is that we can not hope to understand the function of any site without looking beyond the excavation area. The network of relationships that existed between the Green Shiel site and other places is just as important as its own specific situation.

The Early Medieval Environment on Lindisfarne

By this point this thesis has shown that the key to reconstructing the early medieval environment of the north shore of Lindisfarne lies in understanding the history of the dune system. Today the dunes cover about one-third of the island's total area. The investigation into the characteristics of this dune system in the past, specifically during the early medieval period, is crucial to understanding the possible function of the Green Shiel site.

An important element in this work has been the investigation into the form of, and the processes behind, the Lindisfarne dune system. This part of the research concentrated on the area around the Green Shiel site. It investigated the nature of the stratigraphic relationships that exist between the Green Shiel area, the palaeosol and the clay till to the south. The results of this work allowed the topography of the pre-dune environment to be reconstructed. The most important stratigraphical unit in this discussion is the palaeosol. Its stratigraphical position in relation to other units varies across this area: immediately to the south of the settlement site, in the central area of the ridge and furrow, the soil developed directly on top of the glacial till. To the west, in the slack area, the palaeosol emerges as the
present land surface, while to the east the stratigraphy changes and the palaeosol lies on top of a sand unit which in turn covers the till. Moving south of the ridge and furrow area, under the large dune ridge, the palaeosol disappears and the sand is situated directly on top of the clay till. Therefore it is apparent that the palaeosol developed only on the relatively high area of till to the south and east of the Green Shiel site. The soil also developed on top of the sandy unit to the east of the site, towards the shoreline, during what must have been a period of climatic stability when sand blow was of a magnitude low enough to permit this. The complete lack of a palaeosol to the south of the ridge and furrow indicates that the first geomorphic event in this area during the Holocene was sand inundation. This effectively left the ridge and furrow area adjacent to Green Shiel an "island" of till on which a soil could form. It was only with the advent of the intense storms during the high medieval period, or after, that the ridge and furrow was also covered with sand. During the period contemporary with the occupation of the Green Shiel site, during the late eighth and early ninth centuries, the area around Green Shiel and the ridge and furrow was devoid of an extensive dune system, due largely to the lack of high magnitude storm events during this period.

Evidence for the climatic optimum in this area is varied. Although a horizon of stability dated to this period is absent on Lindisfarne, evidence from Northumbria does exist, most notably from Low Hauxley to the south of Lindisfarne (Frank 1982). From Green Shiel itself the biometric analyses of Nucella lapillus (Common dog whelk) indicate less intense wave action in the area (see chapter 4), and therefore supports the widely held contention that the North Sea area witnessed a relatively calm period during early medieval times. The particle size work supports this contention as the sediments from the occupation layers, and beneath the building walls of the Green Shiel settlement, were clearly deposited by forces of a magnitude lower than the sediments found in the dunes and overlying the palaeosol today.

It emerges that the lack of high magnitude storms is probably the key for an understanding of the early medieval environment on the north shore of Lindisfarne. However, it is possible that a dune system of some description may have existed in certain areas of the north shore, such as the Snook for example. There is little doubt that the climatic conditions during this period resulted in a certain level of environmental stability in this area, with a useful agricultural soil relatively unaffected by sand inundation located adjacent to the Green Shiel site, which was itself placed at the top of an extensive sandy beach below the clay cliff-line. The mean temperature in northern Europe is also considered to have been slightly higher during the early medieval period (Lamb 1977: 430). It is believed that arable agriculture was being successfully pursued in environments which are widely considered
as economically marginal today, and were certainly abandoned, or used as poor pasture during the high medieval period (Parry 1978).

Having put the site in its broad geomorphic and climatic contexts, it is necessary to summarise the specific characteristics of the palaeosol, and the palaeoecology.

The palaeosol is a typical homogenous, single grain, apedal, moderately developed, regosol (an A/c soil). It has a mean organic content of c. 0.5% (wet oxidation). The pH of the soil is 9, with a mean calcium carbonate content of c. 2.7%, i.e. it is decalcified compared with some of the modern dune sands. Micromorphological analysis of this soil revealed that microfaunal activity had taken place. It also revealed different levels of development within the profile, and within a pedogenic band located in the blown sand that covered the palaeosol. These analyses show that despite subsequent post-depositional alteration this area would have been able to support a relatively diverse floral community.

The evidence for this soil being used as arable includes the existence of the ridges and furrows which must be associated with ploughing for arable production, and mechanically disturbed till which could have been moved by mouldboard ploughing. Such ploughing may have taken place at any time up to the point of burial by sand which could have taken place as late as the early post-medieval period. The seeds recovered from the flotation programme, although shown to be intrusive by the accelerator date (see chapter 6), may represent an earlier floral community: the assemblage is dominated by *Rumex acetosa* (Common sorrel), a species which is very rare to absent in the ridge and furrow area today (Darlington 1965).

The analysis of the molluscan material implied some level of variability in microhabitats between Green Shiel and the ridge and furrow. The material from the Green Shiel buildings was dominated by *Discus rotundatus* and *Oxychilus alliarius* and *cellarius* as well as *Trichia hispida*. Such an assemblage probably represents the existence of shady and moist microhabitats within a relatively open environment. The material from the palaeosol is typical of such an open environment. Here the assemblage is largely dominated by one species, *Cernuella virgata*. *Pupilla muscorum* is present and dominates one sample which probably represents the transition between the edge of the soil and the beach. Both of these species are typical open country species, probably indicative of short grassland.

The examination of the fungal spore material from the palaeosol, although limited in its usefullness by identification problems, produced some useful information relating to the possible function of this area in the past. Certain fungal spore species present are indicative of either manuring or the actual presence of livestock.
Pollen from the palaeosol was retrieved in negligible amounts only; this was dominated by *Compositae liguliflorae* (Lactuceae type) with Gramineae and Cyperaceae appearing in very low numbers. Limited inferences can be made from such an assemblage, although it can be taken as indicative of pasture of some description.

The investigation into the phytolith assemblage did not (and cannot, given current knowledge) produce species level palaeoecological information. It does however highlight some important and interesting variations in the morphotype compositions of the different samples examined. There are significant differences between the suites of phytoliths found in the modern faecal material of rabbits and sheep, and those from the soil samples. Also, there are significant differences between the suites from the palaeosol and the modern topsoil. Most importantly, there is no significant variation in the suites from the various sample points across the ridge and furrow palaeosol, thus implying that this area was probably characterised by relatively uniform vegetation, although not necessarily lacking diversity.

The pollen diagram from the island Lough shows that at the time of the occupation of the Green Shiel site Lindisfarne was characterised by an open landscape with some areas of hazel scrub-woodland. The generally low levels of cereal pollen throughout the diagram implies that arable farming may have been relatively limited on the island.

The preceding synthesis of the palaeoenvironmental evidence allows us to develop a picture of the environment and its economic potential during the early medieval period. However, any discussion of site function must be put in context with the broader history of settlement in the region.

**The Historic Background to Early Medieval Settlement in the North-East of England**

The following discussion not only considers the early historic settlement of Northumbria, but it also draws out some of the theoretical assumptions regarding the interpretation of sites and their function.

During the Roman and post Roman periods, Northumberland was in some ways characterised by its geographically marginal position in relation to the Roman world. Therefore we might assume that the region was inherently politically unstable as a result of its position as an area under the influence of the Roman Empire, but rarely entirely within
the Imperial fold. Marijke van der Veen has shown from her analysis of seed assemblages from Iron Age and Romano-British sites in the north-east of England that the political instability of the area to the north of Hadrian's Wall was reflected in agricultural practices (1992: 145-156). Her research included multivariate statistical analyses of seed assemblages from six sites in the north-east of England. Three, Thorpe Thewles (NZ 183118), Stanwick (NZ 183118) and Rock Castle (NZ 185067) (group "B"), are located south of Hadrian's wall in the area of the Brigantes. The other three sites, Murton (NT 965496), Dod Law (NU 004317) and Chester House (NU 237025) (group "A"), are all situated north of the wall, and to the south of the Tweed, in the area of the Votadini. The analysis of the crop remains as well as the weed seed assemblages showed that these sites had high levels of annual weeds and possessed soils with high nitrogen contents. These characteristics are indicative of intensive soil preparation (van der Veen 1992: 147). The sites to the south of Hadrian's Wall (group "B") had high levels of perennial weeds and soils with low nitrogen contents. These characteristics are considered to be indicative of fields subjected to less intensive disturbance, perhaps only being ploughed once or twice before sowing. The northernmost sites (group "A") grew emmer, barley and some spelt, while the southern sites (group "B") grew spelt, barley and no emmer. The appearance of spelt on sites during the first millennium BC is considered indicative of agricultural advance. The fact that it is dominant on the group "B" sites, and negligible on the group "A" sites, also supports the idea that agriculture in the south of this region was expanding and advancing, while in the north a more "traditional" regime existed, where arable agriculture was not as significant in food production strategies. As van der Veen observes, given that all environmental factors such as soils, rainfall, temperature and relief are equal across all six sites, the reason for the differences in agricultural strategies must be explained by socio-political phenomena (1992: 150-1). North of Hadrian's Wall settlement at this time was characterised by defended sites where competition between different groups may have been intense. In the south of the region there seems to have been a higher level of political stability. The sites in this area are undefended and would have experienced a greater level of political stability under the aegis of Rome.

During the post-Roman period from AD 400 to 600 evidence for settlement in the Tyne-Forth region is largely comprised of a few fortified sites often referred to as nuclear forts. The nearest forts of this type to Lindisfarne are at Fairfield (NT893477), Milne Graden (NT872438) and Greystonelees (NT952601). All of these sites are situated 20-25km to the west of Lindisfarne. These earthworks have not been excavated, and their chronology is based on morphology, and inference from historical sources. Smith argues that during this period of "British Caputs" the pattern of fortified settlement is quite complete and that a
regular pattern of territorial units can be inferred with each centre being controlled by a minor noble (Smith 1990: 202). There is relatively little evidence for the nature of the economy in the area at this time, although we can assume some continuity from the preceding period, and similarity to the subsequent post-Conquest period, both of which were characterised by a mixed farming economy. The coastal plain of Northumbria did allow very successful arable farming, but in many areas of the north-east the greater proportion of effort was expended on pastoral activity (see Miller 1988: 399-411).

A crucial turning point in the development of Northumbria might be considered to be the battle of Degsastan in AD 603. Here AEthelfrith, king of the English of Northumbria, defeated Aedan, king of the Scots of Dalriata. Bede certainly saw this battle to have been of profound significance for the future stability of Northumbria (Hunter-Blair 1990: 19).

From the end of the sixth and the beginning of seventh centuries AD onwards the pattern of settlement and subsistence, of which Lindisfarne became a crucial part, began to alter. In Northumbria, Anglian strength, and a certain amount of stability, is represented archaeologically by the high-status site at Yeavering, the first phase of which was probably built for AEthelfrith (AD 592-616). The emergent strength of the region is also represented by the establishment of the monastery of Lindisfarne in or about AD 635. The early English Kings of Northumberland divided the region into estates which were then given to their followers, including warriors and monasteries alike. 'The expansion of English Northumbria was more an exercise in patronage than of direct colonization' (Higham 1993: 100). By the 670s large areas of the most valuable land had been passed on to the Church. 'The transfer of entire shires to monasteries such as Hexham, Lindisfarne and Monkwearmouth meant that the richest lands of eastern Bernicia were in clerical hands' (Higham 1993: 137). During this period the monasteries developed a strength and security which largely removed them from the patronage of the King.

The interpretation of the historical documents that relate to settlement development in England as a whole during the period 736 to 1065 has tended to imply that the greatest level of activity was taking place in the southern and West Midland counties (Hallam 1988: 9). While there is only one charter for Northumberland during this period, there are 55 for Kent and 46 for Worcestershire, whilst the average for the forty-one counties considered is c. 13. However there are 12 other documents, including wills, writs and documents relating to the granting of estates, for Northumberland during the pre-Conquest period (Sawyer 1978: 4). We must be aware that the survival of charters and related documents is not necessarily a direct reflection of settlement development. Also, the establishment of
monasteries in the region, including that on Lindisfarne, suggests a level of stability and strength which might not be apparent if we were to rely on documentary sources alone.

The strength and stability of the region undoubtedly start to wain as we move on to the period when the site at Green Shiel was occupied. During this period (the eighth to ninth centuries AD) written sources relating specifically to Lindisfarne itself are largely absent. The late eighth and early ninth centuries do seem on the surface to be a period of great instability. The lack of documentary sources relating to the early medieval period in Northumbria does pose a serious problem when trying to understand this period, and even the post-Conquest period. The fact that the Domessday Book stops at the Tees does not necessarily indicate that Northumbria was an unstable or "poor" area, as Kapelle observes, it merely shows that Northumbria was different from England: a difference which Kapelle believes was due to the fact that the king in this area had a very different role to that he had in England. North of the Tees, the king was the overlord and had no direct powers. There is no evidence for the king having demesne land in Northumbria for example (1979: 12-13).

The first Viking raid on Lindisfarne, in AD 793, did not result in the immediate abandonment of the island. In fact the exact date of the move to the mainland is not known. Probably the most reliable source is the Historia(c9), which states that the bodies of King Ceolwulf and Cuthbert were moved by Ecgred, who was Bishop from 830 to 845. Some time during his period of office, the community moved to Norham-on-Tweed (Sawyer 1978: 5). There is a later tradition which claims that the body of St Cuthbert was not removed from the island until AD 875. The coin evidence from the Green Shiel site (ranging from circa AD 835-871) places the occupation of site within this period of instability. However, we cannot be sure whether the community of St Cuthbert was still present on Lindisfarne while the Green Shiel site was occupied. There is little doubt that Lindisfarne would have been susceptible to attack and the relative safety of the mainland may have been an attractive prospect throughout this period as Norse, and probably more often Danish, raids on Northumbria continued throughout much of the ninth century. These raids culminated in the successful capture of York in AD 867. However, the strength of Danish hegemony in north was somewhat undermined by the death of Healfdene in AD 877. After this the Northumbrian "Saxon" kingship regained a certain level of power. We are sure that the monastic presence was reestablished on Lindisfarne by the tenth century as sculptures dating to this period have been identified (Cramp 1984: 197-208).
The location of Green Shiel

The discussion of Green Shiel's function must include some consideration of why the settlement was located where it is. Today this area, an exposed shoreline with a large dune system, is widely perceived as an economically marginal environment, i.e. an area that offers little in terms of resources and is potentially threatened by shifting sands (bearing in mind that in recent history this part of the dune system does seem to have been the least stable area within the system as a whole). This research has shown that there is no reason to suppose that this part of the north shore of Lindisfarne can be considered in these terms during the early medieval period. More importantly the modern appreciation of the term "marginal" is one mediated by an entirely different understanding of environment to that which must have existed in the past. In any discussion of marginality we must be sure that we differentiate social and economic marginality from geographic marginality. A locality, such as Lindisfarne, may be considered geographically marginal, but it is clearly central, or, important, in cultural terms, and consequently, in socio-economic terms (see chapter 8 for a fuller discussion of this).

Green Shiel may have been a temporary, opportunistic exploitation of a somewhat unusual locality. It is possible that Green Shiel was one of a number of sites on the island sharing a central resource, the land. Also, an important point is that the site is built on sand which may indicate that the land that was available was at a premium and building on this would have removed a substantial part of it from the economy. However, as yet no other settlement sites from this period have been found on the island, although it is possible that the area of the modern village and priory has supported some settlement since early Christian times.

The location of Green Shiel seems sensible for a number of reasons: first, the site is located next to a good source of building material, i.e. the limestone rock from the wave cut platform; second, the occupants had access not only to agricultural land, but also to a range of littoral resources as well as fish. The importance of these resources is considered below.

Anglo-Saxon or Anglo-Scandinavian?

It is important to have some idea as to whether Green Shiel was constructed and occupied by a Viking or an Anglo-Saxon group, as this has some bearing on any discussion of function, and therefore exploitation of the environment. However, it does seem likely that whoever occupied the Green Shiel settlement operated within the pre-existing economic and
social structure, or system, of the Shire or, multiple estate. This is discussed later in this chapter.

It is necessary here to reiterate the point that settlement evidence, along with information for economic and subsistence strategies, is relatively rare for this period, especially for the extreme north-east of England. Therefore many of the discussions of this problem are based on inferences from sites outside of the region, and beyond the temporal boundaries of the early medieval period. Understanding the form and function of sites such as Green Shiel demands that they are studied in relation to other sites, their economic contexts, and the relationship between these.

The artefact assemblage from Green Shiel is very poor, but what material there is, is dominated by Anglo-Saxon material, most notably the coins and the spear head. However, this may not preclude the site from being Scandinavian as the closest parallels for the buildings themselves are those from Scandinavian sites.

It should be made clear from the start that there are no direct analogues for the Green Shiel site. A range of early medieval and medieval sites located in the north of England was considered in chapter Two, but a brief summary of this information is useful here. The nearest parallel to Green Shiel in terms of form is the site at Simy Folds; a similar site also exists at Ribblehead. At both of these sites no distinctive artefact types have been found: `...has integration taken place to such an extent that Scandinavians are no longer culturally identifiable, or are these non-Scandinavian upland settlements of the Viking period?' (Morris 1982: 83). Morris considers that the settlements at both Simy Folds and Ribblehead were in fact relatively self-sufficient and may have actually produced a surplus. It seems that these upland areas during the early medieval period had a climate which permitted the rearing of cattle as well as sheep, along with the possible growing of com, attested to by the presence of a quern-stone at Ribblehead (Morris 1983: 86).

The inability to assign either of these sites as Scandinavian, or non-Scottish, is a problem. There is clearly no parallel for the Green Shiel site, and we cannot identify it as either Scandinavian or Anglian with complete confidence. However, the material culture from the site, along with the importance that must have been attached to the place by the Christian community, does imply Anglian origins for Green Shiel.

The Human Exploitation of the Environment

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Agriculture

In this section the exploitation of the environment, especially agricultural practices, are considered with reference to the nature of agriculture in the north-east as a whole during the early medieval and medieval periods.

There is a lack of information on the types of farming practised in Northumbria during the early medieval and even post-Conquest period, as the Domesday Book does not cover this area. As Hallam notes, this is largely true of most of northern England, which was not included in the survey (1988: 23). Therefore any discussion of early medieval agriculture on Lindisfarne will by necessity be informed by the information that exists for the region as a whole throughout the early medieval period and the early part of the post-Conquest period. This approach obviously has its problems, but is still a useful one, especially in a region where there is a dearth of documentary evidence.

The Organisation of Farming and Field Systems

There is much debate over the origins of the open-field system; some have argued that the fundamentals of this system originated in the Roman world, and would therefore have been present to some extent in certain areas of England when the Anglo-Saxons first arrived (Finberg 1972: 398). It is however improbable that such a system existed in the extreme north of England where Roman influence was not that extensive. More importantly, the Germanic tribes that emigrated to England did not possess such a system at home, and would not have been likely to adopt it on arrival in England (Finberg 1972: 398). It is only for the post-Conquest period that we begin to get a clear idea of the structure and organisation of field-systems in the north-east of England. Even by the fourteenth century no uniform field system existed in the north-east. The impression is that "...irregular and unfinished field arrangements were much more characteristic of northern England than were field systems of the Midland type" (Miller 1988: 401). Some consider that Durham City marks the northern limit of the three-field system and that Northumberland was characterised by a "transitional" system with both "Midland" and Celtic field types (Butlin 1973: 94). Two and three field systems did exist, with places such as Netherwitton in Northumberland possessing a system where arable was interspersed with waste (Miller 1988: 400). Here, waste is taken to mean land that was not continually exploited. It may have been rough pasture, woodland, sources of turf, rushes, fowling areas, in fact any
piece of land which provided resources other than those directly related to arable and pastoral production year in, year out.

What little evidence there is for field-systems in the north-east, even after Domesday, indicates that three field systems were established in some parts of the north-east. In the Durham coastal townships of Fulwell such a system is dated to 1296, and in Alnwick, Northumberland, 35 km to the south of Lindisfarne a three field system is also recorded at 1316 (Miller 1988: 399). However, it does appear that two field systems were also being employed in the region at the same time. Miller considers: 'the impression that remains is that irregular and unfinished field arrangements were much more characteristic of northern England than were field systems of the Midland type' (1988: 401).

It is assumed that the "natural limits" to farming in many areas of Northumberland resulted in the slow development of field systems of the Midland type; pastoral activity was certainly the mainstay of agriculture in many places (Miller 1988 399). Northumberland possessed the arable land on which the lowest value was placed of all the northern counties; it was also considered to have most of the poorest meadow (Miller 1988: 403). The economically "marginal" nature of much of the land in northern England meant that much effort was put into improving the fertility of soil. In Northumberland there is evidence for marling and the application of seaweed to the land, and in some instances the application of sand to the soil was also practised (Miller 1988: 404). As Tuck observes in his discussion of farming in the late fourteenth and fifteenth centuries in the Northern Borders, a fall of only 1 °C in temperature in some places in Northumberland prevents corn from ripening (1991: 41), and as Parry has argued, arable agriculture in southern Scotland and the Borders has been extremely sensitive to climatic change during the last millennia with many upland areas being abandoned during the Little Ice Age (1978).

However, by no means can all of Northumbria be considered as agriculturally marginal. Climatically, the coastal plain of the north-east of England experiences cold, dry winters and cool, dry summers. The coastal plain lies in the rainshadow of the uplands and consequently receives a relatively high level of sunshine; also the land in this area was, and is, generally of a higher quality than that in the rest of the county. Areas along the eastern coastal plain of Northumberland were predominantly arable prior to 1348, but after this there seems to have been a stronger emphasis on pastoral activity. Evidence for this contraction is ephemeral, and it is partly seen as a direct consequence of the decline in population (Tuck 1991: 36). Specifically relating to Lindisfarne, it is noted that, '...the decline in the garbal tithe of Holy Island priory suggests substantial conversion of arable to pasture' (Tuck 1991: 40).
Moving on to consider the information that is available for the field system on Lindisfarne, we can be sure that common, or town, fields were present on Lindisfarne prior to enclosure, although the exact number eludes us. The earliest agricultural map for the island dates to the eighteenth century and shows a basic infield/outfield system with what must be the arable fields surrounding the village. Despite this being the earliest direct evidence of the field system, there is no reason why such a structure should not have its origins in the early medieval period. Whatever the actual structure of the field system we can be confident that arable agriculture on the island during the medieval period was of relatively minor importance compared with pastoral activities. The total acreage of the infields as shown on the manuscript map of c. 1725 is only about 50 acres (see Figure 8.1). The total area of the island excluding the Snook is about 1,100 acres; therefore the total area of infield was just under 5% of the total area of the island. The size of the infield area broadly correlates with calculations of crop yields discussed below. An Act of 1791 and an award of 1793 describe the enclosure of the infields of Holy Island. The Act refers to "a certain large tract of land called or known by the name of Holy Island Common" (Lit. And Phil Soc. of Newcastle upon Tyne, Collections of Local Acts, XIV, no. 10, quoted in Butlin 1973: 109). This tract was some 1023 acres in size (about 93% of the total area of the island). This is much larger than the total area of land which was subsequently enclosed; about 820 acres (about 75% of the total area of the island). Therefore we must assume that this common land included some part, or all, of the dune system, which was also used as a coneygarth. This tract of common land was a stinted common pasture and enclosure demanded the removal of rights of common or "eatage" (Butlin 1973: 109). However, the terms infield and outfield may not be as straightforward in the Northumbrian context as elsewhere in England: the term "infield" seems to have been used in Northumberland "...as a general term describing land which was located near the main settlement and which presumably was subject to a more intensive utilisation than the "outfield" land" (Butlin 1973: 110). Butlin considers in the Northumbrian context that discussions of infields or ingrounds are not necessarily indicative of what is usually considered as the infield-outfield system of agriculture practised elsewhere in the country. He contends that "...the terms were used to contrast the "improved" land near the village with the largely unimproved waste or common. Thus only in a very broad way are they indicative of land management systems" (1973: 137). The reclamation of waste land for arable at different times in Northumbria seems to have been a relatively common practice.
The nature of agricultural organisation on Lindisfarne may have been different to other places because a) it was an island, and b) it was a monastic community. Therefore we should be careful when using generalised models of agricultural organisation, especially when discussing field-systems. Although the existence of two or more open fields on a large estate may have been relatively common (Finberg 1972: 417), we cannot be sure that this was the case on Lindisfarne.

**Agricultural Production in the North-East of England**

In this section the basic structure of agriculture in the north-east of England during the early medieval period is reviewed. The extent and nature of both arable and pastoral production is considered with reference to post-Conquest practices as well, due to the limited data from the pre-Conquest period.
**Arable Activity**

In Anglo-Saxon England there were four dominant crops: wheat and rye, which were usually sown after the harvest, and barley and oats, which were planted in the spring (Finberg 1972: 420).

Inference from medieval records of crop regimes in the region are not terribly useful as the varying ratios of the different crops grown in the area would have been dictated by a complex set of influences from markets, to taste and climate. In other words there would have been a complex range of factors affecting both yield and the perceived value of a crop which would have influenced the level of production. All we can be sure of is that a range of crops that included wheat, barley, oats and peas, were definitely grown during the medieval period.

In terms of winter crops, wheat seems to have been the most important on the better soils, including the Northumberland plain. On the poorer soils of the north, oats would have been more successful. Barley does not appear to have been an important alternative in this region during the post-Conquest period (Miller 1988: 406).

During the early medieval period there is little doubt that arable was of relatively minor importance in many areas of northern England. The pollen diagrams from the north-east (see chapter 6 above) show a period of limited woodland regeneration during the seventh to ninth centuries, followed by renewed clearance. Woodland species in many areas were replaced by pastoral indicators such as *Plantago lanceolata* and *Rumex*. Even though the north-eastern coastal zone provided some excellent arable land, the rearing of livestock was probably the most important element of many farming systems in this area. It should be noted that historically Northumbrian agriculture concentrated on livestock rearing and fattening; this practice has decreased in recent decades as the amount of land taken into arable was increased (Jarvis 1984: 31). An increase in arable activity does appear to have taken place during the twelfth and thirteenth centuries, although, once again, the lack of Domesday coverage for the region is a problem. In the Vill of Bamburgh for example, 42% of demesne land (about 87 acres) was sown with wheat during the winters of 1250-1281 (Miller: 1988: 406).
Pastoral Activity

As argued above, in many areas of north-east England arable activity was quite limited: in this part of England, especially outside of the coastal zone, subsistence strategies during the medieval period were characterised by animal husbandry practices of various types.

During the medieval period poultry was of limited importance, and goats and horses varied in their significance around the region; by the far the two most important animals were sheep and cattle. Durham priory is known to have had a flock of about 4,000 during the 1340s (Miller: 1988: 409), while cattle herds all over the region were clearly of impressive proportions. Much of the evidence implies that mortality in both sheep and cattle was relatively high in the north, and the lamb to ewe and calve to cow ratios were also below the national average. Miller assumes that this is partly due to the climatically "marginal" nature of the region, this being attested to the fact that "...flockmasters and graziers, and sometimes arable farmers too, were using land that in earlier generations was less intensively used or not used at all' (1988: 411).

Cattle were more important in early medieval England than sheep in terms of the number of places that took their names from association with this kind of farming (Hallam 1988: 34). The distribution of pastoral specialisation showed a high level of continuity between the pre- and post- conquest periods.

During the early Anglo-Saxon period the pig seems to have been almost as important as the sheep, and Finberg asserts that swine were actually more important than sheep (1972: 408). However, the limited archaeological evidence from the north of England does not confirm this. Analyses of the animal bone assemblages from the sites considered above (chapter 1) were inconclusive, and merely showed that both pig and sheep were present on most sites during the early medieval period.

Once again, incontrovertible evidence for economic and subsistence strategies in early medieval north-east England is clearly lacking. By employing evidence which is both temporally and spatially diverse, we can make some general inferences: early medieval agriculture in the north-east of England was dominated by pastoral activity, perhaps especially so during the seventh to ninth centuries. However, the more fertile coastal plain of Northumbria may have been characterised by a more intensive arable regime than the rest
of the region. The following section considers how Lindisfarne may have fitted into this system.

Agriculture on Lindisfarne

Arable Activity

We cannot be sure what crops were grown on Lindisfarne during the early medieval period, although we can make certain assumptions based on the discussion of the regional trends considered above, and Bede's *Life of St Cuthbert*, which informs us of the problems that Cuthbert experienced in growing wheat whilst on Inner Farne. When St Cuthbert's wheat failed to grow he is reported to have said, "perchance it is not accordance either with the nature of this land or with the will of God that wheat should grow for me in this place; bring me, I beg you, some barley, to see if perchance that may produce a crop" (Colgrave 1969: 221). Although barley is known to flourish further north than wheat, we cannot necessarily assume that wheat did not grow on Lindisfarne, or on the adjacent mainland; why would St. Cuthbert have attempted to grow wheat on Inner Farne if he had not had experience of its successful growth before he began his hermitude? However, it is important to note that Cuthbert had travelled widely all over the north of England and may have witnessed the growth of wheat in a number of places quite distant from Lindisfarne.

The specific data relating to arable production that does exist for the island comes from the post-Conquest period. However, there is a further problem with this information as much of it relates to economic production for the whole estate (the organisation of which is discussed below). First, the infield system around the village, as shown on figure 8.1, is relatively small and therefore indicates that arable production on the island was not as extensive as pastoral activity. Second, the tithes from the sixteenth century indicate that arable farming remained at a low level throughout the medieval period. When the tithe was worth 20s, the maximum area under crop would have been about 94 acres, possibly a lot less (Fox, *pers comm.*). This figure indicates that roughly twice the acreage included in the infield map of 1725 could have been arable land. Finally, the paraphernalia of arable farming is largely absent from the archaeological record of the island. It is known that during the later medieval period ploughs and grain were stored on the mainland at Fenham where the Lindisfarne monks had a mill (Raine 1857).

A low level of arable activity on the island is also attested by the pollen diagram from the Lough; at one point during the medieval period cereal pollen almost disappears from the
diagram. Like any pollen diagram, that from Lindisfarne only implies an overall level of arable activity and cannot be used to infer specific crop regimes. In the Lindisfarne study we can never be certain that actual characteristics of the crop regime as this cannot even be inferred from documentary evidence, as this is always temporally and spatially specific.

The area of land adjacent to the Green Shiel site has consistently been referred to as the ridge and furrow area; however, it is very unlikely that the ridge and furrow is contemporary with the early medieval settlement. The straightness of the furrows implies a relatively late date for this, but obviously prior to the inundation of the area by blow-sand. In Northumberland the width of ridges ranges from about four metres to about fifteen. 'Its form was not often straight accept where the ridge was relatively narrow at four or five metres' (Dixon 1986: 132).

The earliest ridge and furrow in England is that from Gwithian in Cornwall which is dated by manuring finds to AD 550 to 850 (Fowler & Thomas 1962). At Hen Domen in Montgomeryshire "pre-Norman" ridge and furrow has also been identified (Barker & Higham 1982).

The ploughing of the ridge and furrow area in the dunes on Lindisfarne may be a typical example of the Northumbrian practice of temporary intakes where areas usually considered as waste were exploited for arable from time to time. Such areas of temporary ploughing would rarely have developed large ridges.

The lack of cereal remains, combined with the fungal-spore evidence which is indicative of pastoral activity, does point to this area having been predominantly used as pasture, probably for cattle. The period of ploughing probably represents an attempt at arable farming at some point. However, it is possible that this enterprise was short-lived due to disappointing results.

The relatively small area taken up by the infields indicates that arable production on Lindisfarne was probably quite restricted. This should not be too surprising as it should be remembered that fields probably produced a relatively small proportion of total diet, "...since early-medieval crop yields could be appallingly low" (Tebrake 1984: 172). Therefore emphasis should be placed on considering arable production as just one element of a much more extensive network of strategies. We can only assume that early medieval arable activity on Lindisfarne produced quantities of wheat, barley and perhaps oats, adequate for the needs of the monastic community. It seems unlikely that the arable regime on Lindisfarne produced a surplus that could be traded off the island. In fact the island may have been reliant on inputs of crops from other parts of the estate (see discussion below).
Pastoral Activity

There is little direct evidence for early medieval pastoral activity on Lindisfarne. It is assumed that the area of the island not given over to arable, i.e. most of the island, was used as a pasture. The faunal assemblage from the buildings at Green Shiel (as understood at the time of writing) is dominated by cattle, and its composition is tentatively interpreted as being typical of a dairy herd (Virr 1989) (see chapter 2). During this period, the ridge and furrow area was probably used as pasture; however the quality of such a pasture is difficult to assess. Many of the grasses in this area probably fell into the bent category of grasses, predominantly *Agrostis* species. As cattle require pasture of a good quality, the area around Green Shiel could probably only have supported a relatively small number of animals, unless this area was just one amongst a number used by the Green Shiel population.

The documentary evidence for pastoral activity on Lindisfarne is, as mentioned above, problematical as the main source, the priory rolls, is a post-Conquest record of the whole estate and does not always differentiate between the different parts of the estate. There is one entry for 1376, which refers to 20 oxen and cows for the larder, 54 pigs young and old, and 100 muttons that were specifically located in the island pasture. At some point during the post-Conquest period rabbits were introduced onto the island, undoubtedly into the dune area where the population still flourishes despite continual outbreaks of myxomatosis. Rabbits on Lindisfarne are mentioned in the documents from the fourteenth century onwards and became a useful source of income (priory rolls cited in Raine 1857). The introduction of rabbits into the dune area implies that such an area was of relatively little use as pasture of any quality. Therefore we might infer that the quality of this pasture had deteriorated by the high Middle Ages, perhaps as a result of increased sand inundation.

Other Resources

There are of course a whole range of other resources that the settlement at Green Shiel would have required in order to function. There would also have been a limited range of other resources that probably would have been exploited by the occupants of the site.

The most important resource for any site is of course fresh water. There are no rivers or streams on Lindisfarne, and the only substantial body of fresh water is the Lough on the
eastern side of the island. Historically the island's population has always been reliant on springs or wells. Although no wells appear to exist in the dune system today, there was at least one known well in the nineteenth century adjacent to the Kennedy limeworks (O.S. 1924, sheet N VIII.11). It should also be noted that in the northern area of ridge and furrow fresh water is encountered at a depth of between 50 and 70 centimetres, which is above the level of the clay till in this area. Fresh water is also reached at a similar depth in the slack area to the south of Green Shiel. Therefore there is little reason to doubt that large quantities of fresh water were easily obtainable on the north shore of the island in the past.

Woodland

The pollen diagram (see above, chapter 6) indicates that limited woodland resources were available throughout the early medieval period. During this period the island would have possessed limited hazel and birch woodland. It is quite likely that the hazel woodland would have been coppiced and the material therein exploited for a number of purposes, including poles for withies, and wood for fires (see above chapter 6). There is no clear indication that major trees such as Oak were present on the island; therefore large timbers would have to have been imported from the mainland.

The Sea Shore

Although agriculture was probably the most important element of the subsistence and economic strategy followed by the inhabitants of Green Shiel, we can be sure that other naturally occurring resources would also have been exploited, the most obvious being shellfish. There is even a possibility that the site contributed this resource to the economy of the estate as a whole. Shellfish do seem to have been considered as a useful and important food: Bede refers to the diversity and abundance of shellfish on Britain's coasts, specifically mentioning both cockles and mussels (Blair 1990: 11). However, there can be no suggestion that shellfish comprised an important element in the diet of the occupants of Green Shiel. As Bailey (1978) points out, if nothing else were consumed, a single person would have to eat c. 400 limpets per day. Margaret Deith has described ethnographic evidence which suggests that agriculturalists often use wild foods, gathered in the course of the farming process, as "relishes" (1988). The term "relish" is of course a loaded term, filled with modern connotations. We can consider such resources as marginal foods collected at opportune moments, or at specific times of the year. Or, alternatively, such
resources can be considered as "high value" resources which take on cultural importance at specific times. Estyn Evans has described how in Dundalk Bay...mussels for the table and for bait are scraped up from boats with long handled rakes. Easter and Good Friday in particular were times for visiting the shore' (Evans 1957: 224). The gathering of shellfish may have been just a minor element within the wider food production and procurement system, or it could have been an important economic practice, with some trading value. In either case it is important to realise that farming is not mutually exclusive to other food procurement strategies.

Shellfish can also be considered as evidence for fishing. There is no direct evidence for fishing having taken place from the Green Shiel site, although we might assume that it was undertaken, even if to a limited extent. This part of the shoreline has certainly been used as a place from which to fish in recent history. Just along the shoreline, to the west of the Green Shiel site, the eves of a nineteenth century Shiel are still standing. Such a building would have been a working base for fishermen exploiting this part of the shore. The presence of the *Patella* species on a site has been considered as evidence for fishing as some consider this shellfish unappealing as a food. D.V. Clarke in his discussion of Skara Brae argues that there is little evidence, archaeological or ethnographic, for the common consumption of limpets by people; therefore we might assume that they were used as bait for fishing (1976 & 1976a). However, we can not be confident with this type of inference as there is no reason to suppose that limpets were not consumed as a food: as Evans observed in his *Irish Folkways*, limpets were considered more palatable than winkles after St Patrick's day (Evans 1957: 224). He also noted that shellfish were boiled in milk and fed not only to children but to calves as well. It is clear that shellfish have been, and still are, an important resource for some people. Not only is the marine mollusc itself important, but the shell is also a useful resource in certain environments as a soil fertiliser where low pH levels are a problem. In the case of Lindisfarne, and specifically the area around Green Shiel, acidic soils were probably never a problem, partly due to the fact that the soil matrix is largely comprised of sand with a reasonably high proportion of shell.

One other littoral resource which may have been exploited, although there is no archaeological evidence for it from the Green Shiel site, is sea weed. Historically sea weed has been used as a food source as well as fertiliser (Bell 1981). It is known that sea weed was burnt to produce potash (Jermy 1992: 21). Indirect evidence for sea weed having been brought onto the Green Shiel site may be inferred from the presence of certain small marine mollusca which would have been of little or no benefit as food or bait. Such species include *Littorina neritoides* and *Littorina saxatalis*, both of which constitute 0.26% each of the total
maritime mollusc assemblage from house C (see above, chapter 2). However, the evidence for sea weed exploitation by the Green Shiel occupants is largely based on assumption.

The Structure of the Early Medieval Economy: The Shire and the Multiple Estate

The function and economy of the Green Shiel site cannot be understood without locating the site within the wider economic network of the early medieval estate and shire. The nature of economic/political control is as important as the characteristics of the environment within which a site is located: the economic organisation of an area largely dictates how any environment is exploited.

As with the history of early medieval agriculture, the background to early medieval economic and political organisation is clouded by the lack of documents for the region. As considered earlier in this chapter, the lack of Domesday coverage for the region limits our understanding of early post-Conquest organisation as well. However, we are sure that the *vills* of the Domesday book did extend into County Durham and Northumberland, `

...clinging to the coastal lowlands and valley lands in the foothills,...' (Roberts 1977: 60). We can be sure of this because the Bishop of Durham compiled a survey similar to, but not as extensive as, the Domesday book, known as the Boldon Book. This survey reveals the north of England as an area possessing "thriving" village communities which were arable based, `

...but in their rents and services revealing a pastoral sub-stratum which may well be of great antiquity' (Roberts: 1977: 60). In these two counties, *vills* were sometimes grouped in order to render service to a Lord. As Barrow notes, `

from Kent to Northumbria, without a break, some system of "extensive" royal lordship, based upon a unit known variously as lathe, soke, shire or *manerium cum appendicis*, had survived long enough for its main features to be traceable in record of the eleventh and twelfth centuries' (1973: 27)

In the context of this discussion of northern Northumbria, it is the organisation of the multiple estate which is most important, although it is accepted that there is some controversy surrounding the definition of such organisational structures (Gregson 1985). It would appear that the Cumbrian and Northumbrian multiple estates of the post-conquest period have their origins in the pre-conquest era. As O'Sullivan notes of Cumbria, `

...it seems best to see the multiple estate as without ethnic affinities; it was simply the most appropriate and efficient system for utilising a range of upland and lowland resources in areas without the benefit of centralised government, a good communications network or
developed markets' (1984: 148). It was a system which was adapted by Britons, Anglo-Saxons and Anglo-Scandinavians alike. The period between the seventh and ninth centuries possibly saw the establishment of the majority of foci of the parochial system which was apparent physically in the twelfth and thirteenth centuries (O'Sullivan 1984: 149).

Glanville Jones in his authoritative account of the multiple estate argues that 'the multiple estate in the wider sense of a substantial territorial entity, initially a hundred and later a commote over which regalian rights were exercised, contained nearly all the resources, physical as well as human, needed to sustain its economy, including arable, pasture, meadow, woodland, water, and, not least, labor' (Jones 1984: 32). Higham supports this assessment of the structure of early medieval economy in Northumbria, 'shires were long-lived and self-contained economic systems within which a degree of specialization may have occurred, with one group of tenants responsible for renders of fish, another of honey, a third of barley, and so on. Given the variable quality of the environment confronting most northern communities, such specialization was probably a sound method of exploiting the natural resources of a territory and this element of specialization encouraged a degree of exchange within the several communities of the estate, without the need for an external system of markets' (Higham 1993: 263). However, it should be noted that in many of the places which constitute the multiple estate, many of these resources would have been available within the locality.

One important caveat in the discussion of the multiple estate is the nature and level of Scandinavian impact on pre-existing estates. We cannot be sure what direct effect the Viking raids and invasions had on the economic and subsistence structures of the region. One important question is the extent to which the pre-established estate structures, with their concomitant economic practices, survived. Although the impact of a few notorious military raids should not be underestimated in the context of high level political structures, we might be correct in assuming that many of the pre-existing economic structures in the form of the estate, and the related subsistence strategies, were not undermined or altered to any great extent. The Lindisfarne community continued to exist even if it were not based on the island itself, which was the case during the latter part of the ninth century when it established itself at Chester-le-Street. However, the St Cuthbert community had been dispossessed of large parts of County Durham, and we cannot be sure if Lindisfarne itself was never settled by a Scandinavian group. Whether the St Cuthbert community continued to exist on Lindisfarne itself is open to question, although we might consider the importance that might have been attached to the place itself and therefore the perceived importance of re-establishing a presence there as soon as possible after the Viking raid.
It is assumed that in the long term the structure and organisation of rural economies in the north-east did not alter to any great extent as a direct result of the Scandinavian settlement in the area. In fact, Scandinavian settlement in the northern part of Northumbria above the Tyne (Bernicia) was not extensive. The Norse raiders who were responsible for the early incursions, including that on Lindisfarne in AD 793, did not settle in this area, concentrating their efforts in the Irish Sea basin. From the first half of the ninth century AD onwards the Danes made substantial inroads into northern England, while Norse influence was largely restricted to the upper valleys of the Tees and Wear (Higham 1986: 309).

Bailey points out that by the middle of the ninth century there was a clear division between Deira and Bernicia, the two sub-kingdoms of Northumbria. Despite this, a level of cultural unity was maintained until about the middle of the tenth century when mainly Anglian Bernicia, centred on Bamburgh, was quite distinct from the Anglo-Scandinavian regions that were ruled from York (Bailey 1980: 37). Despite the impact of the Scandinavians, and the fact that Ragnald in c. 919 as the King of York gave some of the Cuthbert community's estates to his supporters (Morris 1983: 86), it seems that the community of St Cuthbert continued to gain extensive estates during the Viking period, and managed to maintain its lands in both Anglian, and Anglo-Scandinavian, Northumbria (Bailey 1980: 37).

Roberts argues that the Anglo-Saxon and Scandinavian patterns of economic practice were broadly similar. In his general model, he states that there were two elements to the organisation of exploitation of the environment, and that these elements were indivisible. First, there was the pattern of economic exploitation: villages with their fields, pastures and meadows; this set-up was integrated with the second pattern, that of the administrative organisation of society which extended beyond the single village (1977: 72-3).

The lands of Lindisfarne included much of what came to be Berwickshire, Norhamshire and Islandshire. The structures of Norhamshire, Coldingham and Islandshire are reasonably well understood, largely because they had been given to St Cuthbert, and church estates tend to remain unaltered for long periods of history (Barrow 1973: 28). The estates lying closest to Lindisfarne may have been a part of King Oswald's (AD 634/5-642) original endowment (Smith 1984: 181). Vills such as these, would have been organised into the administrative unit of the shire in order to give service to a Lord, or thegn. This network of estates and shires allowed the integration of different types of settlement, e.g. upland summer pasture, lowland arable and winter grazing, into unified organizational units. Smith argues that the pattern of exploitation during the late Anglian period in the low lying areas of the region was characterised by `...dispersed, nucleated settlements, surrounded by tracts of arable, with outlying pasture, meadow and woodland' (Smith 1984: 182). During the early thirteenth century Islandshire comprised the coastal plain area
from Elwick in the south to the river Tweed in the north, an area of about 60 Km² (see figure 8.2). At this point the estate centre was at Fenwick on the mainland, but during the early medieval period it is quite possible that the centre would have been on Lindisfarne itself (Jones 1976). Although our understanding of obligations within the post-Conquest multiple estate is reasonable, we are unsure to what extent such obligations would have been different during the early medieval period. There is little doubt that the network of obligations would have been affected by the Scandinavian raids and settlement, and Lindisfarne's position in the multiple estate would have been in flux during the late eighth and ninth centuries. During this period the settlement at Green Shiel may have functioned as an economically insignificant, but politically significant, place within the multiple estate. It may have contributed livestock and dairy produce to the estate, with secondary inputs, in the form of littoral and marine resources, also making some contribution. The range of resources that it may not have been able to provide for itself, mainly arable produce, would have been drawn from the mainland elements of the estate, the strong links with a wider market and estate structure attested to by the relatively high number of coins found on the site.

Figure 8.2: shows the tenurial organisation of Islandshire in the early thirteenth century, when the estate centre was clearly at Fenwick (Jones 1976: 64).

Conclusion
This chapter has brought together a wide range of archaeological, historical and environmental evidence in an effort to elucidate the possible economic function of the Green Shiel site. An important part of this synthesis has been a discussion of wider historical processes which were contingent upon the economic (especially agricultural) practices in the north-east of England during the early medieval period. These various strands of evidence allow us to make full use of the palaeoenvironmental evidence and consequently produce models of subsistence and economic strategies for the site.

The palaeoenvironmental evidence indicates that the north shore of Lindisfarne lacked the extensive dune system that is characteristic of this area today. It is considered that the site may have been a temporary response to Scandinavian raiding, or in any case, a settlement exploiting a specific set of resources within the economic and political structure of the multiple estate. Green Shiel would have contributed a range of resources, mainly livestock, and perhaps certain marine resources to the estate, while it would have been in receipt of any resources that it could not provide for itself. However, we cannot be sure whether the establishment of the Green Shiel settlement was a response to economic requirements, or whether it was a particular cultural or political response during a time of instability.
CHAPTER 9

CONCLUSION

Introduction: the Aims of the Research

The fundamental aim of this research has been to show how our understanding of a settlement site can be greatly enhanced through the investigation of its landscape context. Specifically, this thesis has shown how the study of the immediate environs of a site can tell us just as much about site function as the study of building structures and the artefacts found therein.

The Green Shiel case study has shown how a wide range of environmental and archaeological and historical evidence can be integrated, and consequently allow the articulation of a sophisticated discussion of settlement and economy. Chapter One reviewed the approaches to the investigation of medieval settlement that have been prevalent during the post World War II period. It was argued that the majority of research has placed too much emphasis on the very particular study of settlement buildings and artefacts. It was shown that approaches which attempt to understand site function through an investigation of a site's relationship with the wider environment and landscape, both at a local and regional scale, are quite rare. The Lindisfarne case study placed the Green Shiel site within its socio-economic context through the scientific analysis of palaeoenvironmental information, as well as a consideration of the archaeology of the site itself and historical processes in the region as a whole.

This research was concerned to show how site-based approaches limit the potential of archaeological interpretation and that more rigorous accounts of past subsistence patterns and economic strategies could be produced through an integrated "landscape" approach that takes cognisance of local and regional environmental data, historical evidence, as well as site-based data.

It was argued that too much research into the Dark Ages, especially in northern England, has avoided the analysis of environmental context, and the dearth of artefactual evidence which is common on many of these sites has reinforced notions of the north as marginal to the rest of England, and the Dark Ages as marginal to the rest of History. Part of this problem relates to variations in usage and meaning of a whole range of terms or ideas employed by archaeologists, historians and environmental scientists. Most important is the idea of "marginality" and associated terms. In many instances, previous research in this region has just assumed a geographical, and almost
by default, an economic marginality, rather than attempting to reconstruct past environments and consider each site as a specific case.

The Environmental/Archaeological Dialectic

This research has shown that the Lindisfarne sand dune system has been, and still is to a certain extent, a dynamic and changing system, one which was quite different during the early medieval period. Chapters Three to Seven described and discussed the nature of change in this environment and indicated how environmental conditions were when the site at Green Shiel was occupied.

In previous chapters the so-called "marginality" of Lindisfarne, and in particular, the dune system, has been considered. Here, I wish to expand this discussion through a consideration of the different uses of the term "marginal" and how our modem use of the term, and perception of an environment, informs our view of palaeoenvironments and our understanding of the human activity that took place there.

Today we consider the Green Shiel site, or rather the environment within which it is located, as both geographically and economically marginal. Specifically, we mean that it is a relatively fragile environment, and as we are dealing with a dune system, a potentially unstable environment. If farmers were granted access to the area, it could only offer very limited poor grazing for sheep. This thesis has shown that the physical environment of the north shore of Lindisfarne was quite different during the early medieval period: the dune system was not as extensive, a stable soil was situated adjacent to the settlement site, and the climate was probably more favourable for agricultural activity. Despite the fact that this area may be perceived today as both geographically and economically marginal there is little evidence to support this view of the area during the early medieval period. In order to appreciate more fully notions of marginality and how these may have varied, we need to reconsider our understanding of marginality and land use in the past.

A non-economically marginal locality can be defined as an area which is economically productive, or where the success of a certain economic, especially agricultural, activities, is likely to succeed, while a marginal locality can be considered as an area where an economic practice is statistically prone to failure or low productivity (see Adams 1976: 157).

The transition of an environment to marginal status is often accepted as an explanation, or a reason, for settlement abandonment, or cultural poverty of one sort or another. Randsborg (1980) is a typical example of where a direct correlation is made between
environment (specifically climate) and socio-economic development. The correlation between the major climatic optima and the periods of expansion of the open land for fields and pastures suggests that better harvests in the first place, created a population growth which later caused inroads to be made into the forested area. *The reverse must have happened at the onset of poorer climatic conditions [my italics]* (Randsborg 1980: 53). In this example there may be evidence for the former (but there are still problems with the implications of this), but the assumption that the formula works in reverse is a particularly worrying piece of environmental determinism. This type of approach often relegates, or omits, discussions of socio-economic or cultural factors which influence where and how environments are exploited. If such a deterministic position were to be adopted regarding Green Shiel, we might argue that the site was abandoned in response to the deterioration of the environment, specifically the development of the dune system. However, Green Shiel was probably abandoned during the latter part of the ninth century AD (O’ Sullivan & Young 1991: 67) while the dune system is unlikely to have expanded until some point during the Little Ice Age, between the sixteenth and nineteenth centuries. It is therefore unlikely that sand inundation initiated the abandonment of the site. Also, there is no other identifiable aspect of environmental deterioration which took place during the ninth century. There are undoubtedly some situations where climatic deterioration is the most important factor in forcing settlement abandonment. This certainly seems to be the case with late medieval farm abandonment in Iceland, although in many instances people transferred their efforts from farming to fishing during periods of climatic deterioration (Sveinbjarnardóttir 1992). However, it is apparent that the abandonment of the settlement at Green Shiel must be explained by socio-economic and cultural factors, and just as importantly, there is no reason to assume that the establishment of the settlement was indirectly a result of a climatic amelioration.

**Marginality in the Middle Ages**

Marginality as it is understood today in the context of the discussion about Green Shiel is a complex term. We need to appreciate that marginality would have meant something very different during the ninth century. We cannot hope to understand the exact nature of risk perception, and concepts relating to marginality during this period. However, by appreciating that such ideas would have been mediated by the socio-economic and cultural configurations of the early medieval period we can go some way towards understanding further the settlement at Green Shiel.

Our understanding of the early medieval environment and its exploitation is also constructed through the language, or more specifically, the terminology, that we use.
More problematical is the fact that different disciplines use the terms in different ways, or intend different meanings. The discussion of the environment and function of Green Shiel has been informed by a number of different disciplines and sub-disciplines whose use, or intended meaning, of the terminology varies.

The term "waste", i.e. land that is not exploited to the same extent as permanent arable and pasture, is an important concept in the discussion of Green Shiel and its immediate environs. The concept of waste needs to be considered in relation to infields, outfields and the idea of marginality. Infields were the areas of land deemed to be the most productive in terms of arable agriculture. Usually located around, or adjacent to the settlement, they tended to receive all of the winter dung (Adams 1976: 82). The crops grown in these fields were for food or brewing, as opposed to straw or animal fodder. Outfields were an extension of the infield system where crops were only grown for restricted periods and no manuring was carried out. It should be noted that the infield/outfield system is often associated with Scotland and northern England (Adams 1976: 155). Waste was land which was considered to be uncultivated or uncultivable, and often provided non-agricultural resources such as wood, peat, thatch, and "wild" foods. Waste was often brought into the agricultural system as pasture or even arable through improvement. Waste land is typically referred to as marginal, in that it is thought to be relatively unproductive and not continually in use. We know that Lindisfarne during the later medieval period possessed about 50 acres of infields (see above, chapter 7), and almost all of the remaining area of the island was known as "Holy Island Common" (referred to as such in the Enclosure Act of 1791). It has been argued that the infield system on Lindisfarne comprised a similar area during the early medieval period (see above, chapter 7). We can assume that the remaining land on the island comprised a mixture of outfield and so-called waste. However, as noted above, these terms are confusing, so we should consider that the remaining area on the island was merely land that was not always under arable, but was used for a range of purposes, including the pasturing of animals, the management of small-scale woodland (especially hazel), and the growing of grass for hay.

Part of the reason for the common perception of Lindisfarne as being economically marginal lies with the problem of generally considering the "North" per se as economically marginal. Such a perception is reinforced by a variety of phenomena. These include biogeographical distribution maps and the related discussions which show that there is a fall-off in terms of temperature, floristic diversity, crop yields etc. towards the north. This is compounded archaeologically by many site distribution maps which often indicate that settlement was much less intense than in the southern half of the country. That is not too say that either of these representations are false, but rather that they emphasise and exaggerate this notion of marginality. For example, Welch's
Anglo-Saxon England (1992) through almost all of its distribution maps, and discussion of these, gives the impression that Anglo-Saxon settlement was largely concentrated close to, or below, the Wash-Severn line. This is admittedly a function of where the archaeological sites have been found, but it also gives the impression that the northern part of the country was marginal to the south in all senses of the word.

This thesis has shown that much needs to be done to rectify this position. Even when sites are discovered and excavated, their environmental context is often ignored, or relegated to a series of specialist reports which are hardly synthesised with the main body of the archaeological discussion (see above, chapter 1). Sites in the north of England, especially those situated in Cumbria or Northumberland, are intuitively contextualised in physical environments deemed to be "marginal". Unless each excavation pursues an investigation of the environmental conditions contemporary with the site being researched, then no more than a description of its form and material culture is possible. Sites located within this region will continue to be considered as economically, and therefore, politically and culturally marginal, and their establishment, function, and abandonment, explained by a vague appreciation of environmental, or more specifically, climatic change.

The research at Green Shiel aims to reconstruct the early medieval environment as fully as possible, as it is recognised that the function of the site cannot be understood without an appreciation of the surrounding environment. However, this scientific investigation of the palaeoenvironment cannot fully elucidate site function without a knowledge of the contemporary socio-economic structures. Even if Green Shiel were situated in an economically marginal locality during the ninth century, it should be apparent that such an environmental risk would have been mediated by the socio-economic and cultural mechanisms of that time. As Beck (1992) observes, all risks have increasingly become controlled and mediated by political institutions. The vast majority of risks are actually produced by society, or rather by governments through scientific and technical agencies. Consequently, the definition and management of risks are also mediated by government agencies. This is important, as we should be clear that our ideas of what is acceptable as a risk, or what is accepted as a "useful" environment, is largely mediated by society, or those organisations which govern society. In order to understand early medieval settlement on Lindisfarne we need to appreciate the processes behind the choosing of monastic sites. In the context of the Green Shiel site, we should be aware that the location of a secular settlement would not have been divorced ideologically from those ideas that influenced monastic settlement.

Originally the monastic existence, as established in the Middle East, placed great emphasis on asceticism and eremiticism. Members of a monastic community often lived in solitude and fasting, deprivation of sleep, and other forms of bodily mortification,
were the standard weapons of the ascetic's armoury in his struggle for self-conquest' (Lawrence 1989: 6). It was often important for the monastery to be situated away from secular centres and influences that might distract the religious community in their pursuit of piety. In this sense monasteries were often located in geographically marginal places, but only in the sense that such localities were often relatively distant from "central" places. A monastery would obviously require access to a wide range of resources; therefore location in an economically marginal place would have been unlikely. However, a monastery would not necessarily need to be self-sufficient and many resources would have been imported, or provided from other areas of the estate. Not all monasteries were located in remote localities: many Irish monastic establishments were located in areas with good communications. As Edwards illustrates, monasteries such as that at Clonmacnois required access to good communications if they were to attract prestige and wealth (1990: 104).

The monastery on Lindisfarne was established by Aidan in AD 635. The life followed by the community on Lindisfarne was based on that established by St Columba on Iona (Lawrence 1989: 58). For this reason a brief consideration of the location of the monastery on Iona is useful.

Iona is a small island (5.5km in length, 2.5km wide) located off the western tip of the Ross of Mull in Scotland. The island may be described as typically geographically marginal, and in some senses it may have been economically marginal when compared with some areas on the mainland. In recent times only relatively small areas seem to be suitable for arable agriculture, with much of the island being covered by moorland, although levels of crop production during the nineteenth century seem to have been quite high compared to other areas in the region (RCHM(S) 1982: 10). Agricultural activity has been undertaken on Iona since about 5,000 BP (Scaife & Dimbleby 1990: 48); therefore the island was a viable farming environment prior to the arrival of the monastic community. Today the island bears witness to a previously enhanced level of agricultural activity: ancient field boundaries are common over much of the island's moorland. Despite the fact that Iona clearly possessed a viable farming environment, there is little doubt that its location is remote and that it would not have been as agriculturally productive as many other places in the region. Iona was undoubtedly chosen for its geographical remoteness, a characteristic which would have been important for the Columban eremitic and ascetic existence. Despite this remoteness, Iona's importance as a centre of Christian influence was indisputable; its political and cultural function was of central importance. However, it can be argued that Iona did become politically marginalised to some extent after the dispute with the Roman church over the calculation of Easter which culminated in the Synod of Whitby in AD 664 which accepted the Roman argument (RCHM(S)(S) 1982: 47).
The Ionan mission to Northumberland, requested by King Oswald, would have required sites which were conducive for the Columban way of life. However, this mission was undertaken within a specific political context which would have influenced the location of any monasteries. The development of the Northumbrian monasteries was jointly nurtured by the Northumbrian aristocracy and the Columban missionaries. The land granted by the aristocracy was generally of a good quality, and the locations often possessed good communications, and strong associations between religious sites and royal centres were promoted. Many of the Northumbrian monasteries were founded at the behest of the Northumbrian Kings: Whitby, Tynemouth, Hartlepool and Jarrow were all founded during the seventh century AD (Cramp 1976).

Lindisfarne would have possessed the remoteness demanded by a Columban community, although the fact that it is a tidal island obviously permits greater contact with the adjacent mainland. As this thesis has shown, Lindisfarne was a viable farming environment, albeit with an emphasis on pastoral activity. But as with Iona, there would have been many other locations which would have possessed land of a superior quality within the area. Therefore Lindisfarne's physical characteristics, i.e. its remoteness and relatively harsh environment, would have been important for the founders of the monastic community. From this it seems that early medieval society did have clear notions of what kind of environment certain monasteries should be located in. In some senses some of the localities were probably considered as geographically marginal, but they obviously required access to certain resources and communications. Therefore striking a balance between economic needs and the requirements of an eremitic existence was key.

Both the geographical and economic marginality of such a locality would soon have become an irrelevance once the monastery was established. The centrality of the place would have been guaranteed by the presence of such an important political and cultural force. Lindisfarne would have formed an important axis with the royal site at Bamburgh. Together they would have been a powerful political and social force in this part of the Northumberland.

If we accept that the Green Shiel site was in some way related to the monastic system present on Lindisfarne, we should consider that a similar understanding and appreciation of environment, marginality, and the related risks must apply. If the Green Shiel settlement was Anglo-Saxon (as discussed above, chapter 7), it may have been a temporary response to the Viking raids and the need to maintain some kind of presence on the island once the monastery was abandoned, or it may have been an element of the monastic economy, occupied contemporaneously with the monastery in its final days. In either case similar notions of environment would have applied. The occupants of both the monastery and Green Shiel would not necessarily have considered the
environment on Lindisfarne as one characterised by environmental hazards or risks as such notions would have been mediated by the monastic structure, especially through the economic buffering provided by the multiple estate. As it is we can be quite sure that the potential environmental hazards on the north shore of Lindisfarne during the early medieval were limited as dune development did not occur until the late medieval period. Consequently doubt must placed on any idea that Lindisfarne, or more specifically, Green Shiel, was economically marginal, or subject to environmental hazards which may have posed a threat to the settlement's economy. However, today there is little doubt that the Lindisfarne dune system is a relatively fragile and unstable environment. Consequently, this poses a series of problems for the environmental archaeologist wishing to reconstruct the palaeoenvironment.
Conclusions Concerning Methodology

As will be apparent from the preceding chapters the reconstruction of the palaeoenvironment on the north shore of Lindisfarne demanded that a wide range of methodological approaches be employed. The key strategic move at the outset of the research was the decision to look beyond the site of the Green Shiel excavation, and investigate the relationship between the site and the surrounding sediments, most importantly, the palaeosol.

This research did not aim to test a certain set of pre-defined methods decided upon before the fieldwork had commenced. Rather, the methods that were used for environmental reconstruction were decided upon once the initial survey of the area and the sediments had been completed, and the potential for environmental reconstruction had been assessed. Although palaeoenvironmental work has been carried in similar environments (e.g. Mellars 1987), no single project can offer a ready-made strategy that can be grafted onto another project no matter how similar the environments.

This research has also highlighted the problems and usefulness of certain palaeoenvironmental techniques, especially those which are relatively new. The original aim of the research was not to "test" a set of techniques, or indeed, define a methodological approach for the study of dune environments. However, the experience of investigating such a problem does mean that a number of methodological issues have been identified. Any specific technical problems that were encountered were dealt with in the relevant chapters above. This section considers the methodological strategy as a whole.

The investigation of geomorphological processes has been of fundamental importance to the reconstruction of the early medieval environment. There is little doubt that in terms of the environmental investigations that were carried out for this research, it is the study of the geomorphology and soils around the dune system that has been most successful. The reconstruction of the sub-dune topography and the discussion of the stratigraphic relationships between the Green Shiel site and the surrounding topography forms the basis for the reconstruction of this environment. The geomorphological characteristics of a sand dune system are the most important element within such an environment; they directly affect the ecology, and consequently, the economic potential of the environment. A surprisingly useful technique which gives some insight into the nature of the aeolian processes at work today and just prior to the construction of the Green Shiel settlement is particle-size analysis. These results revealed clear differences in mean grain size, sorting, skewness and kurtosis between the different environments studied. The results of this work supported the results of the biometric analysis of
Nucella lapillus (Common dogwhelk), both of which indicated a less intense aeolian regime during the early medieval period. This hypothesis was supported by the historical evidence relating to storm frequency and intensity, and the general theories relating to the Little Ice Age (Lamb 1977, 1991). It is accepted that documents relating to frequencies of events are problematic in that there is an overall increase in the production of historical sources over time. The reporting of environmental, or more specifically, climatic events, may not necessarily have been pursued purely out of curiosity, or for the sake of science; it was only during the seventeenth and eighteenth centuries that the environment was studied "scientifically" to any great extent (Bowler 1992: 100-1). The early reporting of these events would largely have been due to an economic interest in the landscape; climatic events would have been noted if they had a direct negative impact on a place. This is especially so in the Netherlands (where much of the storm data considered in chapter 4 originates) which has always been susceptible to flooding and storm events. Such historical records can only serve to provide a general impression of climatic trends and can only be used to confirm hypotheses relating to a specific archaeological site. Such data cannot be employed in the actual construction of a hypothesis relating to specific environmental context of a site.

The methods employed in the investigation of the buried soil were many and varied. Estimates of organic content and calcium carbonate yielded some useful results, while the micromorphological study of the soil permitted a more specific and detailed description of the soil which complimented the other work. The investigation of the palaeoecological material from the buried soil clearly showed that there is poor preservation in this soil. The seed assemblage seems to be intrusive (see chapter 5), although it is dominated by a species which is rare or absent on the north shore of Lindisfarne today. This aspect of the research exposes the problem of dating small seeds from sandy deposits where such material can easily be transported down through the sediment. However, this problem would not have been revealed unless the seeds had been dated. Obviously, carbonised seeds from secure archaeological contexts are desirable, but in this instance such material is entirely absent.

The terrestrial mollusc assemblage is dominated by one species which is problematical to a certain extent in that such a lack of diversity is very rare. However, the ecological preferences of the species present do not contradict any of the other information produced during the research.

The analysis of the phytolith material produced information of limited palaeoecological significance, although it did support the inferences made from the other analyses of palaeoecological material. Just as important as the palaeoecological information was the actual trial of the technique itself. The phytolith study showed that these silica bodies do survive in sediments with a very high pH, although in very low frequencies and often
in a deteriorated form. Despite this, differences between modern phytolith suites in the
ridge and furrow area and ancient ones were indicated. It is quite clear that this
technique is still in the developmental stage in Britain, and many more case studies are
required, along with the production of reference material.

Another relatively underused technique is the analysis of fungal spores. Fungal spores
were present in reasonable quantities in the buried soil. In one respect they yielded the
most specific ecological information, indicating the presence of animal dung in the area.
However, the low numbers of identifiable spores greatly detracted from the potential of
this technique. There is though clearly much scope for the application of this technique,
especially in archaeology as certain spores are good indicators of certain types of
agricultural activity. The planned production of a fungal spore key by Gerraint Coles
and Ciera Clarke will undoubtedly enhance the potential of the technique.

Finally, the dearth of pollen in the buried soil is unfortunate and highlights the general
level of poor preservation in sandy palaeosols. Such sediments are characterised by
extreme physical and chemical weathering processes and it is not really surprising that
relatively little palaeoecological evidence survives. Microfaunal activity is responsible
for the moving of seeds through the sediment, while high pH levels are responsible for
the complete or partial destruction of much pollen and phytolith material.

The lack of palaeoecological material from the palaeosol was in some senses
compensated for by the pollen diagram from the Lough which is an extremely useful
piece of ecological data, especially as the radiocarbon dates span the Middle Ages.

Combined, the methods employed in the reconstruction of the early medieval
palaeoenvironment of the Green Shiel environs produced a wide range of data-types,
although sometimes the quantities of certain ecofacts were quite low. A sand dune
system by its very nature poses a set of exceptional problems for the environmental
archaeologist who assumes that a more orthodox set of palaeoecological techniques,
such as palynology, molluscan analysis and seed analysis, will provide the necessary
information. An environment whose fundamental characteristics are moulded by
gemorphological processes obviously demands that the history of geomorphological
process be investigated extensively. Where possible, palaeoecological reconstruction
has been attempted, but the most useful palaeoecological data came from the pollen
diagram from the Lough. This diagram, in conjunction with the few regional diagrams
available from the north east region (see above, chapter 5), allowed a consideration of a
much wider spatial environmental context which is just as important as the specific
context of the Green Shiel environs itself. This thesis has shown that too much reliance
on palaeoecological methods in environmental archaeology is potentially quite
restricting. The full potential of geoarchaeology has been illustrated in this research.
The recognition of the fact that environmental processes on the north shore of Lindisfarne are, and have always been, dominated by geomorphological processes is of great significance and clearly illustrates the need for archaeologists to fully appreciate the potential of geoarchaeology.

The use of environmental data from different spatial scales is in many ways the key to the successful reconstruction of any site's palaeoenvironment. As this research has shown, the function of the Green Shiel site can not be understood without an appreciation of its environmental context and the potential for various economic strategies. This research concentrated on the reconstruction of the environment local to Green Shiel, i.e. the north shore of Lindisfarne. However, it was recognised that the function of this site could not be understood without reference to the palaeoenvironment of the island as a whole, and to a lesser extent the wider region of North East England. This environmental evidence had to be considered in conjunction with what we know about the economic and political organisation of this area during the early middle ages.

Although the greater part of this research has been concerned with the reconstruction of the physical environment contemporary with the settlement of the Green Shiel site, it is felt that this type of work in isolation is quite meaningless to the archaeologist who must ultimately be concerned with people and their actions as societies. This thesis has integrated some quite diverse datatypes, including palaeocological and geomorphological evidence, and historical evidence. The integration of such varied data types is however potentially dangerous. In certain situations such integration could involve the use of one type of data to reinforce another "weaker" piece of evidence: for example one might be tempted to use documentary evidence to support an hypothesis about farming practices generated by a poorly dated pollen diagram. This type of problem is most likely to occur when quite specific resources or practices are being considered. The Lindisfarne study has employed both palaeoenvironmental evidence and documentary evidence whenever possible. Palaeoenvironmental evidence can only inform generalised models of possible human activity in any given environment. While the documentary evidence for the early medieval period is non-specific in as far as it can not be directly correlated spatially or temporally with the Green Shiel site, it can confirm or contradict any inferences made from the palaeoenvironmental data. The most important advantage of considering these two very different types of data together is the fact that they allow us to consider processes at different scales: Much of the palaeoenvironmental evidence discussed in this thesis is specific to the North Shore of Lindisfarne, or the island as a whole. As I have argued, such spatially specific data does not always allow us to develop rigorous hypotheses regarding site function. There can be little doubt that human activity on Lindisfarne during the historical period (and probably prior to this) has been greatly influenced by processes beyond the island.
itself. However, there is admittedly little specific documentary evidence that relates to economic practices on Lindisfarne during the early medieval period. What evidence there is clearly implies that the island would have been an integral element within the multiple estate system (see chapter 7). The fact that the island, and the settlement site at Green Shiel, would have been a part of a well organised socio-economic system that functioned as a kind of collective is crucial to the interpretation of the site. If the site had been considered in isolation, or indeed Lindisfarne had been considered as a socio-economic and ideological island, lacking strong links with the mainland, then the ultimate interpretation of Green Shiel's function would have been quite different.

'Then let me implore you my dear Raphael,' said I, 'describe that island to us. Don't try to be too brief, but explain in order everything relating to their land, their rivers, towns, people, manners, institutions, laws - everything, in short, that you think we would like to know. And you can assume we want to know everything that we don't know yet.'

_Utopia._ Thomas More
Appendix 1

Chi-square tests of the marine mollusc assemblages from Green Shiel, building "C".

Test 1

Chi-square test of total of assemblage from building "C" against major contexts from building "C" and sample from "tower" excavation. The four most numerous species included in the test: Littorina littorea, Littorina littoralis, Nucella lapillus and Patella species.

Expected counts are printed below observed count

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<td>544.37</td>
<td>978.95</td>
<td>20.71</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>24051</td>
<td>3758</td>
<td>6758</td>
<td>143</td>
<td>34710</td>
</tr>
</tbody>
</table>

ChiSq = 0.274 + 6.935 + 1.143 + 0.414 + 166.237 +1.1E+03 + 0.527 + 0.768 + 4.498 + 21.815 + 54.393 + 0.557 + 204.925 +284.732 +206.337 + 0.160 + 64.444 +137.515 + 45.874 + 6.592 + 11.467 +121.815 +214.258 + 0.017 + 2.323 + 36.197 + 61.845 + 11.921 = 2784.889

df = 18

1 cells with expected counts less than 5.0
### Test 2

Chisquare test of total of assemblage from building "C" against major contexts from building "C" and sample from "tower" excavation. *Littorina littorea* and Patella species only included.

<table>
<thead>
<tr>
<th></th>
<th>littea</th>
<th>pat</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12463</td>
<td>3455</td>
<td>15918</td>
</tr>
<tr>
<td></td>
<td>12426.36</td>
<td>3491.64</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2088</td>
<td>757</td>
<td>2845</td>
</tr>
<tr>
<td></td>
<td>2220.95</td>
<td>624.05</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>687</td>
<td>316</td>
<td>1003</td>
</tr>
<tr>
<td></td>
<td>782.99</td>
<td>220.01</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>3150</td>
<td>310</td>
<td>3460</td>
</tr>
<tr>
<td></td>
<td>2701.04</td>
<td>758.96</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1479</td>
<td>213</td>
<td>1692</td>
</tr>
<tr>
<td></td>
<td>1320.86</td>
<td>371.14</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>790</td>
<td>482</td>
<td>1272</td>
</tr>
<tr>
<td></td>
<td>992.98</td>
<td>279.02</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>3394</td>
<td>1225</td>
<td>4619</td>
</tr>
<tr>
<td></td>
<td>3605.82</td>
<td>1013.18</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>24051</td>
<td>6758</td>
<td>30809</td>
</tr>
</tbody>
</table>

\[
\text{ChiSq} = 0.108 + 0.384 + \\
7.958 + 28.322 + \\
11.768 + 41.881 + \\
74.624 + 265.577 + \\
18.934 + 67.384 + \\
41.494 + 147.673 + \\
12.443 + 44.282 = 762.831
\]

\[\text{df} = 6\]

### Test 3

Chisquare test of entire assemblage from building "C" against the sample assemblage from the "tower" excavation. Three most numerous species included: *Littorina littorea, Littorina littorails* and Patella species.

Expected counts are printed below observed counts

<table>
<thead>
<tr>
<th></th>
<th>littea</th>
<th>lital</th>
<th>pat</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12463</td>
<td>2073</td>
<td>3455</td>
<td>17991</td>
</tr>
<tr>
<td></td>
<td>12396.08</td>
<td>1936.37</td>
<td>3658.55</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>3394</td>
<td>404</td>
<td>1225</td>
<td>5023</td>
</tr>
<tr>
<td></td>
<td>3460.92</td>
<td>540.63</td>
<td>1021.45</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>15857</td>
<td>2477</td>
<td>4680</td>
<td>23014</td>
</tr>
</tbody>
</table>

\[
\text{ChiSq} = 0.361 + 9.640 + 11.325 + \\
1.294 + 34.528 + 40.563 = 97.711
\]

\[\text{df} = 2\]
Test 4

Chisquare test of entire assemblage from building "C" against the sample assemblage from the "tower" excavation. The two most numerous species included: *Littorina littorea*, and *Patella* species.

Expected counts are printed below observed counts

<table>
<thead>
<tr>
<th></th>
<th>litea</th>
<th>pat</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12463</td>
<td>3455</td>
<td>15918</td>
</tr>
<tr>
<td></td>
<td>12290.58</td>
<td>3627.42</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>3394</td>
<td>1225</td>
<td>4619</td>
</tr>
<tr>
<td></td>
<td>3566.42</td>
<td>1052.58</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>15857</td>
<td>4680</td>
<td>20537</td>
</tr>
</tbody>
</table>

\[ \text{ChiSq} = 2.419 + 8.195 + 8.335 + 28.242 = 47.191 \]

\[ \text{df} = 1 \]
Appendix 1a

Marine mollusc sample weights before and after immersion in acid solutions. Weights in grammes. Weight 1 = the weight of the sample before immersion; weight 2 = the weight of the sample after immersion.

<table>
<thead>
<tr>
<th>Species</th>
<th>Acid</th>
<th>Weight 1</th>
<th>Weight 2</th>
<th>% of Original weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patella</td>
<td>Acetic</td>
<td>20.4</td>
<td>16.73</td>
<td>82%</td>
</tr>
<tr>
<td>Patella</td>
<td>Formic</td>
<td>8.7</td>
<td>3.97</td>
<td>45.6%</td>
</tr>
<tr>
<td>Patella</td>
<td>Hydro'</td>
<td>17.4</td>
<td>14.79</td>
<td>84.9%</td>
</tr>
<tr>
<td>Littoreia littorea</td>
<td>Acetic</td>
<td>2.3</td>
<td>0.761</td>
<td>33.1%</td>
</tr>
<tr>
<td>Littoreia littorea</td>
<td>Formic</td>
<td>2.2</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Littoreia littorea</td>
<td>Hydro'</td>
<td>2.7</td>
<td>0.68</td>
<td>25%</td>
</tr>
<tr>
<td>Mytilus edulis</td>
<td>Acetic</td>
<td>3.4</td>
<td>2.14</td>
<td>63.08%</td>
</tr>
<tr>
<td>Mytilus edulis</td>
<td>Formic</td>
<td>3.8</td>
<td>1.02</td>
<td>26.97%</td>
</tr>
<tr>
<td>Mytilus edulis</td>
<td>Hydro'</td>
<td>4.5</td>
<td>2.739</td>
<td>60.86%</td>
</tr>
<tr>
<td>Cerastoderma edulis</td>
<td>Acetic</td>
<td>2.7</td>
<td>1.1566</td>
<td>42.83%</td>
</tr>
<tr>
<td>Cerastoderma edulis</td>
<td>Formic</td>
<td>2.6</td>
<td>0.435</td>
<td>16.738%</td>
</tr>
<tr>
<td>Cerastoderma edulis</td>
<td>Hydro'</td>
<td>2.1</td>
<td>1.156</td>
<td>55.06%</td>
</tr>
<tr>
<td>Nucella lapillus</td>
<td>Acetic</td>
<td>1.7</td>
<td>0.447</td>
<td>26.27%</td>
</tr>
<tr>
<td>Nucella lapillus</td>
<td>Formic</td>
<td>2.4</td>
<td>0.0213</td>
<td>88.75%</td>
</tr>
<tr>
<td>Nucella lapillus</td>
<td>Hydro'</td>
<td>2.1</td>
<td>1.005</td>
<td>47.86%</td>
</tr>
</tbody>
</table>

Marine mollusc sample weights before and after immersion in alkaline solutions. Weights in grammes. Weight 1 = the weight of the sample before immersion; weight 2 = the weight of the sample after immersion.

<table>
<thead>
<tr>
<th>Species</th>
<th>Alkal'</th>
<th>Weight 1</th>
<th>Weight 2</th>
<th>% of Original weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patella</td>
<td>Sodium</td>
<td>13.622</td>
<td>13.617</td>
<td>99.96%</td>
</tr>
<tr>
<td>Patella</td>
<td>Potass'</td>
<td>11.7202</td>
<td>11.50</td>
<td>98.12%</td>
</tr>
<tr>
<td>Littorina littorea</td>
<td>Sodium</td>
<td>2.6453</td>
<td>2.6066</td>
<td>98.53%</td>
</tr>
<tr>
<td>Littorina littorea</td>
<td>Potass'</td>
<td>1.8008</td>
<td>1.522</td>
<td>84.51%</td>
</tr>
<tr>
<td>Mytilus edulis</td>
<td>Sodium</td>
<td>3.1572</td>
<td>3.1098</td>
<td>98.49%</td>
</tr>
<tr>
<td>Mytilus edulis</td>
<td>Potass'</td>
<td>3.0505</td>
<td>2.89</td>
<td>94.73%</td>
</tr>
<tr>
<td>Cerastoderma edulis</td>
<td>Sodium</td>
<td>4.2807</td>
<td>4.133</td>
<td>96.54%</td>
</tr>
<tr>
<td>Cerastoderma edulis</td>
<td>Potass'</td>
<td>2.163</td>
<td>1.8987</td>
<td>87.78%</td>
</tr>
<tr>
<td>Nucella lapillus</td>
<td>Sodium</td>
<td>2.0745</td>
<td>2.0041</td>
<td>96.6%</td>
</tr>
<tr>
<td>Nucella lapillus</td>
<td>Potass'</td>
<td>1.3773</td>
<td>1.3035</td>
<td>94.64%</td>
</tr>
</tbody>
</table>
Appendix 2

Descriptive Statistics Of Occupation Levels Of Green Shiel Settlement

Levels of occupation layers of building "c"

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>MEAN</th>
<th>MEDIAN</th>
<th>TRMEAN</th>
<th>STDEV</th>
<th>SEMEAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>C3</td>
<td>10</td>
<td>5.6956</td>
<td>5.7000</td>
<td>5.6839</td>
<td>0.0956</td>
<td>0.0302</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MIN</td>
<td>MAX</td>
<td>Q1</td>
<td>Q3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.5720</td>
<td>5.9130</td>
<td>5.6165</td>
<td>5.7255</td>
<td></td>
</tr>
</tbody>
</table>

Levels of occupation layers of building "A"

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>MEAN</th>
<th>MEDIAN</th>
<th>TRMEAN</th>
<th>STDEV</th>
<th>SEMEAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>C6</td>
<td>34</td>
<td>5.8369</td>
<td>5.8325</td>
<td>5.8311</td>
<td>0.0766</td>
<td>0.0131</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MIN</td>
<td>MAX</td>
<td>Q1</td>
<td>Q3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.7200</td>
<td>6.0390</td>
<td>5.7920</td>
<td>5.8665</td>
<td></td>
</tr>
</tbody>
</table>
Appendix 3

Descriptive Statistics For Particle Size Analysis

1) Ridge and Furrow
The following descriptive terms are taken from Briggs (1977: 80).

Sample 6: Ridge & Furrow, Cntxts 21 & 24a

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median</td>
<td>2.21</td>
<td></td>
</tr>
<tr>
<td>Mean 1</td>
<td>2.19</td>
<td></td>
</tr>
<tr>
<td>Mean 2</td>
<td>2.18</td>
<td></td>
</tr>
<tr>
<td>Skew 1</td>
<td>-0.06</td>
<td>Symmetrical</td>
</tr>
<tr>
<td>Skew 2</td>
<td>-0.04</td>
<td>Symmetrical</td>
</tr>
<tr>
<td>Sort 1</td>
<td>0.39</td>
<td>Well Sorted</td>
</tr>
<tr>
<td>Sort 2</td>
<td>0.37</td>
<td>Well Sorted</td>
</tr>
<tr>
<td>Kurt 1</td>
<td>1.17</td>
<td>Leptokurtic</td>
</tr>
<tr>
<td>Kurt 2</td>
<td>1.13</td>
<td>Leptokurtic</td>
</tr>
</tbody>
</table>

Sample 10: Burried Soil From Ridge And Furrow

Descriptive Stats

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median</td>
<td>2.28</td>
<td></td>
</tr>
<tr>
<td>Mean 1</td>
<td>2.30</td>
<td></td>
</tr>
<tr>
<td>Mean 2</td>
<td>2.28</td>
<td></td>
</tr>
<tr>
<td>Skew 1</td>
<td>0.03</td>
<td>Symmetrical</td>
</tr>
<tr>
<td>Skew 2</td>
<td>0.05</td>
<td>Symmetrical</td>
</tr>
<tr>
<td>Sort 1</td>
<td>0.38</td>
<td>Well Sorted</td>
</tr>
<tr>
<td>Sort 2</td>
<td>0.37</td>
<td>Well Sorted</td>
</tr>
<tr>
<td>Kurt 1</td>
<td>1.38</td>
<td>Leptokurtic</td>
</tr>
<tr>
<td>Kurt 2</td>
<td>1.52</td>
<td>Very Leptokurtic</td>
</tr>
</tbody>
</table>

Sample 36: Ridge & Furrow Pit, Burried Soil

Descriptive Stats

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median</td>
<td>2.28</td>
<td></td>
</tr>
<tr>
<td>Mean 1</td>
<td>2.23</td>
<td></td>
</tr>
<tr>
<td>Mean 2</td>
<td>2.22</td>
<td></td>
</tr>
<tr>
<td>Skew 1</td>
<td>-0.06</td>
<td>Symmetrical</td>
</tr>
<tr>
<td>Skew 2</td>
<td>-0.31</td>
<td>Very Negatively Skewed</td>
</tr>
<tr>
<td>Sort 1</td>
<td>0.29</td>
<td>Very Well Sorted</td>
</tr>
<tr>
<td>Sort 2</td>
<td>0.30</td>
<td>Very Well Sorted</td>
</tr>
</tbody>
</table>
Kurt 1  1.83 Very Leptokurtic  
Kurt 2  4.86 Extremely Leptokurtic

Sample 38: Slack Pit Soil  
Descriptive Stats

<table>
<thead>
<tr>
<th>Stat</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median</td>
<td>2.20</td>
<td></td>
</tr>
<tr>
<td>Mean 1</td>
<td>2.18</td>
<td></td>
</tr>
<tr>
<td>Mean 2</td>
<td>2.18</td>
<td></td>
</tr>
<tr>
<td>Skew 1</td>
<td>-0.09</td>
<td>Symmetrical</td>
</tr>
<tr>
<td>Skew 2</td>
<td>-0.04</td>
<td>Symmetrical</td>
</tr>
<tr>
<td>Sort 1</td>
<td>0.36</td>
<td>Well Sorted</td>
</tr>
<tr>
<td>Sort 2</td>
<td>0.35</td>
<td>Well Sorted</td>
</tr>
<tr>
<td>Kurt 1</td>
<td>1.28</td>
<td>Leptokurtic</td>
</tr>
<tr>
<td>Kurt 2</td>
<td>1.36</td>
<td>Leptokurtic</td>
</tr>
</tbody>
</table>

Ridge And Furrow Area

Sample 25: Ridge And Furrow Pit, Sand From Below Burried Soil  
Descriptive Stats

<table>
<thead>
<tr>
<th>Stat</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median</td>
<td>2.25</td>
<td></td>
</tr>
<tr>
<td>Mean 1</td>
<td>2.44</td>
<td></td>
</tr>
<tr>
<td>Mean 2</td>
<td>2.45</td>
<td></td>
</tr>
<tr>
<td>Skew 1</td>
<td>0.18</td>
<td>Positively Skewed</td>
</tr>
<tr>
<td>Skew 2</td>
<td>0.17</td>
<td>Positively Skewed</td>
</tr>
<tr>
<td>Sort 1</td>
<td>0.34</td>
<td>Very Well Sorted</td>
</tr>
<tr>
<td>Sort 2</td>
<td>0.33</td>
<td>Very Well Sorted</td>
</tr>
<tr>
<td>Kurt 1</td>
<td>0.83</td>
<td>Platykurtic</td>
</tr>
<tr>
<td>Kurt 2</td>
<td>0.77</td>
<td>Platykurtic</td>
</tr>
</tbody>
</table>

Sample 43: Ridge And Furrow, Sand From Below Modern Soil.  
Mean 1  2.19  
Mean 2  2.17  
Skew 1 -0.28 Negatively Skewed  
Skew 2 -0.154 Negatively Skewed  
Sort 1 0.265 Very Well Sorted  
Sort 2 0.262 Very Well Sorted  
Kurt 1 1.212 Leptokurtic  
Kurt 2 1.353 Leptokurtic

Sample 50: Modern Top Soil.  
Mean 1  2.203  
Mean 2  2.185  
Skew 1 -0.259 Negatively Skewed  
Skew 2 -0.166 Negatively Skewed  
Sort 1 0.26  Very Well Sorted  
Sort 2 0.249 Very Well Sorted  
Kurt 1 1.263 Leptokurtic  
Kurt 2 1.516 Very Leptokurtic

272
2) Green Shiel Building
Sample 14: Cntxt 363; 956/1011

Descriptive Stats

Median  
2.28
Mean 1 2.29
Mean 2 2.31
Skew 1 0.26 Positively Skewed
Skew 2 0.16 Positively Skewed
Sort 1 0.27 Very Well Sorted
Sort 2 0.26 Very Well Sorted
Kurt 1 1.15 Leptokurtic
Kurt 2 1.36 Leptokurtic

Sample 24: Bleached Sand From Beneath East Wall

Median 2.25
Mean 1 2.25
Mean 2 2.24
Skew 1 0.00 Symmetrical
Skew 2 0.00 Symmetrical
Sort 1 0.21 Very Well Sorted
Sort 2 0.22 Very Well Sorted
Kurt 1 1.28 Leptokurtic
Kurt 2 1.58 Very Leptokurtic

Sample 27: East Wall, Sand, Below Wall

Descriptive Stats

Median 2.24
Mean 1 2.23
Mean 2 2.22
Skew 1 -0.14 Negatively Skewed
Skew 2 -0.07 Symmetrical
Sort 1 0.17 Very Well Sorted
Sort 2 0.19 Very Well Sorted
Kurt 1 1.18 Leptokurtic
Kurt 2 1.71 Very Leptokurtic

Sample 28: East Wall, Red Sand From Below Wall Stones

Descriptive Stats

Median 2.27
Mean 1 2.26
Mean 2 2.27
Skew 1 0.04 Symmetrical
Skew 2 0.00 Symmetrical
Sort 1 0.20 Very Well Sorted
Sort 2 0.21 Very Well Sorted
Kurt 1 1.26 Leptokurtic
<table>
<thead>
<tr>
<th>Sample</th>
<th>Location</th>
<th>Descriptive Stats</th>
</tr>
</thead>
<tbody>
<tr>
<td>29: East Wall, Sand From Between Top Rocks</td>
<td>Median 2.19, Mean 2.20, Mean 2.18, Skew 1 -0.24 Negatively Skewed, Skew 2 -0.20 Negatively Skewed, Sort 1 0.24 Very Well Sorted, Sort 2 0.23 Very Well Sorted, Kurt 1 1.30 Leptokurtic, Kurt 2 1.45 Leptokurtic</td>
<td></td>
</tr>
<tr>
<td>32: East Wall, Sand From Below Wall</td>
<td>Median 2.25, Mean 2.25, Mean 2.25, Skew 1 0.00 Symmetrical, Skew 2 -0.28 Negatively Skewed, Sort 1 0.22 Very Well Sorted, Sort 2 0.26 Very Well Sorted, Kurt 1 1.79 Very Leptokurtic, Kurt 2 5.05 Extremely Leptokurtic</td>
<td></td>
</tr>
<tr>
<td>54: Green Shiel Building, Context 363. (HCl Treated)</td>
<td>Mean 1 2.26, Mean 2 2.26, Skew 1 -0.08 Symmetrical, Skew 2 0.029 Symmetrical, Sort 1 0.155 Very Well Sorted, Sort 2 0.164 Very Well Sorted, Kurt 1 1.052 Mesokurtic, Kurt 2 1.527 Very Leptokurtic</td>
<td></td>
</tr>
<tr>
<td>55: Green Shiel Building, Context 383. (HCl Treated)</td>
<td>Mean 1 2.186, Mean 2 2.195, Skew 1 -0.139 Negatively Skewed, Skew 2 -0.112 Negatively Skewed, Sort 1 0.295 Very Well Sorted, Sort 2 0.315 Very Well Sorted, Kurt 1 1.532 Very Leptokurtic, Kurt 2 1.542 Very Leptokurtic</td>
<td></td>
</tr>
<tr>
<td>56: Green Shiel Building, Context 414.</td>
<td>Mean 1 2.196, Mean 2 2.207, Skew 1 -0.088 Symmetrical, Skew 2 -0.058 Symmetrical, Sort 1 0.28 Very Well Sorted</td>
<td></td>
</tr>
</tbody>
</table>
Sort 2 0.292 Very Well Sorted
Kurt 1 1.377 Leptokurtic
Kurt 2 1.41 Leptokurtic

Sample 57: Green Shiel Building, Context 375.
Mean 1 2.235
Mean 2 2.226
Skew 1 -0.007 Symmetrical
Skew 2 0.071 Symmetrical
Sort 1 0.23 Very Well Sorted
Sort 2 0.264 Very Well Sorted
Kurt 1 1.541 Very Leptokurtic
Kurt 2 1.814 Very Leptokurtic

Sample 58: Green Shiel Building, Context 385.
Mean 1 2.203
Mean 2 2.201
Skew 1 -0.162 Negatively Skewed
Skew 2 -0.099 Symmetrical
Sort 1 0.265 Very Well Sorted
Sort 2 0.266 Very Well Sorted
Kurt 1 1.266 Leptokurtic
Kurt 2 1.472 Leptokurtic

Sample 59: Green Shiel Building, Context 383.
Mean 1 2.216
Mean 2 2.211
Skew 1 -0.106 Negatively Skewed
Skew 2 0.020 Symmetrical
Sort 1 0.255 Very Well Sorted
Sort 2 0.267 Very Well Sorted
Kurt 1 1.522 Very Leptokurtic
Kurt 2 2.093 Very Leptokurtic
**Dune Samples**  
Sample 15 Sf 5 Dune

**Descriptive Stats**

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<th>Sort 1</th>
<th>Sort 2</th>
<th>Kurt 1</th>
<th>Kurt 2</th>
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Sample 39: Dune Crest

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<th>Sort 2</th>
<th>Kurt 1</th>
<th>Kurt 2</th>
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Sample 44: Dune Blow Out; Mid Height.

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<th>Sort 1</th>
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<td>1.96</td>
<td>1.95</td>
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Sample 45: Dune; Mid Height

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<td>2.22</td>
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<td>0.184</td>
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Sample 48: Dune Crest. (Hcl Treated).

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<th>Kurt 2</th>
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Kurt 2 1.241 Leptokurtic

Sample 49: Dune Crest
Mean 1 2.14
Mean 2 2.138
Skew 1 -0.259 Negatively Skewed
Skew 2 -0.167 Negatively Skewed
Sort 1 0.295 Very Well Sorted
Sort 2 0.298 Very Well Sorted
Kurt 1 1.026 Mesokurtic
Kurt 2 1.116 Leptokurtic

Sample 51: Dune Crest (Hcl Treated).
Mean 1 2.07
Mean 2 2.05
Skew 1 -0.211 Negatively Skewed
Skew 2 -0.204 Negatively Skewed
Sort 1 0.345 Very Well Sorted
Sort 2 0.341 Very Well Sorted
Kurt 1 0.87 Platykurtic
Kurt 2 0.836 Platykurtic

Sample 52: Dune Base. (Hcl Treated).
Mean 1 2.063
Mean 2 2.046
Skew 1 -0.195 Negatively Skewed
Skew 2 -0.246 Negatively Skewed
Sort 1 0.35 Well Sorted
Sort 2 0.351 Well Sorted
Kurt 1 0.863 Platykurtic
Kurt 2 0.967 Mesokurtic

Sample 53: Dune Mid Area. (Hcl Treated)
Mean 1 2.106
Mean 2 1.986
Skew 1 -0.187 Negatively Skewed
Skew 2 -0.184 Negatively Skewed
Sort 1 0.295 Very Well Sorted
Sort 2 0.288 Very Well Sorted
Kurt 1 0.947 Mesokurtic
Kurt 2 0.942 Mesokurtic

Beach
Sample 16 Sf 3 Mid Tide
Descriptive Stats
Median 2.10
Mean 1 2.09
Mean 2 2.09
| Skew 1  | -0.01 Symmetrical  |
| Skew 2  | -0.06 Symmetrical  |
| Sort 1  | 0.41 Well Sorted    |
| Sort 2  | 0.44 Well Sorted    |
| Kurt 1  | 1.00 Mesokurtic     |
| Kurt 2  | 1.06 Mesokurtic     |

**Sample 17: Sf 4 Mid Tide**

**Descriptive Stats**

| Median  | 2.27 |
| Mean 1  | 2.27 |
| Mean 2  | 2.26 |
| Skew 1  | -0.04 Symmetrical |
| Skew 2  | -0.04 Symmetrical |
| Sort 1  | 0.34 Very Well Sorted |
| Sort 2  | 0.32 Very Well Sorted |
| Kurt 1  | 1.36 Leptokurtic    |
| Kurt 2  | 1.37 Leptokurtic    |

**Sample 18: Sf 1 Low Tide**

**Descriptive Stats**

| Median  | 2.19 |
| Mean 1  | 2.17 |
| Mean 2  | 2.18 |
| Skew 1  | -0.08 Symmetrical |
| Skew 2  | -0.13 Negatively Skewed |
| Sort 1  | 0.44 Well Sorted    |
| Sort 2  | 0.42 Well Sorted    |
| Kurt 1  | 1.17 Leptokurtic    |
| Kurt 2  | 1.29 Leptokurtic    |
Sample 40: Beach High Tide
Mean 1  2.183
Mean 2  2.15
Skew 1  -0.235 Negatively Skewed
Skew 2  -0.316 Very Negatively Skewed
Sort 1  0.39 Well Sorted
Sort 2  0.411 Well Sorted
Kurt 1  1.579 Very Leptokurtic
Kurt 2  1.972 Very Leptokurtic

Sample 41: Beach Mid High Tide
Mean 1  2.276
Mean 2  2.256
Skew 1  -0.026 Symmetrical
Skew 2  -0.071 Symmetrical
Sort 1  0.355 Well Sorted
Sort 2  0.35 Well Sorted
Kurt 1  1.49 Leptokurtic
Kurt 2  1.55 Very Leptokurtic

Sample 42: Beach Mide Tide
Mean 1  2.163
Mean 2  2.166
Skew 1  -0.091 Symmetrical
Skew 2  -0.073 Symmetrical
Sort 1  0.37 Well Sorted
Sort 2  0.35 Well Sorted
Kurt 1  1.121 Leptokurtic
Kurt 2  1.086 Mesokurtic

Sample 46: Beach, High Tide. (Hcl Treated).
Mean 1  2.18
Mean 2  2.17
Skew 1  -0.177 Negatively Skewed
Skew 2  -0.23 Negatively Skewed
Sort 1  0.39 Well Sorted
Sort 2  0.379 Well Sorted
Kurt 1  1.37 Leptokurtic
Kurt 2  1.534 Very Leptokurtic

Sample 47: Beach Mid-Tide. (Hcl Treated).
Mean 1  2.16
Mean 2  2.15
Skew 1  -0.157 Negatively Skewed
Skew 2  -0.108 Negatively Skewed
Sort 1  0.32 Very Well Sorted
Sort 2  0.343 Very Well Sorted
Kurt 1  1.052 Mesokurtic
Kurt 2  1.069 Mesokurtic
## Environs

### Cliff Samples

**Sample 2**  
Cn 5, From Above Clay Wash  
**Descriptive Stats**

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<th>Mean 1</th>
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<th>Sort 2</th>
<th>Kurt 1</th>
<th>Kurt 2</th>
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<tbody>
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**Sample 8: Cntxt 5?: Red Sand From Below Clay Wash**  
**Descriptive Stats**

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<th>Kurt 2</th>
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<tbody>
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**Sample 9: Cntxt 4: Soil From Cliff**  
**Descriptive Stats**

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<th>Kurt 1</th>
<th>Kurt 2</th>
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Kurt 2 3.08 Extremely Leptokurtic

Sample 11: Cntxt 5; Red Sand From Above Clay Wash

Descriptive Stats

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<td>Kurt 1</td>
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<td>Kurt 2</td>
<td>0.92 Mesokurtic</td>
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Sample 12: Cntxt 6; Clay Wash

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<td>Skew 1</td>
<td>-0.84 Very Negatively Skewed</td>
</tr>
<tr>
<td>Skew 2</td>
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<tr>
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<td>0.87 Platykurtic</td>
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<tr>
<td>Kurt 2</td>
<td>3.29 Extremely Leptokurtic</td>
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Red Sand
Sample 4 Pit 4 Cntxt 26
Descriptive Stats

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<td>Skew 1</td>
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<tr>
<td>Skew 2</td>
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<td>Kurt 1</td>
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<tr>
<td>Kurt 2</td>
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Sample 5: Sth Slit Trench, Cntxt 15

Descriptive Stats

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Sample 13: Cntxt 26; Red Sand From Pit 4

Descriptive Stats

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<th>Sort 2</th>
<th>Kurt 1</th>
<th>Kurt 2</th>
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<tbody>
<tr>
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<td>0.33 Very Well Sorted</td>
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Sample 30: Pit 1, Red Sand From Above Clay Bands

Descriptive Stats

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<th>Kurt 1</th>
<th>Kurt 2</th>
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<td>0.21 Very Well Sorted</td>
<td>1.24 Leptokurtic</td>
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282
Sample 34: Pit 8, Red Sand Above Ripples

Descriptive Stats

Median 2.28
Mean 1 2.27
Mean 2 2.29
Skew 1 0.17 Positively Skewed
Skew 2 0.10 Positively Skewed
Sort 1 0.21 Very Well Sorted
Sort 2 0.23 Very Well Sorted
Kurt 1 1.36 Leptokurtic
Kurt 2 1.64 Very Leptokurtic

Sample 35: Pit 4, Red Sand

Descriptive Stats

Median 2.28
Mean 1 2.27
Mean 2 2.28
Skew 1 0.14 Positively Skewed
Skew 2 0.21 Positively Skewed
Sort 1 0.19 Very Well Sorted
Sort 2 0.19 Very Well Sorted
Kurt 1 1.26 Leptokurtic
Kurt 2 1.51 Leptokurtic

Sample 37: Tower Trench, Red Sand

Descriptive Stats

Median 2.28
Mean 1 2.27
Mean 2 2.27
Skew 1 0.01 Symmetrical
Skew 2 0.09 Symmetrical
Sort 1 0.15 Very Well Sorted
Sort 2 0.16 Very Well Sorted
Kurt 1 1.08 Mesokurtic
Kurt 2 1.42 Leptokurtic
Pit 'beach Sand'

Sample 3: Sth Slit Trench: mixed red/bleached sand
Descriptive Stats

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<th>Description</th>
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<td>Skew 2</td>
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Sample 7: Sth Slit Trench, mixed red/bleached sand.
Descriptive Stats

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Descriptive Stats

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Sample 26: Pit 8, 'beach' sand'

Descriptive Stats

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<td>Mean 2</td>
<td>2.00</td>
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<td>Skew 1</td>
<td>-0.63 Very Negatively Skewed</td>
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<td>-0.65 Very Negatively Skewed</td>
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<tr>
<td>Sort 1</td>
<td>0.68 Moderately Well Sorted</td>
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<tr>
<td>Sort 2</td>
<td>0.62 Moderately Well Sorted</td>
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<tr>
<td>Kurt 1</td>
<td>2.31 Very Leptokurtic</td>
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<tr>
<td>Kurt 2</td>
<td>2.86 Very Leptokurtic</td>
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Sample 33: Pit 4, 'beach' sand'

Descriptive Stats

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<tr>
<td>Mean 2</td>
<td>2.22</td>
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<td>Skew 1</td>
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<td>Skew 2</td>
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<td>Sort 1</td>
<td>0.24 Very Well Sorted</td>
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<td>Sort 2</td>
<td>0.30 Very Well Sorted</td>
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<tr>
<td>Kurt 1</td>
<td>1.95 Very Leptokurtic</td>
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<td>Kurt 2</td>
<td>2.49 Very Leptokurtic</td>
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Other Samples

Sample 19: Pit 3, 'beach' sand

Descriptive Stats

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<td>Mean 1</td>
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<td>-0.16 Negatively Skewed</td>
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<tr>
<td>Skew 2</td>
<td>-0.12 Negatively Skewed</td>
</tr>
<tr>
<td>Sort 1</td>
<td>0.33 Very Well Sorted</td>
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<tr>
<td>Sort 2</td>
<td>0.36 Well Sorted</td>
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<tr>
<td>Kurt 1</td>
<td>0.99 Mesokurtic</td>
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<tr>
<td>Kurt 2</td>
<td>1.03 Mesokurtic</td>
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</table>
Sample 20: Pit 3, red sand.

Descriptive Stats

Median 2.21
Mean 1 2.20
Mean 2 2.19
Skew 1 -0.11 Negatively Skewed
Skew 2 -0.16 Negatively Skewed
Sort 1 0.36 Well Sorted
Sort 2 0.36 Well Sorted
Kurt 1 1.30 Leptokurtic
Kurt 2 1.50 Leptokurtic

Sample 21: Sth Slit Trench, mixed red/bleached sand.

Descriptive Stats

Median 2.28
Mean 1 2.28
Mean 2 2.31
Skew 1 0.29 Positively Skewed
Skew 2 0.19 Positively Skewed
Sort 1 0.25 Very Well Sorted
Sort 2 0.24 Very Well Sorted
Kurt 1 1.35 Leptokurtic
Kurt 2 1.68 Leptokurtic

Sample 31: Slack Pit, Sand From Beneath Soil

Descriptive Stats

Median 2.10
Mean 1 2.06
Mean 2 2.02
Skew 1 -0.34 Very Negatively Skewed
Skew 2 -0.35 Very Negatively Skewed
Sort 1 0.39 Well Sorted
Sort 2 0.38 Well Sorted
Kurt 1 0.98 Mesokurtic
Kurt 2 1.00 Mesokurtic
Appendix 3a

Analysis Of Variance Of Particle Size Moment Statistics.

Test comparing skewness values.

1. The ridge and furrow buried soil against the Green Shiel buildings.

<table>
<thead>
<tr>
<th>SOURCE</th>
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<td>0.0047</td>
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<td>14</td>
<td>0.2336</td>
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<td>15</td>
<td>0.2384</td>
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INDIVIDUAL 95 PCT CI'S FOR MEAN
BASED ON POOLED STDEV

LEVEL  N  MEAN  STDEV  ^-------------------^  ^-------------------^  ^-------------------^  ^-------------------^  
SKEWRF  4  -0.0847  0.1581  (---------------*---------------)  
SKEWHSE 12  -0.0451  0.1201  (---------*---------)  

POOLED STDEV = 0.1292  -0.160  -0.080  0.000

2. The ridge and furrow buried soil against the dunes.

<table>
<thead>
<tr>
<th>SOURCE</th>
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<td>0.0099</td>
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<td>0.0127</td>
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INDIVIDUAL 95 PCT CI'S FOR MEAN
BASED ON POOLED STDEV

LEVEL  N  MEAN  STDEV  ^-------------------^  ^-------------------^  ^-------------------^  ^-------------------^  
SKEWRF  4  -0.0847  0.1581  (---------------*---------------)  
SKEWDUN 9  -0.1444  0.0901  (---------*---------)  

POOLED STDEV = 0.1128  -0.160  -0.080  0.000

3. The ridge and furrow buried soil against the beach.

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INDIVIDUAL 95 PCT CI'S FOR MEAN
BASED ON POOLED STDEV

LEVEL  N  MEAN  STDEV  ^-------------------^  ^-------------------^  ^-------------------^  ^-------------------^  
SKEWRF  4  -0.0847  0.1581  (---------------*---------------)  
SKEWBE  8  -0.1290  0.0962  (---------*---------)  

POOLED STDEV = 0.1182  -0.160  -0.080  0.000

287
4. The Green Shiel buildings against the dunes.

ANALYSIS OF VARIANCE

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INDIVIDUAL 95 PCT CI'S FOR MEAN
BASED ON POOLED STDEV

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<th>STDEV</th>
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<tbody>
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<td>0.1201</td>
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</tr>
<tr>
<td>SKEWDUN</td>
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<td>-0.1444</td>
<td>0.0901</td>
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POOLED STDEV = 0.1085

-0.210 -0.140 -0.070 0.000

5. The Green Shiel Buildings against the beach.

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INDIVIDUAL 95 PCT CI'S FOR MEAN
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<td>SKEWHSE</td>
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<td>0.1201</td>
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<tr>
<td>SKEWBE</td>
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POOLED STDEV = 0.1114

-0.210 -0.140 -0.070 0.000

6. The dunes against the beach.

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INDIVIDUAL 95 PCT CI'S FOR MEAN
BASED ON POOLED STDEV

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POOLED STDEV =

0.09297

-0.200 -0.150 -0.100 -0.050
7. All "other" environs samples against the red unit from the pits.

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INDIVIDUAL 95 PCT CI'S FOR MEAN BASED ON POOLED STDEV

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POOLED STDEV = 0.2004

8. The ridge and furrow against the red unit from the pits.

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INDIVIDUAL 95 PCT CI'S FOR MEAN BASED ON POOLED STDEV

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<tr>
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<td>SKEWRD</td>
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POOLED STDEV = 0.1018

9. The Green Shiel buildings against the red units from the pits.

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INDIVIDUAL 95 PCT CI'S FOR MEAN BASED ON POOLED STDEV

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<tr>
<td>SKEWRD</td>
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<td>0.0397</td>
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POOLED STDEV = 0.1020
10. The dunes against the red units from the pits.

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INDIVIDUAL 95 PCT CI'S FOR MEAN
BASED ON POOLED STDEV

LEVEL N MEAN STDEV
SKEWDUN 9 -0.14444 0.09008
SKEWRD 6 0.14167 0.03971

POOLED STDEV = 0.07483

11. The beach against the red units from the pits.

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INDIVIDUAL 95 PCT CI'S FOR MEAN
BASED ON POOLED STDEV

LEVEL N MEAN STDEV
SKEWBE 8 -0.12900 0.09617
SKEWRD 6 0.14167 0.03971

POOLED STDEV = 0.07779

Tests Comparing Mean Values.

12. The ridge and furrow buried soil against the Green Shiel buildings.

ANALYSIS OF VARIANCE

<table>
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<th>SOURCE</th>
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INDIVIDUAL 95 PCT CI'S FOR MEAN
BASED ON POOLED STDEV

LEVEL N MEAN STDEV
MEANRF 4 2.2148 0.0460
MEANHSE 8 2.2422 0.0419

POOLED STDEV = 0.0432

290
13. The ridge and furrow buried soil against the dunes.

ANALYSIS OF VARIANCE
SOURCE  DF   SS    MS   F      p
FACTOR   1  0.05289 0.05289  7.89  0.017
ERROR  11  0.07375 0.00670
TOTAL  12  0.12664

INDIVIDUAL 95 PCT CI'S FOR MEAN
BASED ON POOLED STDEV
LEVEL  N  MEAN   STDEV
MEANRF  4  2.2148 0.0460
MEANDUN  9  2.0766 0.0918

POOLED STDEV =   0.0819

14. The ridge and furrow buried soil against the beach.

ANALYSIS OF VARIANCE
SOURCE  DF   SS    MS   F      p
FACTOR   1  0.00385 0.00385  1.35  0.272
ERROR  10  0.02855 0.00286
TOTAL  11  0.03240

INDIVIDUAL 95 PCT CI'S FOR MEAN
BASED ON POOLED STDEV
LEVEL  N  MEAN   STDEV
MEANRF  4  2.2148 0.0460
MEANBE  8  2.1767 0.0563

POOLED STDEV =   0.0534

15. The Green Shiel buildings against the dunes.

ANALYSIS OF VARIANCE
SOURCE  DF   SS    MS   F      p
FACTOR   1  0.11628 0.11628 21.90  0.000
ERROR  15  0.07966 0.00531
TOTAL  16  0.19594

INDIVIDUAL 95 PCT CI'S FOR MEAN
BASED ON POOLED STDEV
LEVEL  N  MEAN   STDEV
MEANHSE  8  2.2422 0.0419
MEANDUN  9  2.0766 0.0918

POOLED STDEV =   0.0729
16. The Green Shiel buildings against the beach.

**ANALYSIS OF VARIANCE**

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</table>

**INDIVIDUAL 95 PCT CI'S FOR MEAN BASED ON POOLED STDEV**

| LEVEL   | N | MEAN | STDEV | -------+---------+---------+------|
|---------|---|------|-------|-------|--------|--------|------|
| MEANHSE | 8 | 2.2422 | 0.0419 |       |--------|--------|------|
| MEANBE  | 8 | 2.1767 | 0.0563 |       |--------|--------|------|

**POOLED STDEV = 0.0496**

17. The dunes against the beach

**ANALYSIS OF VARIANCE**

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**INDIVIDUAL 95 PCT CI'S FOR MEAN BASED ON POOLED STDEV**

| LEVEL    | N | MEAN   | STDEV | -------+---------+---------+------|
|----------|---|--------|-------|-------|--------|--------|------|
| MEANDUN  | 9 | 2.0766 | 0.0918 |       |--------|--------|------|
| MEANBE   | 8 | 2.1767 | 0.0563 |       |--------|--------|------|

**POOLED STDEV = 0.0773**

18. The ridge and furrow buried soil against the red unit from the pits

**ANALYSIS OF VARIANCE**

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**INDIVIDUAL 95 PCT CI'S FOR MEAN BASED ON POOLED STDEV**

| LEVEL    | N | MEAN   | STDEV | -------+---------+---------+------|
|----------|---|--------|-------|-------|--------|--------|------|
| MEANRF   | 4 | 2.2148 | 0.0460 |       |--------|--------|------|
| MEANRD   | 6 | 2.3150 | 0.0432 |       |--------|--------|------|

**POOLED STDEV = 0.0443**
19. The Green Shiel buildings against the red unit from the pits.

ANALYSIS OF VARIANCE

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INDIVIDUAL 95 PCT CI'S FOR MEAN BASED ON POOLED STDEV

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POOLED STDEV = 0.0424

19. The dunes against the red unit from the pits.

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INDIVIDUAL 95 PCT CI'S FOR MEAN BASED ON POOLED STDEV

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POOLED STDEV = 0.0768

20. The beach against the red unit from the pits.

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INDIVIDUAL 95 PCT CI'S FOR MEAN BASED ON POOLED STDEV

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<td>0.0432</td>
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POOLED STDEV = 0.0513

293
Tests comparing Kurtosis values

21. The ridge and furrow buried soil against the Green Shiel buildings.

ANALYSIS OF VARIANCE
SOURCE  DF   SS   MS   F   p
FACTOR   1   0.32  0.32  0.22  0.650
ERROR   14  20.77  1.48
TOTAL   15  21.09

INDIVIDUAL 95 PCT CI'S FOR MEAN
BASED ON POOLED STDEV
LEVEL  N  MEAN  STDEV
KURTRF  4  2.217  1.770
KURTHSE 12  1.891  1.017

POOLED STDEV = 1.218

22. The ridge and furrow buried soil against the dunes.

ANALYSIS OF VARIANCE
SOURCE  DF   SS   MS   F   p
FACTOR   1  3.937  3.937  4.46  0.058
ERROR   11  9.720  0.884
TOTAL   12 13.657

INDIVIDUAL 95 PCT CI'S FOR MEAN
BASED ON POOLED STDEV
LEVEL  N  MEAN  STDEV
KURTRF  4  2.2170  1.7700
KURTDUN 9  1.0247  0.2003

POOLED STDEV = 0.9400

23. The ridge and furrow buried soil against the beach.

ANALYSIS OF VARIANCE
SOURCE  DF   SS   MS   F   p
FACTOR   1   1.93  1.93  1.91  0.197
ERROR   10  10.09  1.01
TOTAL   11 12.02

INDIVIDUAL 95 PCT CI'S FOR MEAN
BASED ON POOLED STDEV
LEVEL  N  MEAN  STDEV
KURTRF  4  2.217  1.770
KURTBE  8  1.366  0.315

POOLED STDEV = 1.005

294
24. The Green Shiel buildings against the dunes.

ANALYSIS OF VARIANCE
SOURCE   DF   SS   MS   F   p
FACTOR    1   3.857 3.857 6.27 0.022
ERROR    19  11.690 0.615
TOTAL    20  15.547

INDIVIDUAL 95 PCT CI'S FOR MEAN
BASED ON POOLED STDEV

LEVEL   N   MEAN  STDEV
KURTHSE 12  1.8907 1.0167
KURTDUN  9  1.0247 0.2003

POOLED STDEV = 0.7844

25. The Green Shiel Buildings against the beach.

ANALYSIS OF VARIANCE
SOURCE   DF   SS   MS   F   p
FACTOR    1   1.321 1.321 1.97 0.177
ERROR    18  12.065 0.670
TOTAL    19  13.385

INDIVIDUAL 95 PCT CI'S FOR MEAN
BASED ON POOLED STDEV

LEVEL   N   MEAN  STDEV
KURTHSE 12  1.8907 1.0167
KURTBE   8  1.3661 0.3151

POOLED STDEV = 0.8187

26. The dunes against the beach.

ANALYSIS OF VARIANCE
SOURCE   DF   SS   MS   F   p
FACTOR    1   0.4938 0.4938 7.29 0.016
ERROR    15  1.0161 0.0677
TOTAL    16  1.5099

INDIVIDUAL 95 PCT CI'S FOR MEAN
BASED ON POOLED STDEV

LEVEL   N   MEAN  STDEV
KURTDUN  9  1.0247 0.2003
KURTBE   8  1.3661 0.3151

POOLED STDEV = 0.2603
27. The ridge and furrow buried soil against the red unit from the pits.

ANALYSIS OF VARIANCE

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**INDIVIDUAL 95 PCT CI'S FOR MEAN BASED ON POOLED STDEV**

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**POOLED STDEV** = 1.099

28. The Green Shiel buildings against the red unit from the pits.

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**INDIVIDUAL 95 PCT CI'S FOR MEAN BASED ON POOLED STDEV**

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**POOLED STDEV** = 0.8529

29. The dunes against the red unit from the pits.

ANALYSIS OF VARIANCE

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**INDIVIDUAL 95 PCT CI'S FOR MEAN BASED ON POOLED STDEV**

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<td>1.3050</td>
<td>0.2324</td>
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**POOLED STDEV** = 0.2132
30. The beach against the red unit from the pits.

ANALYSIS OF VARIANCE
SOURCE DF SS MS F p
FACTOR 1 0.0128 0.0128 0.16 0.697
ERROR 12 0.9653 0.0804
TOTAL 13 0.9781

INDIVIDUAL 95 PCT CI'S FOR MEAN
BASED ON POOLED STDEV
LEVEL N MEAN STDEV
KURTBE 8 1.3661 0.3151
KURTRD 6 1.3050 0.2324

POOLED STDEV = 0.2836 1.20 1.35 1.50

Tests comparing Sorting values

31. The ridge and furrow buried soil against the Green Shiel buildings.

ANALYSIS OF VARIANCE
SOURCE DF SS MS F p
FACTOR 1 0.03193 0.03193 19.00 0.001
ERROR 14 0.02353 0.00168
TOTAL 15 0.05546

INDIVIDUAL 95 PCT CI'S FOR MEAN
BASED ON POOLED STDEV
LEVEL N MEAN STDEV
SORTRF 4 0.34775 0.03135
SORTDSE 12 0.24458 0.04325

POOLED STDEV = 0.04100 0.250 0.300 0.350

32. The ridge and furrow buried soil against the dunes.

ANALYSIS OF VARIANCE
SOURCE DF SS MS F p
FACTOR 1 0.00430 0.00430 1.62 0.229
ERROR 11 0.02914 0.00265
TOTAL 12 0.03345

INDIVIDUAL 95 PCT CI'S FOR MEAN
BASED ON POOLED STDEV
LEVEL N MEAN STDEV
SORTRF 4 0.34775 0.03135
SORTDUN 9 0.30833 0.05722

POOLED STDEV = 0.05147 0.280 0.320 0.360 0.400

297
33. The ridge and furrow buried soil against the beach.

ANALYSIS OF VARIANCE

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INDIVIDUAL 95 PCT CI'S FOR MEAN
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POOLED STDEV = 0.03810

34. The Green Shiel buildings against the dunes.

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INDIVIDUAL 95 PCT CI'S FOR MEAN
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POOLED STDEV = 0.04962

35. The Green Shiel buildings against the beach.

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INDIVIDUAL 95 PCT CI'S FOR MEAN
BASED ON POOLED STDEV

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<tr>
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POOLED STDEV = 0.04226

298
36. The dunes against the beach.

ANALYSIS OF VARIANCE

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INDIVIDUAL 95 PCT CI'S FOR MEAN
BASED ON POOLED STDEV

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<td>SORTBE</td>
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<td>0.04064</td>
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POOLED STDEV = 0.05017

0.280 0.320 0.360 0.400

37. The ridge and furrow buried soil against the red unit from the pits.

ANALYSIS OF VARIANCE

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</tr>
<tr>
<td>TOTAL</td>
<td>9</td>
<td>0.04240</td>
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INDIVIDUAL 95 PCT CI'S FOR MEAN
BASED ON POOLED STDEV

<table>
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<th>MEAN</th>
<th>STDEV</th>
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<td>0.03135</td>
</tr>
<tr>
<td>SORTHSE</td>
<td>12</td>
<td>0.24458</td>
<td>0.04325</td>
</tr>
</tbody>
</table>

POOLED STDEV = 0.06093

0.240 0.300 0.360 0.420

38. The Green Shiel building against the red unit from the pits.

ANALYSIS OF VARIANCE

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
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<th>p</th>
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<td>ERROR</td>
<td>16</td>
<td>0.04733</td>
<td>0.00296</td>
<td></td>
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<tr>
<td>TOTAL</td>
<td>17</td>
<td>0.05103</td>
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INDIVIDUAL 95 PCT CI'S FOR MEAN
BASED ON POOLED STDEV

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>N</th>
<th>MEAN</th>
<th>STDEV</th>
</tr>
</thead>
<tbody>
<tr>
<td>SORTHSE</td>
<td>12</td>
<td>0.24458</td>
<td>0.04325</td>
</tr>
<tr>
<td>SORTHSE</td>
<td>12</td>
<td>0.24458</td>
<td>0.04325</td>
</tr>
</tbody>
</table>

POOLED STDEV = 0.05439

0.240 0.270 0.300
39. The dunes against the red unit from the pits.

ANALYSIS OF VARIANCE
SOURCE DF SS MS F p
FACTOR 1 0.00400 0.00400 0.98 0.340
ERROR 13 0.05294 0.00407
TOTAL 14 0.05694

INDIVIDUAL 95 PCT CI'S FOR MEAN
BASED ON POOLED STDEV
LEVEL N MEAN STDEV ------------------------
SORTDUN 9 0.30833 0.05722 (----------*---------)
SORTRD 6 0.27500 0.07314 (-------------*---------)

POOLED STDEV = 0.06382 0.240 0.280 0.320 0.360

40. The beach against the red unit from the pits.

ANALYSIS OF VARIANCE
SOURCE DF SS MS F p
FACTOR 1 0.03532 0.03532 11.06 0.006
ERROR 12 0.03831 0.00319
TOTAL 13 0.07364

INDIVIDUAL 95 PCT CI'S FOR MEAN
BASED ON POOLED STDEV
LEVEL N MEAN STDEV ------------------------
SORTBE 8 0.37650 0.04064 (-------*------)
SORTRD 6 0.27500 0.07314 (--------*-------)

POOLED STDEV = 0.05651 0.240 0.300 0.360 0.420
**Appendix 3b**

**Tree Deformation data from Lindisfarne**

The given angles indicate the wind direction; e.g. 270° = westerlies

<table>
<thead>
<tr>
<th>Car park</th>
<th>1</th>
<th>340°</th>
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<tbody>
<tr>
<td></td>
<td>2</td>
<td>340°</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>0°</td>
</tr>
<tr>
<td>Farm</td>
<td>4</td>
<td>350°</td>
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<td></td>
<td>5</td>
<td>330°</td>
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<td>6</td>
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<tr>
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<td>7</td>
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<td></td>
<td>8</td>
<td>330°</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>280°</td>
</tr>
<tr>
<td>Crooked loaning</td>
<td>10</td>
<td>0°</td>
</tr>
<tr>
<td></td>
<td>11</td>
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<tr>
<td></td>
<td>12</td>
<td>335°</td>
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<tr>
<td></td>
<td>13</td>
<td>330°</td>
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<td>14</td>
<td>350°</td>
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<tr>
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<tr>
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<td>340°</td>
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<tr>
<td></td>
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<td>340°</td>
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<td>345°</td>
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<td>19</td>
<td>20°</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>350°</td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>345°</td>
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<td>22</td>
<td>345°</td>
</tr>
<tr>
<td></td>
<td>23</td>
<td>340°</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>345°</td>
</tr>
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<td></td>
<td>25</td>
<td>340°</td>
</tr>
<tr>
<td></td>
<td>26</td>
<td>340°</td>
</tr>
<tr>
<td></td>
<td>27</td>
<td>355°</td>
</tr>
<tr>
<td></td>
<td>28</td>
<td>15°</td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>350°</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>350°</td>
</tr>
<tr>
<td>Lough</td>
<td>31</td>
<td>325°</td>
</tr>
</tbody>
</table>

| Dunes: leeward side, eastern area. | 32 | 10°   |
|                                   | 33 | 15°   |
|                                   | 34 | 20°   |
|                                   | 35 | 0°    |
|                                   | 36 | 15°   |

| Dunes: windward side of oldest ridge, eastern area. | 37 | 350°  |
|                                                   | 38 | 340°  |
|                                                   | 39 | 325°  |

| Top of Straight Loaning | 40 | 330°  |
|                        | 41 | 330°  |
|                        | 42 | 350°  |
|                        | 43 | 350°  |
|                        | 44 | 350°  |
|                        | 45 | 350°  |
|                        | 46 | 350°  |
|                        | 47 | 350°  |
|                        | 48 | 320°  |
|                        | 49 | 340°  |

| Ridge and Furrow        | 50 | 340°  |
|                        | 51 | 315°  |
|                        | 52 | 350°  |
|                        | 53 | 340°  |
|                        | 54 | 330°  |
|                        | 55 | 300°  |

| Green Shiel             | 56 | 335°  |
|                        | 57 | 330°  |
|                        | 58 | 325°  |
|                        | 59 | 325°  |
|                        | 60 | 330°  |
|                        | 61 | 335°  |
|                        | 62 | 330°  |

| Slack                  | 63 | 310°  |
|                       | 64 | 340°  |
|                       | 65 | 335°  |
Appendix 3c

Chi-square test of tree deformation angles

Expected counts are printed below observed counts

<table>
<thead>
<tr>
<th>Angle</th>
<th>295°</th>
<th>320°</th>
<th>340°</th>
<th>0°</th>
<th>15°</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>121</td>
<td>18</td>
<td>39</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>13</td>
<td>13</td>
<td>13</td>
<td>13</td>
</tr>
</tbody>
</table>

\[ \text{ChiSq} = 9.3 + 1.9 + 52 + 7.6 = 78.5 \]

Appendix 3d.

Statistical Tests On The Length To Aperture Ratio Of *Nucella lappillus*

ANALYSIS OF VARIANCE
Archaeological samples compared with modern samples collected September 1990.

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>FACTOR</td>
<td>1</td>
<td>0.9760</td>
<td>0.9760</td>
<td>64.87</td>
<td>0.000</td>
</tr>
<tr>
<td>ERROR</td>
<td>96</td>
<td>1.4444</td>
<td>0.0150</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>97</td>
<td>2.4204</td>
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<td></td>
</tr>
</tbody>
</table>

INDIVIDUAL 95 PCT CI's FOR MEAN BASED ON POOLED STDEV

<table>
<thead>
<tr>
<th>Level</th>
<th>N</th>
<th>Mean</th>
<th>STDEV</th>
<th>(---*---)</th>
</tr>
</thead>
<tbody>
<tr>
<td>archaeo</td>
<td>38</td>
<td>1.8183</td>
<td>0.1420</td>
<td>(---*---)</td>
</tr>
<tr>
<td>mod-sep'</td>
<td>60</td>
<td>1.6135</td>
<td>0.1088</td>
<td>(---*---)</td>
</tr>
</tbody>
</table>

POOLED STDEV = 0.1227

1.600 1.680 1.760 1.840

ANALYSIS OF VARIANCE
Archaeological samples compared with modern samples collected early April 1990.

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
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<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>FACTOR</td>
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<td>0.4624</td>
<td>0.4624</td>
<td>27.76</td>
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<td>ERROR</td>
<td>72</td>
<td>1.1995</td>
<td>0.0167</td>
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<tr>
<td>TOTAL</td>
<td>73</td>
<td>1.6619</td>
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</tbody>
</table>

INDIVIDUAL 95 PCT CI's FOR MEAN BASED ON POOLED STDEV

<table>
<thead>
<tr>
<th>Level</th>
<th>N</th>
<th>Mean</th>
<th>STDEV</th>
<th>(---*---)</th>
</tr>
</thead>
<tbody>
<tr>
<td>archaeo</td>
<td>38</td>
<td>1.8183</td>
<td>0.1420</td>
<td>(---*---)</td>
</tr>
<tr>
<td>mod-apri'</td>
<td>36</td>
<td>1.6602</td>
<td>0.1139</td>
<td>(---*---)</td>
</tr>
</tbody>
</table>

POOLED STDEV = 0.1291

1.680 1.750 1.820
## ANALYSIS OF VARIANCE

All samples.

<table>
<thead>
<tr>
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<th>MS</th>
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<th>p</th>
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<tr>
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<td>1.0043</td>
<td>0.5021</td>
<td>34.66</td>
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<td>ERROR</td>
<td>131</td>
<td>1.8981</td>
<td>0.0145</td>
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</tr>
<tr>
<td>TOTAL</td>
<td>133</td>
<td>2.9024</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

### INDIVIDUAL 95 PCT CI'S FOR MEAN BASED ON POOLED STDEV

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>N</th>
<th>MEAN</th>
<th>STDEV</th>
<th>(---*---)</th>
</tr>
</thead>
<tbody>
<tr>
<td>archaeo</td>
<td>38</td>
<td>1.8183</td>
<td>0.1420</td>
<td>(----*----)</td>
</tr>
<tr>
<td>mod-sep'</td>
<td>60</td>
<td>1.6135</td>
<td>0.1088</td>
<td>(---*---)</td>
</tr>
<tr>
<td>mod-apri'</td>
<td>36</td>
<td>1.6602</td>
<td>0.1139</td>
<td>(----*---)</td>
</tr>
</tbody>
</table>

POOLED STDEV = 0.1204

## ANALYSIS OF VARIANCE

Test of archaeological sample against both modern samples.

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<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>FACTOR</td>
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<td>0.9564</td>
<td>0.9564</td>
<td>64.73</td>
<td>0.000</td>
</tr>
<tr>
<td>ERROR</td>
<td>132</td>
<td>1.9505</td>
<td>0.0148</td>
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<tr>
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</table>

### INDIVIDUAL 95 PCT CI'S FOR MEAN BASED ON POOLED STDEV

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>N</th>
<th>MEAN</th>
<th>STDEV</th>
<th>(---*---)</th>
</tr>
</thead>
<tbody>
<tr>
<td>archaeo</td>
<td>38</td>
<td>1.8183</td>
<td>0.1420</td>
<td>(----*----)</td>
</tr>
<tr>
<td>mod-sep'</td>
<td>96</td>
<td>1.6309</td>
<td>0.1126</td>
<td>(---*--)</td>
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</table>

POOLED STDEV = 0.1216

## ANALYSIS OF VARIANCE

Modern samples: April compared with September 1990.

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<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>FACTOR</td>
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<td>0.0490</td>
<td>0.0490</td>
<td>4.00</td>
<td>0.048</td>
</tr>
<tr>
<td>ERROR</td>
<td>94</td>
<td>1.1523</td>
<td>0.0123</td>
<td></td>
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</tr>
<tr>
<td>TOTAL</td>
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<td>1.2013</td>
<td></td>
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</table>

### INDIVIDUAL 95 PCT CI'S FOR MEAN BASED ON POOLED STDEV

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>N</th>
<th>MEAN</th>
<th>STDEV</th>
<th>(---*---)</th>
</tr>
</thead>
<tbody>
<tr>
<td>mod-sep'</td>
<td>60</td>
<td>1.6135</td>
<td>0.1088</td>
<td>(----*----)</td>
</tr>
<tr>
<td>mod-apri'</td>
<td>36</td>
<td>1.6602</td>
<td>0.1139</td>
<td>(--------*--------)</td>
</tr>
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</table>

POOLED STDEV = 0.1107

---

303
Mann-Whitney Test On *Nucella lapillus*

Mann-Whitney Confidence Interval and Test
Archaeological samples tested against modern samples collected September 1990.

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Median</th>
<th>Point estimate for ETA1-ETA2</th>
<th>95.1 pct c.i. for ETA1-ETA2</th>
<th>W</th>
<th>Test of ETA1 = ETA2 vs. ETA1 n.e. ETA2 is significant at 0.0000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Archaeological</td>
<td>38</td>
<td>1.7952</td>
<td>0.1997</td>
<td>(0.1568, 0.2487)</td>
<td>2815.0</td>
<td>The test is significant at 0.0000 (adjusted for ties)</td>
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<tr>
<td>Modern September</td>
<td>60</td>
<td>1.6025</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Mann-Whitney Confidence Interval and Test
Archaeological sample tested against sample collected April 1990.

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Median</th>
<th>Point estimate for ETA1-ETA2</th>
<th>95.0 pct c.i. for ETA1-ETA2</th>
<th>W</th>
<th>Test of ETA1 = ETA2 vs. ETA1 n.e. ETA2 is significant at 0.0000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Archaeological</td>
<td>38</td>
<td>1.7952</td>
<td>0.1344</td>
<td>(0.0786, 0.1971)</td>
<td>1881.5</td>
<td>The test is significant at 0.0000 (adjusted for ties)</td>
</tr>
<tr>
<td>Modern April</td>
<td>36</td>
<td>1.6973</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Mann-Whitney Confidence Interval and Test
Test of archaeological sample against both modern samples.

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Median</th>
<th>Point estimate for ETA1-ETA2</th>
<th>95.0 pct c.i. for ETA1-ETA2</th>
<th>W</th>
<th>Test of ETA1 = ETA2 vs. ETA1 n.e. ETA2 is significant at 0.0000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Archaeological</td>
<td>38</td>
<td>1.7952</td>
<td>0.1791</td>
<td>(0.1349, 0.2261)</td>
<td>3955.5</td>
<td>The test is significant at 0.0000 (adjusted for ties)</td>
</tr>
<tr>
<td>Modern September</td>
<td>96</td>
<td>1.6296</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modern April</td>
<td>36</td>
<td>1.6973</td>
<td></td>
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</tr>
</tbody>
</table>

Mann-Whitney Confidence Interval and Test
Test of modern samples: April sample against September sample

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Median</th>
<th>Point estimate for ETA1-ETA2</th>
<th>95.0 pct c.i. for ETA1-ETA2</th>
<th>W</th>
<th>Test of ETA1 = ETA2 vs. ETA1 n.e. ETA2 is significant at 0.0001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modern September</td>
<td>60</td>
<td>1.6025</td>
<td>-0.0756</td>
<td>(-0.1065, -0.0406)</td>
<td>2374.0</td>
<td>The test is significant at 0.0001 (adjusted for ties)</td>
</tr>
<tr>
<td>Modern April</td>
<td>36</td>
<td>1.6973</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Descriptive statistics of all measurements on *Nucella lapillus*.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>N</th>
<th>MEAN</th>
<th>MEDIAN</th>
<th>TRMEAN</th>
<th>STDEV</th>
<th>SEMEAN</th>
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<td>arch' length</td>
<td>38</td>
<td>25.187</td>
<td>25.390</td>
<td>25.253</td>
<td>2.633</td>
<td>0.427</td>
</tr>
<tr>
<td>arch' ap'</td>
<td>38</td>
<td>13.902</td>
<td>13.950</td>
<td>13.946</td>
<td>1.543</td>
<td>0.250</td>
</tr>
<tr>
<td>archaeo ratio</td>
<td>38</td>
<td>1.8183</td>
<td>1.7952</td>
<td>1.8191</td>
<td>0.1420</td>
<td>0.0230</td>
</tr>
<tr>
<td>mod' ap'</td>
<td>60</td>
<td>13.848</td>
<td>14.000</td>
<td>13.880</td>
<td>1.422</td>
<td>0.184</td>
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<tr>
<td>mod' length</td>
<td>60</td>
<td>22.298</td>
<td>22.45</td>
<td>22.272</td>
<td>2.308</td>
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<td>17.097</td>
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## Appendix 4
Results of organic content and carbonate tests with two-dimensional coordinates n.b.(999.999 = no result)

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306
Appendix 4a
Statistics: Chi-Square For Phytolith Assemblages

Expected counts are printed below observed counts

Morphotype codes: sr = smooth rod; cw = coarse, wavy rod; tr = trapezoid; ss = short smooth rod

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307
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2 cells with expected counts less than 5.0

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\[ \text{ChiSq} = 0.745 + 0.388 + 0.599 + 1.295 + 1.635 + 0.851 + 1.316 + 2.843 = 9.673 \]

df = 3
2 cells with expected counts less than 5.0

**Test 5**

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\[ \text{ChiSq} = 3.248 + 8.404 + 1.273 + 1.053 + 11.679 + 2.781 + 0.945 + 0.381 + 12.296 + 1.071 + 7.622 + 0.587 + 0.001 + 4.444 + 0.075 + 0.000 + 2.968 + 1.458 + 0.416 + 0.049 + 0.189 + 7.250 + 1.219 + 0.856 + 4.199 + 0.088 + 0.878 + 0.025 + 18.079 + 1.575 = 95.112 \]

df = 20
8 cells with expected counts less than 5.0
### Test 6.

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\[ \text{ChiSq} = 6.399 + 0.465 + 0.030 + 1.035 + 3.033 + 0.005 + 13.713 + 0.997 + 0.064 + 2.219 + 6.499 + 0.011 = 34.470 \]

\( \text{df} = 5 \)

1 cells with expected counts less than 5.0

### Test 7i

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Appendix 5

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Selaginella selaginoides (L.) Link
Equisetum variegatum Schleih.
—fluvial L.
—palustrum L.
—arvense L.
Pteridium aquilinum (L.) Kuhn
Phyllitis scolopendrium (L.) Newn.
Asplenium adiantum-nigrum L.
—trichomanes L.
—ruta-muraria L.
Dryopteris filix-mas (L.) Schott.
Polypodium vulgare L.
Botrychium lunaria (L.) Sw.

SPERMATOPHYTA

Pinus sylvestris L.

DICOTYLEDONS

Ranunculus acris L..
—repens L..
—bulbosus L..
—flammmula L..
—scleratus L..
—trichophyllum Chaix
—aquatilis L..
Aquilgia vulgaris L..
Thalictrum minus L..

Papaver rhoes L..
—dubium L..

Fumaria capreolata L..
—officinalis L..
Sinapis arvensis L..
—alba L..
Raphanus raphanistrum L..
Cakile maritima Scop.
Coronopus squamatus (Forsk.) Aschers.
Capsella bursa-pastoris (L.) Medic.
Cochlearia of —icinalis L..
—danica L..
Alyssum alyssoides (L.) L..
Erophila verna (L.) Chevall.
Cardamine pratensis L..
Rorippa nasturtium-aquaticum (L.) Hayek.

—microphylla (Boenn.) Hyland
Matthiola incana (L.) R. Br.
Hesperis matronalis L..
Cheiranthus cheiri L..
Alliaria petiolata (Bieb.) Cavara & Grande

Sisymbrium officinalis (L.) Scop.
Reseda luteola L..
Viola odorata L..
—hirta L..
—riviniana Reichb.
—canina L..
—tricolor L..
Polygala vulgaris L..

Helianthemum chamaecistus Mill.
Silene vulgaris (Moench) Garcke
—maritima With.
—noctiflora L..
—dioica (L.) Clairv.
—alba (Mill.) E. H. L. Krause.
Lychnis flos-cuculi L..
Dianthus plumarius L. Cerastium arvense.
L..
—holostoeoides Fr.
—glomeratum Thuill
—atrovirens Bab.
—semidecandrum L..
Stellaria media (L.) Vill.
—palliata (Dumort). Pire
Sagina apetala Ard.
—ciliata Fr.
—maritima Don.
—procumbens L..
—nodosa (L.) Fenzl.
Honkenya peploides (L.) Ehrh.
Arenaria serpyllifolia L..
—leptoclados (Reichb.) Guss.
—balearica L..
Spergula arvensis L..
Spergularia media (L.) C. Presl.
—marina (L.) Griseb.
Scleranthus annus L..

Montia fontana L..

Chenopodium bonus-henricus L..
—album L..

Chenopodium rubrum L..
Atriplex littoralis L..
—patula L..
—hastata L.

311
—glabriuscula Edmondst.
—laciniata L...
Halimione portulacoides (L.) Aellen.
Suaeda maritima (L.) Dumort.
Salsola kali L.
Salicornia dolichostachya Moss
—europaea L..
Malva sylvestris L..
—neglecta Wallr.
Linum catharticum L.
Radiola linoides Roth.
Geranium phaeum L..
—sanguineum L..
—dissectum L..
—molle L..
—pusillum L..
—robertianum L..
Erodium cicutarium (L.) L’Herit.
Acer pseudoplatanus L..
Laburnum anagyroides Medic.
Ulex europaeus L..
Ononis repens L..
Medicago sativa L..
—lupulina L..
Mellotus officinalis (L.) Pall.
Trifolium pratense L..
—arvense L..
—striatum L..
—scabrum L..
—hybridum L..
—repens L..
—campestris Schreb.
—dubium Sibth.
Anthyllis vulneraria L.
Lotus corniculatus L.
Astragalus danicus Retz
Vicia hirsuta (L.) Gray

Vicia cracca L..
—sepium L..
—sativa L..
—angustifolia L..
—lathyroides L..
Lathyrus pratensis L..
Filipendula ulmaria (L.) Maxim.
Rubus fruticosus L. sensu lato
Potentilla palustris (L.) Scop.
—sterilis (L.) Garcke
—anserina L..
—reptans L..
Fragaria vesca L..
Geum urbanum L..
Agrimonia eupatoria L..
—odorata (Gouan.) Mill
Alchemilla vulgaris L. sensu lato
Sanguisorba officinalis L.
Poterium sanguisorba L.
Acaena anserinifolia (J.R. & G. Forst.) Druce
Rosa pimpinellifolia L..
—rubiginosa L..
Prunus spinosa L.
Cotoneaster horizontalis Decne.
Crataegus monogyna Jacq.
Sedum rosea (L.) Scop.
—anglicum Huds.
—album L..
—acre L..
Saxifraga granulata L..
Parnassia palustris L..
Epilobium hirsutum L..
—purpuratum Schreb.
—montanum L..
—palustre L..
—angustifolium L..
Oenothera erythrosepala Borbas
Myriophyllum spicatum L..
Hippuris vulgaris L..
Callitrichestagnalis
Hydrocotyle vulgaris L.
Chaerophyllum temulentum L.
Anthyllis caucalis Bieb.
—sylvestris (L.) Hoffm.
Torilis japonica (Hoult.) DC
—nodosa (L.) Gaertn.
Conium maculatum L.
Cnopodium majus (Gouan). Loret.
Aegopodium podagraria L.
Oenanthe lachenalii C. C. Gmel.
Foeniculum vulgare Mill.
Ligusticum scoticum L.
Angelica sylvestris L.
Heracleum sphondylum L.
—mantegazzianum Somm. & Levier
Euphorbia helioscopia L. —peplus L..

Polygonum aviculare L. sensu lato
—raii Bab.
—amphibium L..
—persicaria L..

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—convolvulus L..
Rumex acertosella L. sensu lato
—acetosa L..
—crispus L..
—obtusifolia L..

Urtica urens L.
—dioica L..

Betula pendula Roth.
—pubescens Ehrh.
Alnus glutinosa (L.) Gaertn.

Salix viminalis L.
—caprea L..
—aurita L..
—repens L..

Limonium vulgare Mill.
Armeria maritima (Mill.) Willd.

Primula veris L..
—vulgaria Huds.
Anagallis tenella (L.) L.
Glaux maritima L.
Samolus valerandi L.

Fraxinus excelsior L..

Centaurium erythraea Rafn.
—capitatum (Willd.) Borbas
—littorale (D. Turner) Gilmour
Gentianella campestris (L.) Borner
—amarella (L.) Borner sensu lato

Menyanthes trifoliata L..

Cynoglossum officinale L..
Omphalodes eurna Moench.
Symphytum x uplandicum Nyman.
Pentaglottis sempervirens (L.) Tausch.
Lycopsis arvensis L..
Myosotis scorpioides L..
—caespitosa K. F. Schultz
—arvensis (L.) Hill.
—ramosissima Rochel.
Echium vulgare L..

Convolvulus arvensis L..
Calystegia sepium (L.). R. Br.

Lycium chinese Mill.
Hyoscyamus niger L..
Solanum dulcamara L..
Datura stramonium L..

Verbascum thapsus L..
Linaria vulgaris Mill.
Cymbalaria muralis Gaertn., Mey. & Scherb.
Scrophularia nodosa L..
—umbrosa Dumort.
Mimulus guttatus DC.
Erinus alpinus L..
Verona beccabunga L..
—anagallis-aquatica L..
—scutellata L..

Veronica officinalis L..
—chamaedrys L..
—serpyllifolia L..
—arvensis L..
—hederifolia L..
—persica Poir.
Rhinanthus minor L..

Orobanche minor Sm.

Pinguicula vulgaris L..

Mentha arvensis L..
—aquatica L..
Thymus drucei Ronn.
Salvia verbenaca L..
Prunella vulgaris L..
Stachys palustris L..
Lamium amplexicaule L..
—moluccellifolium Fr.
—purpureum L..
—album L..
Glechoma hederacea L..
Teucrium scorodonia L..
Ajuga reptans L..

Plantago major L..
—media L..
—lanceolata L..
—maritima L..
—coronopus L..
Littorella uni.flora (L.) Aschers.

Campanula rotundifolia L..

Sherardia arvensis L..
Galiurn cruciata L. Scop.
—mollugo L..
—erectum
—verum L..
—palustre L..
—aparine L..

Sambucus nigra L..
Valerianella locusta (L.) Betcke.
Valeriana officinalis L..
—dioica L..

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Centranthus ruber (L.) DC.
Dipsacus fullonum L..
Knautia arvensis (L.) Coult.
Senecio jacobaea L..
—sylvaticus L..
—vulgaris L..
Tussilago farfara L..
Pulicaria dysenterica (L.) Bernh.
Solidago virgaurea L..
Astor tripolium L..
—novae-belgii L..
Erigeron acer L..
Bellis perennis L..
Eupatorium cannabinum L..
Achillea millefolium L..
Tripleurospermum maritimum (L.) Koch
Matricaria matricarioides (Less.) Porter
Chrysanthemum parthenium (L.) Bernh.
—vulgare (L.) Bernh.
Artemisia vulgaris L..
Carlina vulgaris L..
Arctium minus Bernh.
Carduus tenuiflorus Curt.
—acanthoides L..
Cirsium vulgare (Savi) Ten.
—palystre (L.) Scop.
—arvense (L.) Scop.
Centaurea nigra L..
Cichorium intybus L..
Lapsana communis L..
Hypochoeris radicata L..
Leontodon autumnalis L..
—hispidus L..
—taraxacoides (Vill.) Merat.
Tragopogon pratensis L..
Sonchus arvensis L..
—oleraceus L..
—asper (L.) Hill
Hieracium pilosella L..
—auranticum L..
Crepis capillaris (L.) Wallr.
Taraxacum officinale Weber
—laevigatum (Willd.) DC

MONOCOTYLEDONS
Baldellia ranunculoides (L.) Parl.
Alisma plantago-aquatica L..
Triglochin palustris L..
—maritima L..
Zostera angustifolia (Hornem.) Reichb.
—noltii Hornem.

Potamogeton natans L..
—gramineus L..
—pectinatus L..

Endymion non-scriptus (L.) Garcke
Muscari atlanticum Boiss. & Rent.

Juncus gerardii Lois.
Juncus bufonius L..
—inflexus L..
—efusus L..
—maritimus Lam.
—conglomeratus L..
—articulatus L..

Allium oleraceum L..

Iris pseudacorus L..

Epipactis palustris (L.) Crantz
Listera ovata (L.) R. Br.
Coeloglossum viride (L.)
Orchis mascula (L.) L..
Dactylorhizas fuchsii (Druce) Vermeul.
—maculata (L.) Vermeul.
—incarnata (L.) Vermeul.
—purpurella (T. & T. A. Stephenson) Vermeul.

Anacamptis pyramidalis (L.) Rich
Leonurus trisulca L..
—minor L..

Spargatuzium erectum L..

Eriopliorum angustifolium Honck.
—vaginatum L..
Scirpus maritimus L..
—setaceus L..
Eleocharis quinqueflora (F. X. Hartmann) Schurz.
—palustris (L.) Roem. & Schutt.
Blysmus compressus (L.) Panz. ex Link.
—rufus (Huds.) Link.
Schoenus nigricans L..
Carex distans L..
—demissa Hornem.
—serotina Merat.
—extensa Gooden
—rostrata Stokes
—vescararia L..
—acutiformis Ehrh.
—panicula L..
—flacca Schreb.
—hirta L..
—caryophyllea Latourr.
—nigra (L.) Reichard

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—otrubae Podp.
—disticha Huds.
—arenaria L.
—disticha Huds.
—maritima Gunn
—pulicaris L.
Sieglingia decumbens (L.) Bernh.
Festuca pratensis Huds.
—rubra L.
—ovina L.
Lolium perenne L.
Puccinellia maritima (Huds.) Parl

Catapodium rigidium (L.) C.E. Hubbard

Poa annua L.
—pratensis L.
—trivialis L.
Dactylis glomerata L.
Cynosurus cristatus L.
Briza media L.
Anisantha sterilis (L.) Nevski
Bromus mollis L.
Agropyron repens (L.) Beauvois
—junceiforme (A. & D. Love) A. & D. Love
Elymus arenarius L.
Hordeum murinum L.
Koeleria cristata (L.) Pers.
Trisetum flavescens Beauv.
Avena sativa L.
Helictotrichon pratense (L.) Pilg.
—pubescens (Huds.) Pilg.
Arrhenatherum elatius (L.) Beauv. ex J. & C. Presl.
Holcus lanatus L.
—mollis L.
Deschampsia cespitosa (L.) Beauv.
Aira praecox L.
—caryophyllea L.
Ammophila arenaria (L.) Link
Ammocalamagrostis baltica (Schrad.) P. Fourn.
Agrostis stolonifera L.
Phleum pratense L.
—arenarium L.
Alopecurus pratensis L.
—geniculatus L.
Anthoxanthum odoratum L.
Phalaris arundinacea L.
Parapholis strigosa (Dumort) C. E. Hubbard
Nardus stricta L.
Spartina anglica C. E. Hubbard
—townsendii H. & J. Groves
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