THE ARCHAEOLOGICAL POTENTIAL OF WINDBLOWN SAND AND ITS IMPACTS ON PREHISTORIC SETTLEMENTS AND LANDSCAPES IN THE ORKNEY ISLANDS, SCOTLAND

Emily Louise Gal

A Thesis Submitted for the Degree of PhD
at the
University of St Andrews

2019

Identifiers to use to cite or link to this thesis:

DOI: https://doi.org/10.17630/10023-17889
http://hdl.handle.net/10023/17889

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St Andrews

This thesis is submitted in partial fulfilment for the degree of

Doctor of Philosophy (PhD)

at the University of St Andrews

April 2019

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Abstract

This thesis comprises an investigation into the nature, chronology, and significance of prehistoric windblown sand deposition on archaeological sites in the Orkney Islands, Scotland. One of the most visible and frequently-encountered forms of evidence for dynamic coastal processes which took place over the last four millennia are horizons of calcareous (shell) and mineral (quartz and feldspar) sands, which were deposited in coastal landscapes and settlements by wind and wave dynamics. Around 20% of the Scottish coastline is made up of sand-based features, with the dune area comprising some 48,000ha (Dargie and Duncan 1999, 143).

Such coastal zones were densely settled in the prehistoric period. As monitoring of the modern coastline for changes affecting known archaeological sites continues, deposits of windblown sand - often interleaved with material evidence for human occupation – are becoming frequently recognised in the archaeological record. One coastal region which has felt the impacts of this coastal process (and continues to do so), is the Orkney archipelago, located off the northern coast of Mainland Scotland. It is this group of islands which form the geographical focus of this thesis. Previous archaeological interpretations of this important coastal process have been concerned with the development of chronologies of deposition in an attempt to tie the deposition of windblown sand to narratives of climatic deterioration. Such approaches fail to recognise the broader social significance of these windblown sand deposits, and how they were encountered by prehistorical inhabitants of the coastline. This thesis synthesises all known occurrences of windblown sand on archaeological sites in Orkney, and suggests additional ways in which their socio-economic significance can be realised.

Acknowledgements

My first thanks go Richard Bates and Tom Dawson, for supervising this PhD. I also owe a great deal of thanks to Tim Kinnaird for his guidance during the OSL dating process. Katie Roucoux and Althea Davies offered advice on a successful application to the NERC Radiocarbon dating fund, while Paula Reimer offered valuable advice during the dating process. Tom Dawson, Jo Hambly, and Ellie Graham provided information from the SCHARP Sites at Risk database, useful feedback, and lots of fun. I would also like to thank the people of Sanday - particularly Cath Parker - for imparting their knowledge and experience, and all landowners, for allowing me to undertake fieldwork and assessment across the island. I thank SNH for granting the relevant permissions to work in many areas of the island.

Steve Dockrill, Julie Gibson, Anne Sommerville, David Sanderson, Mike Church, Hazel Moore and David Clarke are all thanked for their advice and feedback on the project. Rob Wilson, Colin Richards, and Niall Sharples are all thanked for their thorough and insightful comments during my viva, and on the thesis itself. My thanks must also go to Lekky Shepherd for her thoughts on matters of sand, and for pulling me up on some important aspects of my terminology. Rod McCullagh, Kirsty Owen, Lisa Brown, Mairi Davies, and Georgie Ritchie at Historic Environment Scotland provided invaluable information in the form of unpublished material.

I extend my love and thanks to my wonderful friends, who kept me going during what turned out to be a far from straightforward PhD journey: my 7pm warriors and FFSA for keeping me sane; my 2013 cohort for all the fun; and Jenna, Kelly, and Kristina. Special thanks must go to Tanya Venture and Johnny Horn, for too many things to mention. To Paul for keeping me calm and putting things into perspective. To Rachel for letting me use her house as a refuge during the final push. To Liam O'Brien and Fiona Cunningham, who through it all have been my constant, and a source of much humour and comfort.

I owe my biggest thanks to my wonderful family, for their fierce support and faith in me. Special mention must go to Dave for the laptop, which made the final push so much easier. This thesis is for them all.

Funding

This work was supported by The University of St Andrews 600th Anniversary Scholarship, and the Marine Alliance for Science and Technology Scotland (MASTS) [JHI/FRR/RBG/SAC/UDD/UHW/UEH/USA/856/11].

Funding for a series of radiocarbon dates was provided by the NERC Radiocarbon Facility [1994.0416].

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Chapter 1. Introduction

Three key physical processes directly shape and affect the coastline and its immediate hinterland: erosion of sediments, accretion of sediments, and flooding (Hickey 1997). Such processes have important implications for the evolution of our modern coastline, and significant concerns surround the impacts of an increasingly dynamic coastal zone. Physical evidence of similar coastal processes in the prehistoric period can be identified in palaeoenvironmental deposits and on archaeological sites. Archaeological research and speculation on the impacts of these past physical processes on the coastal zone, and its inhabitants, is developing rapidly.

One of the most visible and frequently-encountered forms of evidence for dynamic coastal processes which took place over the last four millennia are horizons of calcareous (shell) and mineral (quartz and feldspar) sands, deposited in coastal landscapes and settlements by wind and wave dynamics. Around 20% of the Scottish coastline is made up of sand-based features, with the dune area comprising some 48,000ha (Dargie and Duncan 1999, 143). Such coastal zones were particularly densely settled in the prehistoric period. For sand to move, critical physical thresholds including precipitation, grain size and wind speed must be reached (Chapter 2). Resultantly, these deposits are frequently associated with high-energy conditions, such as strong winds and storms. Episodes of increased storminess are recognised as being climatically-driven (Chapter 3) but the physical manifestations of this storminess (such as windblown sand) vary according to numerous factors which interact within depositional environments.

As monitoring of the modern coastline for changes affecting known archaeological sites continues, deposits of windblown sand - often interleaved with material evidence for human occupation – are becoming a frequently-recognised feature of the archaeological record. One coastal region which has felt the impacts of this coastal process (and continues to do so), is the Orkney archipelago (Figure 1.1), located off the northern coast of Mainland Scotland. These islands form the geographical focus of this thesis.

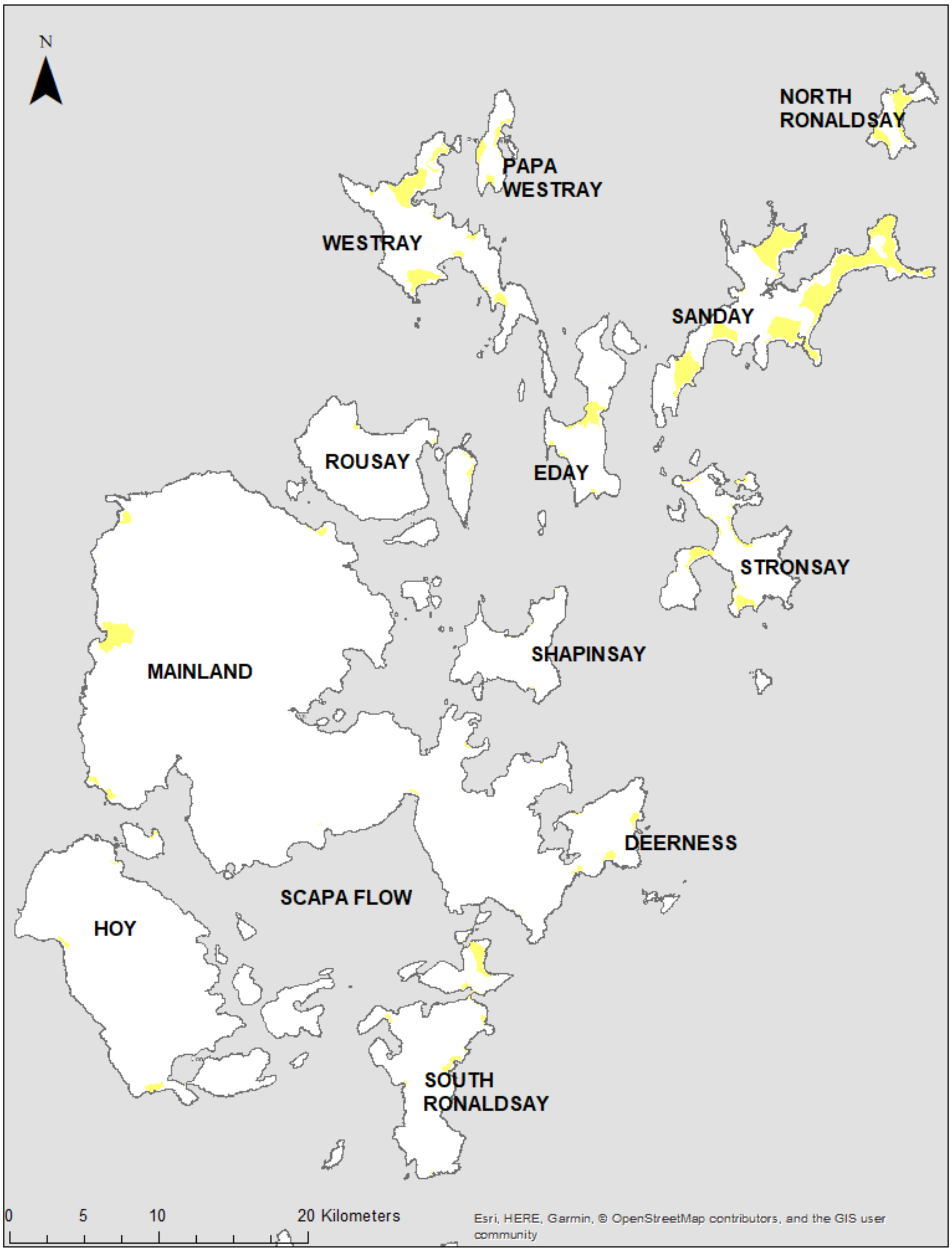

Figure 1.1. Key windblown sand deposits mentioned in the text.

Holocene sand horizons are complex physical markers of coastal change which can be scientifically dated. They are points in time which occurred alongside human settlement trajectories and use of the coastline and resultantly they stand as an important strand of archaeological evidence. Studies of the chronological distribution and impacts of windblown sand deposition across the British Isles have largely focussed on the Medieval and historic period, often within the period of climatic deterioration from the 16^{th} – 19^{th} centuries AD termed the 'Little Ice Age' (Lamb. H. H. 1991). Given the availability of historical data, instrumental measurements and high-resolution proxy data measurements, the focus on the Medieval and historic periods is hardly surprising. Multiple records attest to the occurrence of large-scale sand movements during this period, with written records focusing primarily on the socio-economic impacts of these movements which inundated entire villages, and laid swathes of agricultural land to waste (Brown, P. 2015; Griffiths, D. 2015).

Palaeoenvironmental and archaeological evidence indicates that similar quantities of windblown sand were also deposited on prehistoric and early historic sites (Gilbertson *et al.* 1999; Sommerville 2003). Despite their frequent occurrence, only two extensive pieces of work have been published on the significance of coastal sand horizons on, and near, prehistoric archaeological sites. Both ultimately derive from the perspective of environmental science. Work by David Gilbertson (1999) and Ann Sommerville (2003; 2007), on deposits in the Outer Hebrides and Orkney Islands respectively, focussed almost solely on the chronological applications of Optically Stimulated Luminescence (OSL) dating to prehistoric blown sand horizons, and their correlation with North West European storminess proxies. The limitation of these interpretations is that they have presented sand horizons as merely datable environmental deposits with little consideration of their archaeological implications and wider socio-economic significance. Thus far, windblown sand has remained the preserve of Quaternary scientists modelling storm activity.

The archaeological knowledge basis is therefore patchy and sparse. Discussions of sand layers often occur only as incidental comments within a broader discussion of an archaeological site, with little inter-site comparison. Most existing descriptions of archaeological sand horizons are contained within archaeological site reports, and broader patterns of sand movement on a regional scale are poorly-understood. Windblown sand horizons have not yet been systematically discussed and identified on a site by site basis, and these sites have not been amalgamated into a regional narrative. This has made it difficult to carry out satisfactory studies of the significance of these deposits beyond their physical and mineralogical characteristics.

Where they are considered in archaeological narratives, windblown sand horizons are typically interpreted as representing climatically-driven increased storminess or one-off, localised events leading to the marginalisation of landscapes. On a closer inspection of the evidential basis, employing more than one interpretative tool, the significance of sand horizons can be understood as far more than just natural occurrences; indeed, it will be demonstrated that they hold specific cultural significance. Sand horizons, no matter how deep, are not just an overburden to be removed to reach more enticing archaeological remains; they are a notable and vital part of the archaeological record, requiring more in-depth recording, acknowledgement and interpretation.

Archaeologies of climate change are witnessing a resurgence spurred by modern societal explorations of the significance of climate (van de Noort 2011), and the Scottish research context is no exception. Most recently, having reviewed extensive proxy evidence for climatic deterioration in northwestern Europe and Scotland, Tipping *et al.* (2012) identified three ‘moments of crisis’ during the prehistoric occupation of Scotland, dating to two periods within the Neolithic (at c. 3600 to c. 3300 cal. BC and c. 3000/2900 to c. 2700 cal. BC), and one in the Iron Age (at c. 850 to c. 500 cal. BC). The paper has served as a call to arms, encouraging the archaeologist to investigate human-environment relationships using hypothesis-driven approaches to specific landscapes and environmental proxies.

The question remains whether a deeper exploration of this single type of environmental deposit – windblown sand - can shed further light on the relationship between humans and climate. This thesis seeks to contribute to this broader research theme. Sand movement is one of the most commonly-occurring, yet least well-understood, processes in sedimentary coastal environments and associated archaeological records. As such, it warrants a more critical understanding which has so far been lacking. In the current research climate (see 1.4) this work is timely; plenty of relevant data exists and requires summation and comparison.

A note on radiocarbon dating conventions

In this thesis, wherever possible dates are expressed as calibrated years BC/AD. The radiocarbon dating ‘present’ is defined as 1950AD, while the luminescence dating presence is defined as the year the sample was processed in the laboratory. Where calibrated dates were presented in original publications, these are cited within the thesis. Any dates published in their uncalibrated state were calibrated using OxCal 4.3 and the IntCal13 curve (Bronk Ramsey 2009; Reimer *et al.* 2013). Radiocarbon dates are denoted by ‘(lab code, sample number)’ e.g. (GU-9481), while luminescence dating samples are denoted by ‘<lab code, sample number>’ e.g. <SUTL888>. Unless otherwise stated, calibrated radiocarbon dates are quoted at their 95% confidence limits, and rounded to the nearest 10 years. Some radiocarbon determinations have been provided by the Historic Environment Scotland Radiocarbon Database developed by Patrick Ashmore (see Ashmore *et al.* 2000). Where this is the case, the reference used is (Ashmore, P.J. C14dates.mdb. 15 June 2003) alongside the database ID number, as stipulated in the Conditions of Use provided by Historic Environment Scotland.

1.1. Thesis aims

This thesis proposes that sand, how it moves and where and when it was deposited is an important issue. It is more than an environmental deposit which can be separated for the archaeological horizons it is stratified with; rather, it is a key strand of archaeological and environmental evidence and provides an important and novel evidence base through which to explore human-environment interactions. Windblown sand on archaeological sites is frequently interpreted purely as an environmental deposit with little deeper archaeological or taphonomic significance, despite its visible deposition in concentrated settlement landscapes. Two key problems currently hinder our understanding of windblown sand. Firstly, most discussions of the possible significance of sand horizons are incidental, dichotomised and sparse. Secondly, when they are discussed it is only with reference to their use as chronological markers (e.g. Hunter, J. *et al.* 2007), or as a source of evidence for climatic deterioration. This is despite a poor understanding of chronology (and significant dating errors) - a tight constraint on which is arguably the most important facet of a sound climatic reconstruction. To tackle these conceptual and interpretative problems, it is important to understand the spatial and chronological distribution of windblown sand horizons. Chronological methods in the Scottish context have previously been applied by Sommerville (2003), Gilbertson *et al.* (1999), Kinnaird (2012), and Tisdall *et al.* (2013), but in the years which have followed this work, advances in archaeological dating and further excavations have been undertaken, and new data recovered. This has yet to be synthesised with earlier data.

The aim of this thesis is to highlight the broader archaeological significance of windblown sand horizons in prehistoric Orkney, by synthesising all currently-available evidence for the deposition of windblown sand on or near prehistoric archaeological sites. Here, 'prehistory' is defined as the period encompassing c. 4,000 BC – c. AD 500 (from the Neolithic period to the Iron Age. To achieve this aim, five key research questions are posed;

1. What is our current state of understanding of the nature and geographical extent of blown sand deposits in the Orcadian archaeological record?
2. Can chronological variation in patterns of sand movement be detected, and how does this fit within proxy evidence for northwest European storminess?
3. How have sand horizons on prehistoric archaeological sites previously been identified and interpreted?
4. Did coastal sand movement have a notable impact on contemporary prehistoric settlements?
5. What is the cultural significance of settlement in coastal and dune landscapes?

The methods by which these questions will be explored are detailed in section 1.5.

1.2. The Orkney Islands

1.2.1. Location and geology

The Orkney archipelago is formed of around 90 islands and skerries and is separated from mainland Scotland by the Pentland Firth (Figure 1.2). The archipelago can be further divided between the Mainland-Rousay-Shapinsay island group and the northern islands (Mykura 1976, 3). The bedrock geology consists for the most part of Middle and Upper Old Red Sandstone (Mykura 1976, 1-8 and Figure 1.3). Approximately 85% of Orkney is covered by superficial deposits, comprising postglacial boulder clay deposited in the lower-lying areas, and aeolian sand deposits (Davidson and Jones 1985; Brown, J. F. 2000). Peat deposits have also been observed across the West Mainland, Hoy and Rousay (Farrell 2009, 18), with a patchier distribution on the smaller, northern islands (e.g. Davidson and Jones 1985).

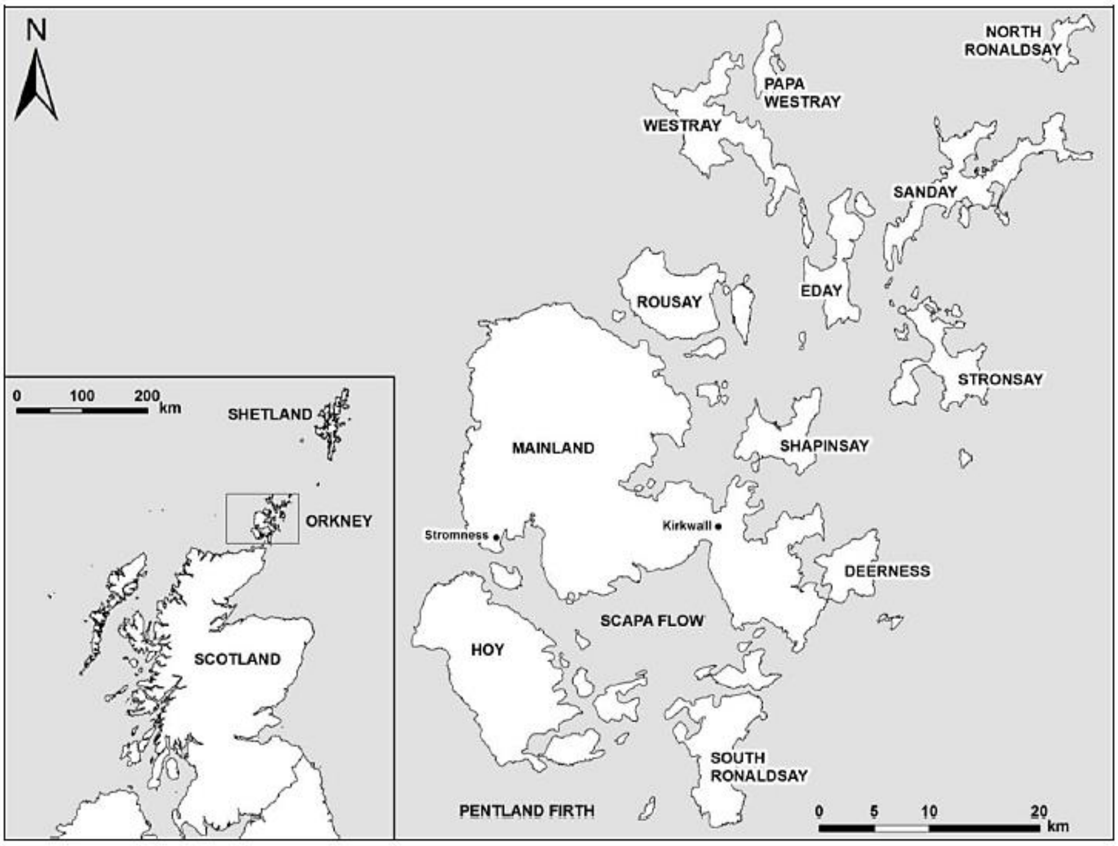

Figure 1.2. Orkney location map.

The current primary sand sources in the Orkney archipelago are blown sand accumulations and beach sands, consisting primarily of shell fragments with high proportions of carbonates transported by winds inland from beaches. Significant mainland deposits include those at the Bay of Skaill and Sandside Bay, (Skaill), Aikerness, and Birsay. Larger deposits are present in the northern isles of Orkney, notably Sanday, Eday, North Ronaldsay and Westray (Figure 1.4). Smaller areas of silica, quartz-based sand exist on beaches on Hoy, Eday, Sanday, and Westray (Mykura 1976, 123-4). The last glaciation and subsequent sea level rise saw the development of many of the significant topographical features which characterise the landscape of Orkney. The topography of the islands was 'smoothed' and large areas of the landscape drowned; this submergence along with strong winds served to drive rapid marine erosion leading to the development of geos, sea stacks and arches along the exposed coastline (Mykura 1976, 3).

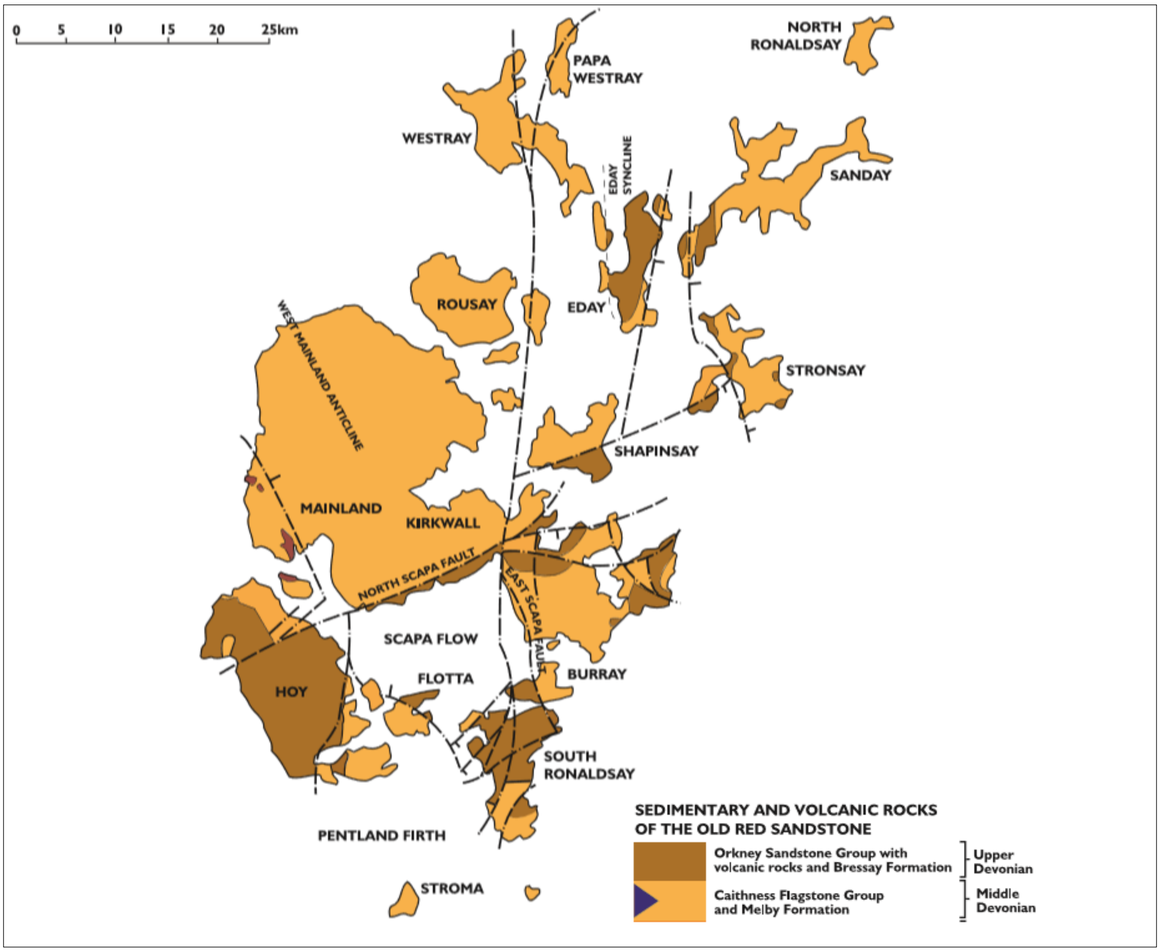

Figure 1.3. Orkney bedrock geology map. After McKirdy 2010, 3.

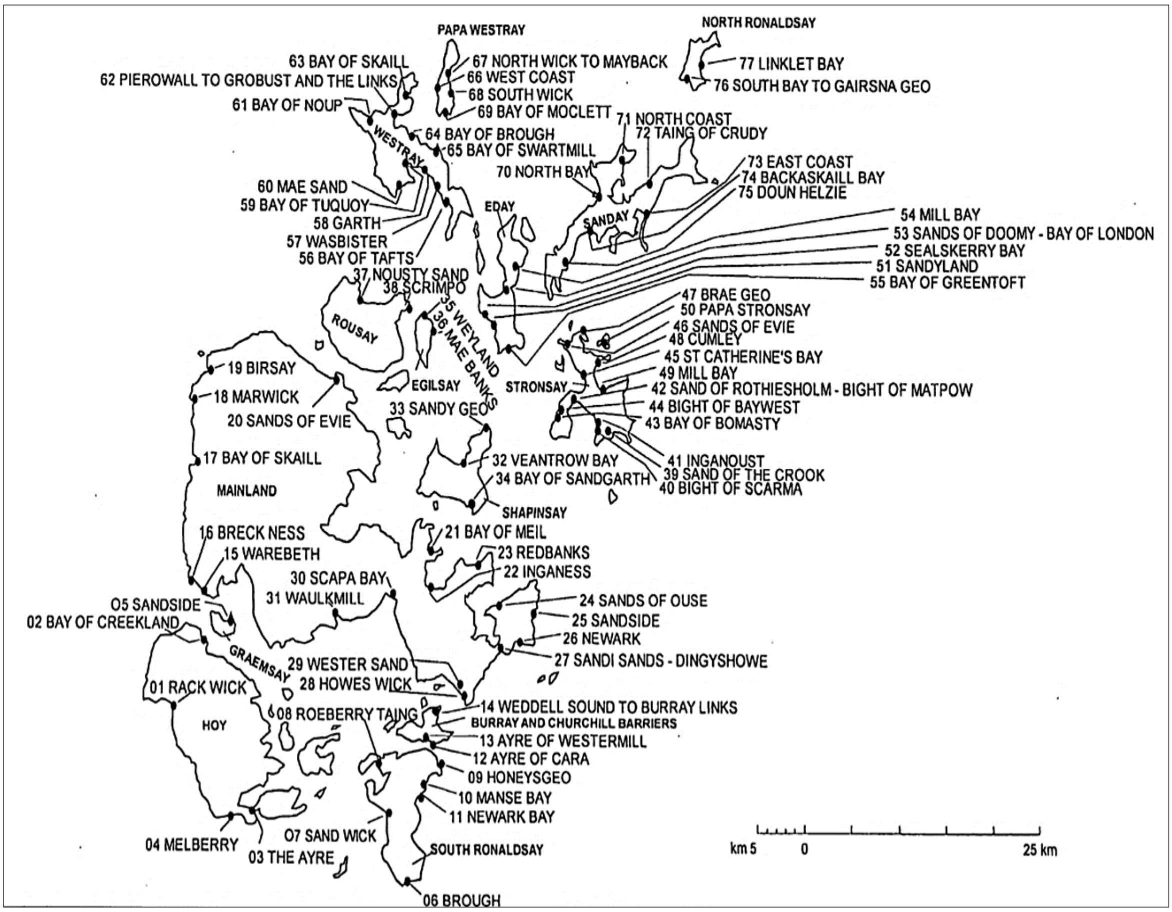

Figure 1.4. Location of sand dunes and links/machair deposits in Orkney. After Dargie 1998a. 2; Map 1.

1.2.2. Present-day climate and weather

Orkney’s current climate is temperate, with an average annual temperature of around 8.1°c, due in part to its interaction with the westerly Gulf Stream. Average summer temperatures lie at 13°c, with winter temperature averaging 4°c. Strong winds are frequent, with westerly and south-westerly prevailing winds c. 60% of the year (Figure 1.5) and gales occurring c. 30 days per year. This ensures a high-energy wave climate (Berry 2000; Hansom 2003a, 2). Average annual rainfall ranges from c. 800mm in the south and east of the islands to over 1000mm in the uplands (e.g. Hoy, west Mainland) (Davidson and Jones 1985). Over half of the present-day landscape is agricultural, predominantly pastoral.

Direction	Percentage
N	7.02
NNE	2.84
NE	1.55
ENE	1.37
E	2.7
ESE	5.26
SE	7.94
SSE	11.55
S	9.66
SSW	3.46
SW	4.51
WSW	9.76
W	12.91
WNW	5.27
NW	5.37
NNW	8.84

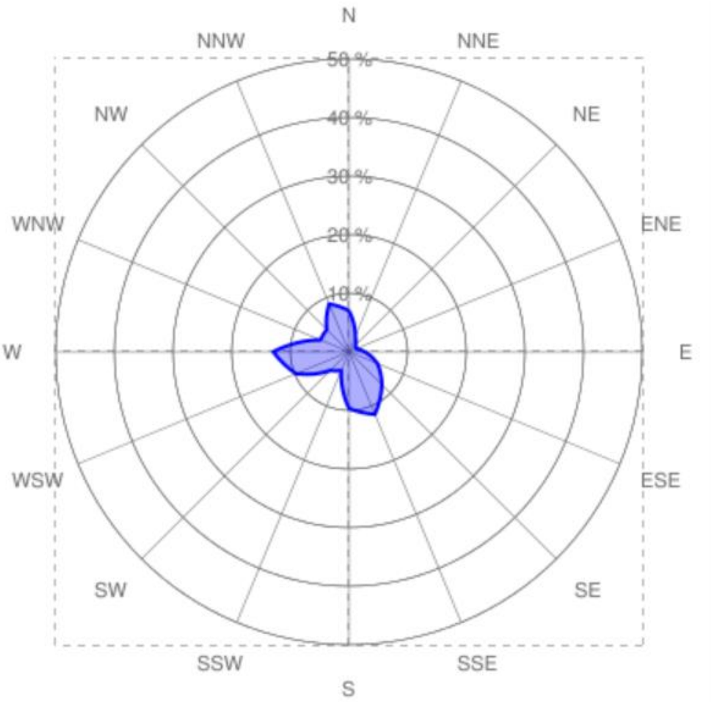

Figure 1.5. Wind rose for Kirkwall, Orkney, showing the dominant wind direction 2000-2010. RenSMART Wind Data Archive

1.3. Archaeological context

1.3.1. The Mesolithic (c. 9000-4000 BC)

The Mesolithic period in Scotland and beyond is generally characterised by a more mobile use of the landscape for hunting, gathering, and impermanent settlement (Saville and Wickham Jones 2012). The Mesolithic is often identified by its palaeoecological record, with archaeological evidence proving challenging to locate and identify. The submergence of large areas of the coast and hinterland following the last glaciation ensured that the Mesolithic palaeolandscape was significantly different to what is understood today (e.g. Bates, M. R. *et al.* 2013; Bates, C. R. 2016; Timpany *et al.* 2017). The primary evidence base for the Mesolithic occupation of Orkney and indeed elsewhere are surface scatters of lithic artefacts, as have been recovered from Long Howe, Tankerness (Mainland Orkney) (Wickham Jones 1990b), Mill Bay, Stronsay (Lee and Woodward 2009), and Wideford Hill (Richards *et al.* 2016).

1.3.2. The Neolithic (c. 4000-1900 BC)

The Mesolithic-Neolithic transition continues to be debated throughout the European context. The level of continuity of activities from the Mesolithic appears to be varied, with significant continuity noted in the west of Scotland (Finlayson and Edwards 2003) and far less elsewhere (Noble 2006a). In Orkney the lack of Mesolithic settlement means that this picture is still relatively unclear, but it seems likely that continuity would have been a significant feature of Early Neolithic life. The period is subdivided into early and late phases; artefactually, this is reflected in the use of Unstan ware pottery in the former and by Grooved Ware in the latter (Macsween *et al.* 2015). Early Neolithic settlement in Orkney is generally characterised by rectangular houses with rounded corners, and room divisions represented by upright slabs. Similarities between interior furnishings and Early Neolithic Orkney-Cromarty tomb layouts have also been identified. Stalled cairns are typical of this period, such as Midhowe, Rowiegar and Yarso (Rousay). Early Neolithic stone houses and settlements have been excavated at the Knap of Howar (Papa Westray), Pool (Sanday), Stonehall (Mainland) and Braes of Ha'Breck (Wyre), as well as timber buildings at Wideford (Mainland) (Brophy and Sheridan 2012, 77; Richards and Jones 2016). Towards the end of the fourth millennium BC, the timber houses of the early Neolithic began to be replaced by stone house construction (Richards *et al.* 2016).

Traditionally, the nature of settlement was thought to be characterised by individual, dispersed households with increasingly nucleated settlements developing into the Late Neolithic. However, given the significant contrast between the nature of the houses at Pool and the Knap of Howar, the picture is far more complex than that. It may be that settlement was generally better represented by scattered village settlements. The Late Neolithic is characterised by the construction of Maes Howe-type chambered tombs and passage graves, increasingly nucleated and aggregated settlement, and the cluster of monuments which today form the Heart of Neolithic Orkney World Heritage Site (e.g. Maes Howe, Barnhouse, Stones of Stenness) (Brophy and Sheridan 2012, 77-8).

1.3.3. The Bronze Age (c. 1900-800 BC)

The Scottish Bronze Age is characterised by the widespread use of copper and copper alloys for the manufacture of material culture, from tools to personal ornaments. Beyond this, it is a period frequently associated by increasingly visible trade with the Continent, and other significant socio-economic changes including shifts in social stratification and the development of specific regional trends. Perhaps most importantly for this thesis, it is often cited as a period of notable climatic and environmental change, and perceived 'marginalisation' although this has recently been challenged (Farrell 2009). A shift to individual interment (cremations and cist burials, e.g. Lopness, Sanday) and rich variation in ceramic styles may indicate an increase in the significance of the importance of the 'individual' as opposed to the earlier importance of group identity (see Sharples 2012).

Evidence for settlement landscapes and increasing investment in Orcadian agricultural landscapes becomes more visible in the Middle Bronze Age, with the flourishing of unenclosed platform settlements, oval houses, and distinct upland and lowland settlement traditions (Downes 2012). The Bronze Age settlement context in Orkney typically comprises of hut circles (e.g. Spurdagrove, Mainland (Hedges, M. E. 1978) and Whaness Burn, Hoy (Lamb, R. G. 1996)), enclosed settlements, field systems and a proliferation of burnt mounds on agricultural land (Anthony, I. 2003).

1.3.4. The Iron Age (c. 800 BC-AD500)

In northern Scotland the Iron Age is traditionally subdivided into early (up to c. 200 cal. BC), middle (c. 200 cal. BC-c. cal. AD300) and late (c. cal. AD300-c. 800), together comprising the 'long Iron Age'. Additionally, from c. cal. AD600 the term 'Pictish' is also employed (Foster 1990). Studies of the Scottish Iron Age have long been dominated by the archaeology of its rich and varied domestic settlement, comprising brochs, duns, wheelhouses, hillforts, crannogs, enclosed farmsteads and roundhouses. Beyond this, there is increasing evidence for social stratification, regional patterning and identities and continental exchange. The Iron Age domestic record in the Orcadian context is associated with deeply stratified settlements (e.g. Pool), promontory forts, souterrains and the drystone architecture of roundhouses (e.g. Bu, Pierowall, Tofts Ness and Quanterness) and the later (c. 3rd century) brochs (e.g. The Cairns, Howe and Midhowe), and nucleated broch settlements (e.g. Gurness). Such settlements were frequently reoccupied and remodelled in later periods.

Agricultural landscapes expanded with a rise in arable farming, with increasing palaeoenvironmental evidence for anthropogenically-altered soils (Dockrill and Bond 2009; Hunter, F. and Carruthers 2012). Until relatively recently the burial record for Iron Age Orkney was patchy and ephemeral, although excavations at Knowe of Skea, Westray (Moore and Wilson 2005b), and Mine Howe, Mainland (Card and Downes 2003) have revealed evidence for an inhumation mortuary tradition. There is a lack of evidence for ceremonial monuments, with an apparently greater concern for the monumentalisation of the household (Hunter, F. and Carruthers 2012). Towards the end of the Iron Age, however, it has been suggested that a significant social transformation from communal expression through monumental constructions to individual expression through adornment and portable material culture took place (Sharples 2003).

1.3.5. The Pictish Period (c. AD600-800)

Orkney became part of the 'Pictish kingdom' by the sixth century AD, with Pictish communities believed to have descended from the communities occupying farmsteads such as those at Pool and Tofts Ness (Sanday), and nucleated broch villages (Ritchie 1985). Cellular architecture and dispersed farmsteads dominate the Pictish domestic tradition, with frequent reuse and remodelling of earlier prehistoric settlements (e.g. Buckquoy and later phases at Gurness, Howe, and Pool) (Ritchie 1977; Hunter, J. *et al.* 2007). Evidence for inhumation as well as cremation increases during this period, for example at Hermisgarth, Sanday and Westness, Rousay (Farrell 2009). The most significant societal development came with the introduction of Christianity in the sixth century AD (Ritchie 2003). There is also evidence for the development of an increasingly stratified society with centralised leadership (Hall and Price 2012).

1.3.6. The Viking Period (c. AD 800-1065)

The Norse settlement of Orkney began in the late eighth century AD when the northern and western Scottish coastal regions were settled. By 900 AD the Norse earldom of Orkney and later Shetland, Caithness, and the Western Isles was established (Grieve and Gibson 2005). The domestic architecture of this period is typified by some reuse of Pictish structures, and by longhouse dwellings, as at Saevar Howe, Brough of Birsay, Skaill and Buckquoy (Mainland). Other Norse settlements include the later phases at Pool, and Quoygrew, Westray (Barrett *et al.* 2005). Land ownership became extremely fragmented with the introduction of the udal system of land tenure, whereby the primary settlement land was inherited by the eldest son and the rest divided between his siblings (Farrell 2009). Pagan burials including boat burials and short cist burials became prevalent, as did the inclusion of grave goods (Owen and Dalland 1999), and there appears to have been a decline in the practice of Christianity, and the appearance of metalwork hoarding. The mixed economy of previous periods continued into the Viking period, with a more intensive fishing strategy being developed (Barrett *et al.* 1999).

1.4. Thesis rationale

To define the rationale for this thesis, the following section examines the wider context of research into human-climate interactions. It considers the increase in climate-culture studies (defined here as the study of links between climate-driven environmental change and changes in human behaviour), their global and political importance, and the role played by archaeology in such discussions. It is argued that the study of *observable* (e.g. perceptible by humans) environmental changes examined through inter-site comparisons within specific regions (in the case of this research project, coastal sand movement in Scottish islands) can allow for a more nuanced understanding of localised human responses to change.

1.4.1. Climate-culture correlations

Having become a 'key environmental narrative of the 21st century' (Allan et al 2016, 164), it has never been so important to study and understand climate change, environment, and human responses to it. Historically, the natural sciences have retained a dominant stance in climate research, with the arts, humanities and social sciences having taken a more submissive role given that such fields cannot always match the use of statistical averages and modelling (Hastrup 2016, 35-6 in Lazrus 2016). Prehistoric and historic climate change and its perceived effect on human populations, their cultures and economies are being readdressed by current research agendas (e.g. Brown, T. 2008; Downes 2012; Tipping *et al.* 2012), alongside growing debate over the value and definition of the 'Anthropocene' as a defining period in which the earliest human impacts on landscape and environment can be detected (Foley *et al.* 2013).

Human interpretations of climate change and history are beginning to be re-evaluated as part of the increasing discourse between archaeology, humanities and the Earth sciences (e.g. Foley *et al.* 2013). Such discussions previously fell out of favour with archaeologists, partly due to the reliance on causal environmental determinism as an explanation for changes and 'deterioration' in culture (Pillatt 2012, 30). The revisiting of such themes is developing alongside an increasing concern with modern and future climate change and how societies will adapt to these changes. In the archaeological research context, this is coupled with an awareness of the effects of climate change and its localised manifestations, such as coastal erosion, on the heritage resource in the present day. Resultantly, archaeologists are seeking to establish the role, contributions, and relevance of their discipline within modern climate change debates (e.g. Van de Noort 2011; Sandweiss and Kelley 2012; Allan *et al.* 2016).

Evidence for significant social and economic change in prehistory is well-recognised at multiple scales and can include the spread of animal and plant domestication, changes in economic strategy, centralisation of power, collapse of trade networks, construction of monuments, the production and exchange of metalwork and abandonment or nucleation of settlements (e.g. Bradley, R. 2007). The drivers and influences behind this, and the nature of such a relationship (which is often a two-way interaction) are difficult to identify and disentangle; indeed, questions surrounding societal development are described as continuous "grand challenges" for archaeology (Kintigh *et al.* 2014, 880). It is sensible to assume that a wide range of drivers and multidirectional, flexible relationships between people and place lay behind many of these developments. However, given the current preoccupation with present and future climate - and the fact that socio-economic development in the past did not take place in a vacuum - specific debates surrounding human-environment interactions have been reignited. More localised transitions in settlement location, economy and resource procurement may have been influenced by external climatic and environmental factors. A long-established theoretical paradigm is that of correlative studies, with negative impacts of climate and associated environmental change being associated with disaster and collapse (e.g. Burroughs 2005; Cooper 2012). The perceived failures of the past, however, are now joined by an increasing focus on past *successes* in adaptation to, and benefitting from, marginal environments taking a more prominent role (Guttman-Bond 2010).

Climate, environmental change and weather permeate our daily lives at various scales, and there is no reason to assume that this was any different during earlier periods. John G. Evans (2003) demonstrates that climate in many ways is a human construct and is used as a means of social engagement. He discusses the multiscalar nature of climate, from single events to seasons, millennia and across large geographical areas. Climate is constituted in its relevance to human action and is used to establish identities, and in developing socio-economic relationships (Evans, J. G. 2003, 117-8). As such, it is vital that climate and environment are grounded within any study of archaeological landscapes, and vice versa.

With some exceptions (for example, dendrochronological data or historical documents), proxy climate data and archaeological data are rarely resolvable to an event or year, although our ability to chart changes is improving as chronological techniques develop. To be identified correctly, correlations must be localised with human actions driven by ‘event effects’ such as flooding or sand mobilisation (Brown, T. 2008). The way we understand and approach the rate and scale of Holocene climate change is beginning to move away from a paradigm of gradual change towards one which recognises abrupt, shorter-timescale changes over the decadal to century scale, punctuated by longer periods of stasis, and manifested in smaller, localised changes (Mayewski *et al.* 2004; Tipping *et al.* 2012, 9; Bell 2012; 43). Additionally, the impact of humans on their environments is being increasingly recognised.

1.4.2. The role of archaeology in climate debates

As the negative effects of climate change increase, modern societies are seeking mitigation against the consequences of climate change and to develop resilience and adaptation strategies. If the environmental impacts of anthropogenic-driven emissions are to be tackled, a strong understanding of natural climatic and atmospheric fluctuation must first be developed (O’Brien *et al.* 1995) (see Chapter 3). This involves taking the ‘long view’, which by its very nature requires the acquisition of data for past climatic variability. There is renewed discourse developing between archaeology, anthropology and the earth sciences as we seek to understand current societal impacts and their drivers for change. Climate, weather and their landscape impacts provide a major backdrop to lives past and present, and as such it is too important to be excluded from any discussion of human environment (Evans, J. G. 2003, 95-6). Palaeoenvironmental data can aid an understanding of past climatic deterioration in different environments, particularly as scientists and policy makers in the present day seek to predict catastrophic events using long records of environmental change and response.

In current climate research, the value of Traditional Environmental Knowledge (TEK) of non-westernised and other 'traditional' societies, to understandings of climate resilience and adaptation is increasingly recognised. TEK can be defined as "…a cumulative body of knowledge, practice, and belief, evolving by adaptive process and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment" (Berkes 1999, 8). The use of archaeological data in conjunction with more recent historical records can complement TEK, an important and relatively untapped resource for understanding elements of environmental observation, as well as spiritual and moral practices, which enabled adaptation and resilience to past climatic fluctuations (Lazrus 2016; Rockman *et al.* 2016, 9-12).

Archaeological data has been described as a series of completed experiments, and as concerns with present and future climate change develop, a backward-looking approach which regards the past as a means by which to understand the future has often been taken. The extent to which the study of past climate can inform understanding of our current climatic situation and the way we should approach it is debatable. Vulnerability and the character of human response to climatic and environmental change are highly contextual, and as such it is impossible to make any universal generalisations which could be applied to our current cultural and economic context. However, while the past cannot always provide us with any precise analogues, it can reveal significant information on the complex interaction between physical and social systems (Brooks *et al.* 2005, 280).

By developing an understanding of critical thresholds and 'tipping points' (a point at which an ecological system experiences an abrupt or discontinuous change) (Jax 2016), we can gauge how events and processes of varying severity may have been felt and dealt with. This in turn may have relevance for future policy makers. There is a growing need for archaeology as a discipline to mature and cement its role as a contributor to current climate change debates. In this case, its relevance to modern society lies in its ability to provide a 'story', perhaps even something of a morality tale or parable for approaching climate change (R. Van de Noort *pers. comm.*; Rockman *et al.* 2016).

A move towards a more environmentally-sustainable planet requires a strong contribution from wider society and not just policy-makers, scientists and other academics. Humans relate to other humans, past and present; archaeological and anthropological data (in other words, the broad field of humanities as a whole) provide an inclusive and wholly relevant discussion point for a nuanced and holistic understanding of climate change in the present. A focus on scientific evidence alone holds the danger of overlooking the socio-cultural context in which such knowledge is produced (Allan *et al.* 2016).

Ultimately a multidisciplinary approach which combines the social with the natural sciences can feed into risk management strategies by understanding societal perception and response. Admittedly it is logistically and financially challenging to build and sustain a capacity for such multi-stranded research, although some projects have made notable contributions (Allan *et al.* 2016). Furthermore, multi-stranded approaches may exist within each discipline, allowing for greater freedom of interpretation and creativity tied down to specific scientific data. The significance of this is illustrated by this thesis, which utilises multiple strands of interpretation to consider the nature, chronology and significance of windblown sand deposits in archaeological sites and landscapes in the Orkney Islands.

1.4.3. Islands and climate

Islands have served as a source of fascination for archaeological researchers. Early approaches referred to islands as 'laboratories' for the study of cultural processes (e.g. Evans, J. D. 1973), an approach which has been widely critiqued (e.g. Rainbird 1999). More recently discourse has seen a tension between a desire to treat islands as detached features of wider mainland cultural traditions and an over-emphasis on their 'otherness' and perceived marginality. A careful balance must be sought between these approaches, one which takes account of the nuances of different island lifestyles and levels of connectivity (Fleming 2008, 11). It has been argued that far from being marginalised and isolated, island communities are in fact "globally connected" in a way which cannot be easily described or quantified (Lazrus 2012, 286). Rainbird (1999; 2007) has argued that as the disciplines of coastal/intertidal and maritime archaeology develop and mature, the concept of 'island archaeology' is meaningless as it is surely embedded within these research communities. Rather than laboratories, Fleming argues that islands should be approached and treated as "worlds in microcosm", drawing specific themes and narratives into sharper geographical and social focus (Fleming 2008, 20).

Present day coastal communities are some of the most immediately-affected by global climate change, and some resultantly have become the world's first modern 'climate refugees'. Of annually-recorded world coastal disasters, two thirds are associated with extreme weather events (Adger *et al.* 2005); although these events do not stand alone as drivers to social and economic change, they can exacerbate pre-existing socio-economic, political and environmental trends (Lazrus 2012, 288).

1.4.4. The Scottish coastal zone

The Scottish islands feature extensive coastlines (Berry 1985, 45). Orkney comprises some c. 1085km of coastline, the Western Isles 3032km, the Inner Hebrides 3000km and Shetland 2063km - totalling 15,415km (Dawson, T. 2015, 86). The coast has been defined as the place where land, water and air meet (Carter 1989, 1). A more formal physical definition is offered by Carter:

"The 'Coastal Zone' is that space in which terrestrial environments influence marine (or lacustrine) environments and vice versa. The coastal zone is of variable width and may also

change in time. Delimitation of zonal boundaries is not normally possible, more often such limits are marked by an environmental gradient or transition. At any one locality the coastal zone may be characterised according to physical, biological or cultural criteria. These need not, and in fact rarely do, coincide" (Carter 1989, 1).

The coastal zone is a dynamic, locally-variable area which is sensitive to climate change impacts. Storms and their impacts on exposed coastlines are direct and highly perceivable, and therefore provide an ideal testing ground for an exploration of human ecodynamics – that is, human relationships with their environments. Coastlines are navigable and a means by which to explore new islands and landscapes, and depending on topography, can be easily defended. The resources they provide are numerous (see chapter 7), making them an attractive prospect for settlement.

Given their geographical location within the Atlantic zone, Scotland and its archipelagos are sensitive to climatic fluctuations and ecological shifts. Scotland's proximal location to the northern Atlantic holds significant implications for its short- and long-term climate given its exposure to oceanic as well as continental climatic factors and the circumpolar vortex which influences airflow systems (Whittington and Edwards 1997, 11-12). As such, Scotland and its islands are well-placed for the integrated study of environmental change and human adaptation (Bigelow *et al.* 2005). The Northern and Western Isles display several interesting contrasts in their geology, coastal geomorphology and topographies. Whereas most of the Orkney archipelago is comprised of soft geology in the form of laminated Devonian Old Red Sandstone, Shetland is characterised by its metamorphic geology, while the Western Isles are comprised of various igneous terrains (Mykura 1976).

1.4.5. The archaeology and morphology of sand dune landscapes

Sand environments represent a common feature of the coastal zone (Bigelow *et al.* 2005). A significant number of archaeological sites in the Scottish islands were constructed directly onto windblown sand deposits within coastal dune systems or hold sand layers between cultural horizons indicative of sandblow events either during or after the life of the settlement (see Chapter 4). Both carbonate and quartz-based sands feature in these environments and landforms, with varied formation processes and sources lying both offshore and on land (Gilbertson *et al.* 1999).

Dynamics of Holocene sediment supply in the Scottish island region are complex and variable, with localised interaction between sediments and sea level change influencing the response of coastlines and their sediment budgets to change. Late-glacial and Holocene sediment supply is largely controlled by the availability of glacially-derived sediments from rivers and the continental shelf (Hansom 2003a). From c. 11,000BC, rapid sea level rise and transgression allowed for only limited amounts of sediment transport onshore, and modification of the coastline by these sediments (Hansom *et al.* 2000). As this rate slowed, opportunities for sediment transport and modification of shorelines increased, with large quantities of gravel and then sand being deposited on Scottish shorelines (Hansom *et al.* 2000). This increase roughly correlated with a reduction in sea level rise rates at c. 4550 cal. BC, although after this date levels of sediment availability were reduced (see Hansom 2003). This deficit led to a change in nearshore gradients, and a reorganisation of coastal sediment supplies. In the Outer Hebrides, the carbonate sands forming the North Uist and Benbecula west-facing coastlines arrived from the offshore zone from at least c. 7000-6400 cal. BC (GU-1762) at Cladach Mór (Ritchie and Whittington 1994, 44), from c. 6600-6400 cal. BC (SRR-1224) at Pabbay, North Uist, and 5600-5500 cal. BC (SRR-4915) at Borve, Benbecula (Gilbertson et al. 1999, 463).

Blown sand horizons on archaeological sites (sand layers containing archaeological remains, or stratigraphically associated with them) can be broadly divided into two observable - sometimes coinciding - sets of material remains; between landscape stabilisation layers, and on settlement sites (Griffiths, D. 2015, 109). Stabilisation layers could be formed through natural processes, or by the addition of organic materials including peat, seaweed, midden or turf to facilitate the creation of agricultural and occupation surfaces over sand horizons (e.g. at Tofts Ness, Sanday and Old Scatness, Orkney). Although they could be much thinner than their associated sand layers, they may have accumulated over a longer period of time. Sandblow deposits have been identified as laminated windblown sands and palaeosols interleaved with archaeological remains such as hearths, structures and middens (Griffiths, D. 2015, 109).

Sand formed, and continued to form, a key part of coastal landscape configurations and influences how they are perceived and used. The nature and themes of research within sand landscapes can take many forms, whether they are chronological, morphological or concerned with movement and its impacts on landscapes. Sand dunes comprise a significant proportion of coastal landscapes, and have excellent levels of preservation. Their construction and chronology are key sources of information for understanding storminess as an environmental stressor (Sommerville et al, 2007; Downes 2012, 38; Kinnaird *et al.* 2012). They are fragile and can shift and change at a perceptible scale, and with this comes the turbation, migration and destruction of contexts which can cause significant practical and theoretical problems when it comes to interpretation (Griffiths, D. and Ashmore 2011). The primary threats to this changeable archaeological and palaeoenvironmental resource are deflation, where sand deposits are removed by wind action, leading to the sinking of heavier deposits and thus confusion of the stratigraphic record as well as burrowing and marine erosion caused by wind eddies (Griffiths, D. 2015, 109). Equally, remains can be obscured by accretion, where sand and other sediments are moved by wind and sea inland.

Evidence for localised and wider climate and environmental change is evidenced by a wide array of physical and atmospheric changes, some of which are more visible – with more direct impacts on human populations – than others, at multiple temporal and spatial scales. These differing tempos of change will have had variable effects, some of which are easier to quantify than others. Relative sea level change was responsible for large areas of land becoming submerged across the Orkney archipelago (Bates M. R. *et al.* 2013, 24-6), and may have been partially imperceptible on the human scale except for large surges or floods. We must therefore look to more immediate events with direct impacts, such as storms which would have had impacts at a perceptible scale. These may have included physical impacts such as erosion, accretion or flooding through wind or waves. Orkney's low-lying nature and position within the wider North Atlantic storm track ensures its vulnerability to storm events, both in the past and present.

Sand and its movement continue to pose a significant problem in contemporary landscapes, particularly in terms of agricultural land and small-scale coastal change. The Outer Hebrides machair landscapes stand as a stark example of this. Machair has long been an important agricultural resource, and much of the upper machair that we see today is relatively modern in its formation (forming around the last 200-500 years). There is a fine balance to be struck between small-scale sand movement - which can increase soil fertility by neutralising acidity – and large-scale movement and flooding which can significantly hinder growing potential. These landscapes continue to be threatened today; flooding threatens to submerge and damage the machair (D. Muir *pers. comm*.), thereby leading to a loss of the crofting culture, an important part of Scottish island heritage and identity.

There are some problems when it comes to quantifying the impacts of storms and the evidence they leave behind in the prehistoric record. There is still a comparative lack of high-precision Holocene palaeoclimatic records for the North Atlantic, leaving the issue wide open to debate and hypothesis. Historical (from the 13^{th}-17^{th} centuries) and indeed modern evidence tells us that sand movement had/has a significant effect on landscape, agriculture and settlement, particularly in coastal dune areas. However, little attention has been paid to the prehistoric evidence for these processes. Some sites appear to display evidence for the abandonment of the site as a result of such events, as has been argued for the sites at Tofts Ness and Pool, Sanday, Orkney (Sommerville 2003, 3; Hunter, J. *et al.* 2007, 26; D. Sanderson *pers. comm*.; Dockrill *et al.* 2007, 52), and Skara Brae, mainland Orkney (Childe 1931). The presence of interstratified sand of varying thickness associated with archaeological remains of course does not always have to signify abandonment as a direct result of sand inundation, and can instead signify periods where a site was uninhabited, or when a shift of settlement focus occurred (e.g. Macsween *et al.* 2015). Gauging the nature of windblown sand deposits, their source and how they relate to the archaeological record is challenging and requires both palaeoenvironmental and archaeological understanding and investigation on an appropriate scale (Griffiths, D. and Ashmore 2011).

1.4.6. Conclusions

Consideration of past climate and its possible effects on humans stand as a vital facet of our understanding of environmental change. Climate and environmental change in prehistory is something which must be considered and integrated, with the archaeological record feeding into both broader and short-timescale climatic narratives. Attempts to create direct links between the present climate change situation and the past remain somewhat tenuous and unclear (Sommerville *et al.* 2007, 634; Grattan and Gilbertson 2000). However, it is clear that a thorough understanding of climate change beyond purely empirical observations has important implications for our conceptions of risk, vulnerability and adaption in the past and present.

Considerable progress has been made with the availability of palaeoclimatic proxies and archaeological data, with some relevant regional studies in Ireland (e.g. Armit *et al.* 2014) and Scotland (Sommerville *et al.* 2007; Kinnaird *et al.* 2012; Tipping *et al.* 2008). Many palaeoclimatic studies fail to take account of human activities and impacts in the landscape and vice versa, and there is a gap in terms of our understanding of early responses to climatic fluctuations in Atlantic Scotland. This is coupled with the recognition that there are still aspects of settlement and landscape culture in Scotland that require further exploration by increasing dialogue across the disciplines, such as widespread settlement abandonment and changes in economy. Universal explanations are sought for what might have been highly contingent events, and as such site by site interpretations are required, which can be placed within broader landscape and climatic studies (Blackford 1993; Brophy and Sheridan 2012, 59).

In this section it has been proposed that Scottish islands, their climatic and geomorphological settings and rich archaeological records, stand as important locations in which to test key hypotheses relating to localised human-environment interactions. Several important coastal processes have impacted the densely-settled coastal zone throughout history, including the deposition of windblown sand onto archaeological sites and landscapes. Such accumulation events, which took place on a range of temporal and geographical scales, are particularly visible and measurable in the archaeological record, with distinct impacts on sites, landscapes and their inhabitants. As a discipline, the role of archaeology in current climate change debates is to provide a relatable 'long view' through which to explore concepts of resilience and adaptation to climate-driven environmental change.

1.5. Climate and environmental change impacts on human populations: a review

1.5.1. Introduction

Human beings are shaped socially and biologically by the changing weather, environment and climate, and vice versa (Baer and Singer 2014). Energetic debates surrounding the extent to which human society and their activities are governed by their environment can be identified in the literature of a number of related fields. On the broad scale, these debates can be summarised by two opposing viewpoints; that environmental determinism shaped human culture, or that humans and their technology were in fact capable of overcoming many environmental restraints and fluctuations, dependent on the nature, extent or duration of a deterioration event (Masse *et al.* 2006, 106). Similarly, perspectives of human-environment interactions either stem from the destructive actions of humans on their environments, or the impacts of 'natural' events and forces on human populations; this pits climatic determination against resource exploitation (Dearing 2006, 187). Here it will be demonstrated that as scientific evidence increases in resolution, and inter-disciplinary research flourishes, such a division becomes less useful. Rather, humans and environment should be increasingly viewed as adaptive and reflexive in their relationships with each other.

The content of the archaeological literature surrounding past climate change can be broken down into two guiding themes; impact and response. The former is generally concerned with rapid and significant environmental changes and their impact on humans and ecosystems. The latter is concerned with the responses and adaptation of humans and ecosystems to these fluctuations and their capacity to do so. Responses are generally manifested within population dynamics (such as collapse or migration), societal structures, worldview/beliefs and activities, such as subsistence and land use (Leroy *et al.* 2006, 1). Scholars have a long-held interest in the concept of societal collapse driven by rapid climatic shifts. Case studies such as the fall of the Mayan civilisation (Hodell *et al.* 1995 cited in Armit *et al.* 2014, 1; Haug *et al.* 2003), attract interest as contemporary concern with climate change heightens. The publication of popular and accessible literature by the likes of Jared Diamond (2011) have also served to increase the interest of general enthusiasts.

It has been argued that the assignation of cause, whether it is autogenic, anthropogenic or climatic, is a key structuring paradigm within debate of this nature and one which is predominantly informed by metadata-sets (Brophy and Sheridan 2012, 58). Two relevant approaches, which are often undertaken side by side with one informing the other, are the use of archaeological and palaeoenvironmental data, with one strand generally taking a more dominant role in each publication or research project depending on specialisms and project aims. Contained within these approaches are geoarchaeology, palaeoecology and geomorphology amongst other interlinked disciplines.

1.5.2. Theoretical approaches

Although climate change science has continued to play a dominant role since the mid-19th century (Allan *et al.* 2016), early twentieth century studies in the fields of geography and social anthropology influenced early archaeological studies of human engagement with the environment. The publication of geographer Ellsworth Huntington's 'Civilisation and Climate' (1914) examined the rise and fall of civilisations, corresponding climatic conditions and impact of weather on societal efficiency, and paved the way for the causality paradigm although it faced critique for its deterministic approach (Allan *et al.* 2016). From the 1920's, the role of subsistence in cultural evolution was highlighted (e.g. Childe 1925) and was to remain a major archaeological paradigm in prehistoric studies (Hassan 2000). Influenced by Marxist theory, Childe's culture history models emphasised the influence of environmental conditions on technological innovation and social life, which in turn shaped cultural developments such as the advent of agriculture and metalworking (Hassan 2000).

The 1970's and early 1980's witnessed a rise in explorations of the extent to which humans are influenced by their climatic surroundings in anthropology, history, ecology, social theory and archaeology. Prominent works by Le Roy Ladurie (1972), De Vries (1980) and Lamb, H. H. (1972; 1977) concerning historical climate change and its impacts on society continue to stand as some of the earliest and most influential texts in their field (Pillatt 2012, 33). It is notable that even during this earlier period of research some caution was taken in pursuing causal, deterministic approaches and correlative studies, with recommendations made for the integration of social and environmental narratives (e.g. McGhee 1985, 163). A comparatively early argument for the importance of human perception of place and environment was given by Collingwood, who stated that "the fact that certain people live for example on an island has in itself no effect on their history: what has an effect is the way they conceive of their position" (1946, 200). These early views were developed by geographer Harold Brookfield, who suggested that 'decision makers operate within an environment as they perceive it, not as it is' (1969, 75-6).

From the 1990's, scholars became more concerned with human perspectives in the fields of social anthropology, ecology and history, partly in reaction to culture-history and functionalist models. This led to the expansion of 'historical ecology', a more balanced perspective which gave precedence to human experiences of climate and welcomed interdisciplinary discussion (Crumley 1994; Pillatt 2012, 31). It was this application of ecological perspectives to historical data which caught the attention of archaeology as a research discipline (Evans, J. G. 2003). Its emphasis on human-environment interaction appealed to scholars, given their own similar expansion from the New Archaeology movement to post-processual paradigms, and continues to be a highly influential perspective within this field (e.g. Evans, J. G. 2003; McGovern *et al.* 2007; Cooper 2012).

In the last two decades, a more dynamic interaction between humans and their environments has been promoted in the literature. Constructions of regionally-specific climate histories and social responses have increased dramatically in the last decade, as have studies at the interface of historical and documentary data by historians and geographers (Allan *et al.* 2016; van Bavel and Curtis 2016). As calls for multidisciplinary research increase, the last decade has witnessed the development of a number of University-led databases promoting a collaborative research environment. Databases and sources developed by the 'Climate and Environmental History Collaborative Research Environment' (Tambora) (Riemann *et al.* in press) and Euro-Climhist (www.euroclimhist.unibe.ch/en/) (Pfister and Dietrich 2006) provide tools for accessing, managing and analysing European climate proxy evidence and historical sources documenting climate parameters (Allan *et al.* 2016). Such resources aim to facilitate discussion across disciplinary boundaries to promote a more flexible approach to climate culture studies. International multidisciplinary collaborations such as ACRE (Atmospheric Circulation Reconstructions over the Earth) is one of a proliferation of 'data rescue initiatives' (Allan *et al.* 2016, 166) focussing on historical reanalyses of climate and cultural change by drawing together climate sciences with the humanities.

1.5.3. Can archaeology save the planet? The resilience paradigm.

As will be further illustrated in Chapter 6, most of literature is concerned with the *failures* of the past and with environmental destruction. The current climate change agenda focussing on present and future adaptation to climate change (e.g. Holling 2001) is mirrored in current archaeological approaches, which advocate for the importance of the successes of the past and the lessons they offer (e.g. Guttman-Bond 2010). Drawing a thread through concepts of sustainability, resilience and adaptation with a focus on past agricultural practices (particularly land drainage and manuring), Guttman-Bond identified sustainable techniques which are resilient in the face of environmental change, particularly in desert and wetland environments. Such perspectives go hand-in-hand with those which promote the use of archaeological sites as 'Distributed Observation Networks of the Past' (DONOP), whereby the study of archaeological deposits can reveal important long-term environmental trends (Sandweiss and Kelley 2012, 371-91).

Critiques of historical and anthropological perspectives on impact and response have noted that they are often isolated and disintegrated from climate science, remaining wholly tied up in individual disciplines (Allen *et al.* 2016). Although there is some way to go before climate science and historical perspectives are fully integrated, the 'resilience paradigm' of the last two decades has paved the way for a reinvigorated relationship between these fields (Holling 2001). Initiatives including IHOPE (Integrated History and future of People on Earth) – a global network of research projects which link human and earth system histories – typify this approach (Armstrong *et al.* 2017).

The resilience paradigm recognises the complexity of the intertwining socio-economic and ecological systems which govern human-environment interactions and adaptation to change. A 'panarchy' has been used by Holling to describe the way in which such complex adaptive systems evolve and change. Here, the panarchy forms the governing structure within which natural environmental systems (e.g. grasslands and seas), humans (e.g. settlements), and human-nature combined systems (e.g. controlling natural resources – slash and burn) are "interlinked in adaptive cycles of growth, accumulation, restructuring and renewal" on a variety of spatial and temporal scales (Holling 2001, 392). Such a perspective offers more flexibility to the traditional cause and effect model, and allows for historical and archaeological data to shed light on sustainable practice.

1.5.4. Scales of investigation

Chosen spatial and temporal scales of investigation continue to be a problematic concept within any study of human-environment interactions (e.g. Stein 1993). Correlative approaches have continued to hold popularity as a means of exploring the relationships between society and climate, whereby notable changes in the archaeological record are compared and associated with evidence for broad-scale environmental or climatic change (e.g. Tipping *et al.* 2012; Armit *et al.* 2014). This stems in part from the longstanding interpretative paradigm of the '*longue durée'* in archaeology (i.e. the 'long term'), an approach which emphasises long-term processes over events. Resultantly, the vast majority of studies are focused on broad-scale impacts occurring over the longterm, characterised by a reliance on palaeoclimatic proxies.

In the study of climate change impacts, Quaternary science and archaeology are intrinsically linked. However, these two disciplines frequently operate on significantly different temporal and geographical scales, at variable precisions. Correlation between palaeoclimatic data and archaeological activity is thus fraught with difficulty, given the broad chronological resolution of many palaeoenvironmental proxy studies. Additionally, off-site palaeoenvironmental records are often used to contextualise on-site stratigraphies, which can lead to disparate and questionable chronological and spatial relationships (Bell and Walker 2005, 52; Pillatt 2012, 30). Climate has traditionally been given higher precedence in archaeological research than weather, a concept which can allow a more humanised and experiential understanding of environmental impacts on human existence (e.g. Pillatt 2012, 30, and see Chapters 3 and 5).

Studies of human-environment interactions take place on two partially intertwining geographical scales, each with its own limitations: local/regional and regional/global (Dearing 2006). An early local/regional study in the developing literature can be exemplified by Berglund's (1991) mixed-method analysis of the trajectories of human activity and environmental change in southern Sweden over the last 5,000 years, which utilised archaeological, environmental and palaeoecological data. More recent regional and period-specific palaeoenvironmental data syntheses have been published by T. Brown (2008), Tipping (2010) and Tipping *et al.* (2012).

Earth systems research provides the contextual backdrop against which more challenging global studies are undertaken. Such studies have become more prevalent as global processes are sought to explain occurrences on local and regional scales. Earth system processes such as atmospheric changes and global warming are recorded in ice cores, marine sediments and loess records (Ruddiman and Thomson 2001), proxies which provide the physical science context of climate change (Dearing 2006, 194). Such global scales are often broad and lack resolution, and as such they are typically employed as correlative tools to validate, corroborate or disprove research undertaken at smaller spatial scales (e.g. Sommerville 2003). Here, incidents of environmental change recorded at the local/regional level, for example in palynological archives, are drawn up to the global atmospheric scale in an attempt to correlate these with global proxy records for change. This is a popular practice amongst climate researchers in archaeological and palaeoenvironmental fields.

It is proposed that over-reliance on attempts to correlate global records and highly variable localised evidence conflates data and produces a cause-and-effect picture which is difficult to interpret, placing too much reliance on climatic processes as opposed to human-environment interactions on the localised, inhabited scale. Humans perceive their environments on local and regional scales, with change being experienced through extremes in weather, flooding, sea level rise, and soil erosion. Resultantly, these relationships will vary depending on whether they are played out in a coastal zone, urban area or rural hinterland (Dearing 2006). Geographic scale alongside temporal scale becomes key here.

1.5.5. Perception of the environment

To understand human response to impact, investigations must focus on scales relevant to the human perspective – particularly in terms of temporal resolution. However, this is often easier said than done; as we reach further back in time data becomes ever-fuzzier, and although significant progress has been made in some areas of chronological modelling (e.g. Whittle *et al.* 2011), matching multiple scales of research remains a challenge (Bell and Walker 2005, 9). It will be contended in this thesis that human experiences of weather, and how this concept relates to broader climatic scales, is a more fruitful pursuit which requires further exploration - particularly in the prehistoric archaeological context (e.g. Ingold 2011; Bell 2012) (see Chapter 6). Related to this is the need to explore more short-term, high-impact climatic events (see Bell 2012; Sommerville 2003).

Archaeological treatment of impact perception and reactions to a changing landscape in the European context are almost exclusively the preserve of one impact, landscape type and period; sea level rise in the lowland landscapes of the Mesolithic and Neolithic. Exemplified by the work of Jim Leary on the changing landscapes of Doggerland/Northsealand (Leary 2013), a wealth of literature exists on this landscape and those akin to it throughout Northern Europe. These perspectives are often heavily embedded in theoretical frameworks of bodily experience and phenomenology of landscape developed by anthropologists (e.g. Tilley 1997; Ingold 2011). Beyond this, anthropological observations of indigenous communities are also frequently relied upon and used as analogous studies (e.g. Rumsey 1994; Thibault and Brown 2008).

In order to get to explore human perception of such impacts, the narrative (whether it be descriptions in the first person or creative nonfiction) is frequently used as a tool to describe experience (e.g. Spector 1993; van Dyke and Bernbeck 2015). Drawing upon the work of Mark Edmonds' *Ancestral Geographies of the Neolithic* (1999), in which textual vignettes from the point of view of Neolithic individuals precede each chapter, Leary explores the experiential qualities of a changing coastal landscape through the eyes of two Mesolithic brothers in his treatment of Northsealand. The ‘imagined narrative’, in which authors make use of archaeological information to depict past lives, has developed a new way of exploring the past through ‘creative non-fiction’. However, the lack of ‘traditional’ trajectories of scholarship within such interpretations has been viewed with some scepticism. Critics have argued that such narratives can be hard for a reader to accept due to the lack of accepted formulae for presenting academic authority, and that past peoples’ voices are rather being subjugated and appropriated (van Dyke and Bernbeck 2015, 83-4).

1.6. Methodology and approach

1.6.1. Interdisciplinary archaeological study

This research has developed within a broader theoretical framework of multi-disciplinary research, which seeks to overcome conceptual and methodological barriers between the sciences and humanities built by the development of increasingly specialised methods, theoretical frameworks and research traditions. Given the complexity of environmental change, weather and climate, interdisciplinary research approaches utilising knowledge and skills from a range of disciplines have been increasingly adopted (Xu *et al.* 2016, 49). A growing concern with climate change from the 1960's and 1970's led to increased discussion between disciplines. This culture of knowledge exchange was first solidified and institutionalised by the formation and work of the Intergovernmental Panel on Climate Change (IPCC) in 1988. Interdisciplinary research has continued to flourish from the 1990's and 2000's (Weart 2013).

Since the formation of the Past Global Changes (PAGES) network to support and promote international and interdisciplinary research on past environmental changes in 1991 (Bradley, R. S. 2000), there has been a marked increase in cross-disciplinary projects. Consilience refers to the belief that evidence and methodologies from independent and often unrelated sources in the sciences and humanities can be used to develop strong research conclusions. The consilience debate has highlighted the high potential for unity between differing research methodologies seeking to answer similar questions. (Izdebski *et al.* 2016, 6).

In their 2016 paper (a product of a PAGES collaborative project), Izdebski *et al.* suggested that many fundamental methodological similarities can be identified between archaeology, history and the natural sciences and their approach to the past. Fundamentally, this is characterised by a common interest in studying environmental and societal phenomena that no longer exist, and in the use of specific narrative structures to communicate the results of research (Izdebski *et al.* 2016, 5). The interdisciplinary method has been employed to some success in archaeological projects investigating human-environment interactions, with the aim of reconciling archaeological, Earth science and historical timescales and interpretations. As an example, recent studies of the impacts of prehistoric sea level rise on humans frequently involve collaboration across and outwith the archaeological discipline. The ephemeral nature of the submerged prehistoric archaeological record has ensured that interdisciplinary approaches have flourished as experts seek to reconstruct these palaeolandscapes and their submergence through multiple analytical techniques. In the UK context, palaeoenvironmental reconstruction work by Bates, M. R. *et al* (2016) and Gaffney *et al* (2007) has seen collaborations between geophysicists, archaeologists, DNA specialists and quaternary scientists alike.

This research project pursues a smaller-scale approach influenced by interdisciplinary research; by utilising and evaluating parallel methods of approach, it seeks to develop a fuller picture of the current state of knowledge and understanding of windblown sand movement in the archaeological record. It combines two primary strands of investigation;

a). The development of a full site database and gazetteer to gather all known archaeological sites in the Orkney archipelago with sand horizons;

b). A study of a specific archaeological site with windblown sand horizons in Orkney (Pool, Sanday) and, with a broad reinterpretation of archaeological evidence for sand movement through the in-depth analysis of selected site sequences supported by historical sources and interpretative archaeology. Specific, detailed methodologies of primary field data collection, laboratory processes and secondary data collection will be described in detail at the beginning of their relevant chapters.

1.6.2. Geoarchaeology

Much of research undertaken into the significance of blown sand horizons has been within the field of Quaternary science (e.g. Sommerville 2003; Kinnaird *et al.* 2012), where it has been used as proxy evidence for climatically-driven increased storminess and a subject for OSL (Optically Stimulated Luminescence) dating with little in-depth discussion of impacts on the cultural landscape. Optically Stimulated Luminescence dating is a technique which involves the measurement of energy stored in minerals in sediments, predominantly quartz and feldspar, and the amount of radiation they have received from their depositional environments to calculate a chronological date. In this case, the event being dated is the last episode in which the minerals forming sand deposits were exposed to light, during the depositional process (Duller 2008).

These scientific pursuits are generally characterised by investigations as part of a larger archaeological excavation on a single site-basis in order to contribute to the wider scientific dating strategy, or by in-section sampling (from test pits and erosion faces) (Figure 1.6). Geoarchaeology is defined here as a specific approach to the archaeological record, in which earth science principles and techniques are applied to the understanding of the archaeological record. Geoarchaeological research is not limited by scale and can be undertaken from landscape level to the investigation of the micromorphology of specific deposits (Canti *et al.* 2007).

Figure 1.6. In-section OSL sampling at Bailesear wheelhouse, North Uist. T. Kinnaird

Beginning with a review of published geoarchaeological and luminescence dating studies of blown sand as a dating mechanism and storm proxy, this portion of the thesis will evaluate the luminescence method, its contributions and drawbacks. This strand of research continues with a report of the author's own field and lab investigations undertaken at the site of Pool on Sanday, Orkney, and the associated findings. The field and lab work were undertaken primarily to contribute to the dataset currently available for luminescence dating in the Scottish islands. This can then be linked into a longer-term proxy-based storminess record which provides a foundation for future predictions and projections (Clarke and Rendell 2011).

1.6.3. Archaeological evidence

This archaeological study comprises firstly a Microsoft Access database, within which every known archaeological site with windblown sand horizons in Orkney is gathered and described. Each database entry includes site names, CANMORE site numbers, island, grid references, site type, broad chronological period, dating details (OSL and Radiocarbon) and report references where further descriptions and information may be found. This allowed for the amalgamation of large numbers of sites to identify regional trends and patterns. The Orkney sites are summarised on an island-by-island basis to develop a deeper understanding of this archaeological and environmental resource. Archaeological sequences at key excavated sites containing windblown sand horizons are then discussed in more detail.

1.6.4. Multi-strand methodology: Implications

By pursuing a method which combines both descriptive and analytical information it is intended that this research will advocate and highlight the advantages of the use of parallel methods. The use of this overarching interdisciplinary method will demonstrate that it is possible to draw multiple narratives of evidence for past coastal changes together from three traditionally separated disciplines (archaeology, natural sciences and history), thus supporting and advocating for Izdebski *et al.* ’s (2016) conclusions on the merits of such an approach. The method will be used to demonstrate that not only does the nature and chronology of windblown sand horizons within and near archaeological sites warrant further investigation as a unique geomorphological phenomenon, but that this research also represents a pertinent and timely contribution to current debates on the coastal change. As such sand horizons are ultimately both an environmental, and archaeological, resource.

Chapter 2. Climate, Weather and Environment

This thesis argues that the significance of 'weather' should be placed at the heart of any discussion of human-environment interaction (Chapter 6). It is important, however, to first place 'weather' within its wider climatic context, in order the fully understand the tension between the two terms. As such, this chapter comprises a summary of global climate dynamics and how climate as a science, and as a concept, is defined. In recent years climate change in various guises has become a frequent theme within the archaeological literature (see Chapter 1), as decision-makers display an increasing preoccupation with current and future climate projections, resilience and adaptation to change.

The increasing influence of climate change on political and social agendas is a relatively recent occurrence, having been given more prominence with the establishment of the Intergovernmental Panel on Climate Change in 1988. The IPCC was developed in recognition of the problem of human-induced climate change, with the aim of assessing impacts and options for mitigation and adaptation. This was followed by the publication of its first report in 1990 (Houghton *et al.* 1990). In the spheres of heritage management, discussions of climate are primarily related to how adverse manifestations of climate affect archaeological remains (for example flooding or coastal erosion). In archaeology as an academic discipline, climate change studies are more typically characterised by debates surrounding environmental and climatic determinism (whereby a human trajectory is dictated and influenced by external forces rather than the agency of the individual person or persons), or by the study of archaeological sites as 'Distributed Observation Networks of the Past' (DONOP), whereby the study of rich archaeological deposits can reveal deeper-time trends in marine and terrestrial ecosystems and the ways in which humans interact with these systems (Sandweiss and Kelley 2012, 371-91). In contrast, approaches to climate change by the Earth Sciences are characterised by hypothesis testing through environmental proxies, with a human context often being bypassed or an afterthought.

Arguably we must become more nuanced in our discussions of climate; such an encompassing term requires definition if it is to be properly understood and employed in academic debate, moreso if we wish to investigate the relationships between humans and climate. It is suggested that two other key terms and processes must be considered when exploring relationships on any localised scale (in this case on an inter-island scale): namely *weather*, which can be viewed as a small-scale, active, perceivable manifestation of climate; and *environment*, the sphere in which the weather is perceived and experienced on a human level. It is important to define and distinguish between climate, environment and weather. What are they, and how do they relate to and interact with one another? The primary difference between weather and climate is a measure of time and scale, whereby weather represents short term conditions while climate represents the behaviour of the atmosphere over longer periods of time. In turn, climatic variations can occur on both relative long- and short-term timescales, and multiple spatial scales.

To understand interactions between climate and weather, four key scientific factors must be observed and understood (Dawson, A. G. 2009, 7);

1. The structure and nature of the earth's atmosphere, and how it is created and controlled;
2. The changing motions of the earth in space, its orbit and how this impacts climate and weather;
3. The movement of air masses, and how they affect climatic and weather conditions;
4. For the purpose of this research, how Scotland's weather and climate are affected by the north Atlantic Ocean and its circulation

2.1. Climate

Climate is defined by the IPCC as the projection of longterm averages in the weather (Cubasch *et al.* 2013, 123). As a result, climate can hold more scope for predictability (Kirtman and Power 2013, 955-1008). The frequency and intensity of weather events change with the climate, and as such climate can be understood as the background conditions for weather.

On the broadest scale, the Earth's climate system is governed by solar radiation (Figure 2.1), which is distributed in three ways; around half of the sun's total energy is supplied by the electromagnetic spectrum and approximately 50% of solar shortwave radiation (SWR) is absorbed by the surface of the earth. A further 30% is reflected back into space by gases, clouds, the earth's albedo (surface) and aerosols while the remaining 20% of the sun's energy budget is absorbed in the atmosphere (Cubasch *et al.* 2013, 126). Climate change occurs when there is an imbalance in ingoing and outgoing radiation, and a change in the earth's radiative balance (Farmer and Cook 2013, 8). Changes in the Earth's governing systems (the ocean, atmosphere, land, biosphere and cryosphere) drive a radiative forcing (RF) which in turn affects climate. It is important to note that such changes can be driven by anthropogenic action as well as natural events, for example deforestation and other changes in land use (Cubasch *et al.* 2013, 127).

Four key forcing factors behind climate change can be identified; solar, anthropogenic, volcanic and internal variability (Masson-Delmotte *et al.* 2013, 392) (Figure 2.1). It is a complex and varying combination of these natural and anthropogenic factors which ultimately drive climate change. Alongside solar and anthropological forcing, volcanic forcing through eruptions also influences climate by injecting sulphate aerosols into the atmosphere (Masson-Delmotte *et al.* 2013, 391).

'Internal variability' represents the variation within the Earth's climate system, for example due to fluctuations in the weather or phenomena such as the El Niño- Southern Oscillation (ENSO), a periodical variation in sea-surface temperatures and wind over the eastern Pacific Ocean. It is this variability, combined with volcanic, anthropological and solar forcing, which dictates earth temperature (Masson-Delmotte *et al.* 2013, 392).

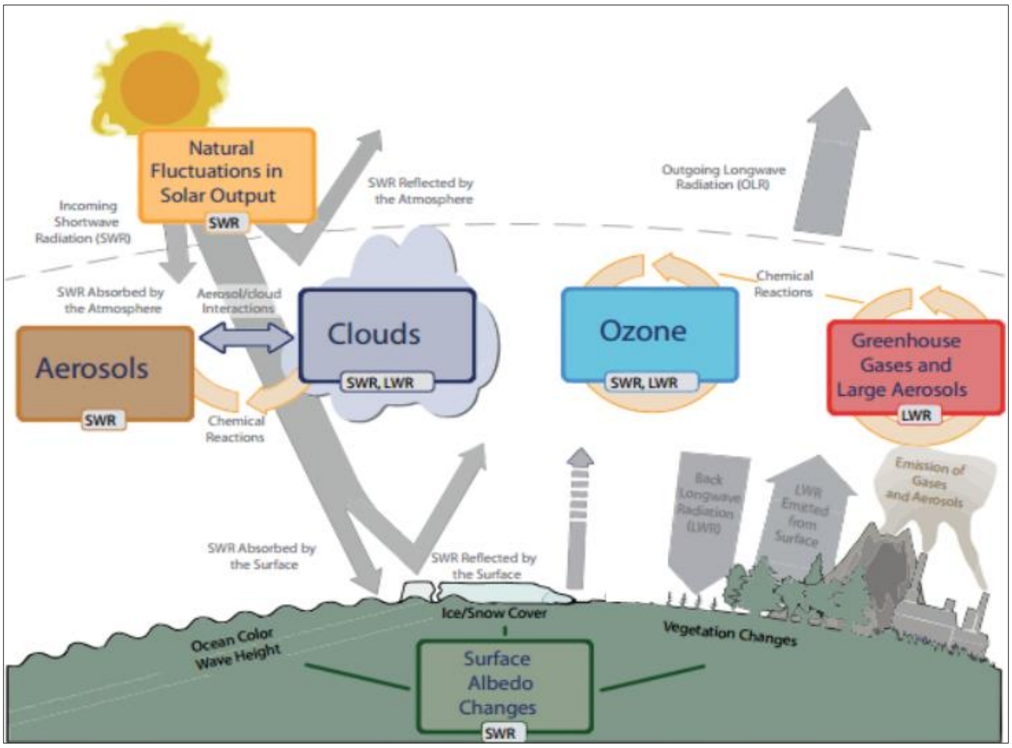

Figure 2.1 Primary drivers of climate change. Cubasch et al. 2013, 126

2.1.1. Evidence for and indicators of climate change

Past climate variability from regional to global scales can be measured by historic sources and proxies for specific climate variables, including marine sediment cores, ice cores and tree rings. Palaeoclimate reconstructions are a valuable means of understanding modern climate change within a context of wider natural climate variability (Cubasch *et al.* 2013, 129-30). Palaeoclimatic and palaeoenvironmental proxies can be defined within four major categories; Lithological/Mineralogical (e.g. aeolian sediments, carbonates, palaeosols and speleothems), geochemical (e.g. isotopes, trace elements), geophysical (e.g. palaeomagnetism), and palaeontological (e.g. diatoms, tree rings, pollen and foraminifera) (Gornitz 2009, 716-21).

2.1.2. Scotland's climate and weather: present and future

Scotland's weather is highly dependent upon conditions in the North Atlantic Ocean and how these influence the climate. As part of a global system of heat transport from lower latitudes to the arctic, the surface waters of the North Atlantic play a key role in the rebalancing of net heat loss from the Earth's surface. The majority of this heat accumulates in the Gulf Stream (a warm and powerful Atlantic Ocean current) and cools as water moves northwards, with heat moving from the ocean to the atmosphere (Dawson, A. G. 2009, 32). This northward movement forms part of the global thermohaline conveyor (a complex of ocean currents transporting heat and salt). The polar oceanic front is the interactive boundary between the North Atlantic Ocean and northern seas, and it is on this boundary that the polar atmospheric and polar oceanic fronts interact to create climate and weather (Dawson, A. G. 2009, 34-5).

Scotland's current climate is temperate, being warmed by the Gulf Stream. Exposed to the Atlantic Ocean, the north and west of Scotland are on average the windiest in the United Kingdom with southwesterly prevailing winds. The frequency of windy conditions is a result of eastward-moving Atlantic depressions (MET Office: Scottish Climate). Mean speeds and gusts are strongest between December and February. Annual mean temperatures vary from 7̊c in Shetland to 9̊c in the Western Isles with January and February being the coldest months (MET office [Online]). Future projections by the UKCP predict that Scotland will experience warmer, wetter winters and drier, hotter summers with more extreme weather events and extended hot periods (UKCP09).

2.2. Weather

Some important and fundamental differences between climate and weather can be identified, although they are also intrinsically linked to one another. Weather is chaotic, short-term and relatively unpredictable, and describes atmospheric conditions at a particular place and time with reference to important parameters such as wind, pressure and humidity (Cubasch *et al.* 2013, 123)**.** Weather can also be defined on a different, relatively shorter chronological scale, as the way the atmosphere is behaving, and its effects on life and human activity. Weather as a construct is concerned with the short-term (minute, day, month, and season) changes in the atmosphere, and can include variation in temperature, cloud, visibility, humidity and pressure. Rain, wind and snow can all be described in a perceptual sense as 'weather'; the climatic drivers behind these manifestations cannot be perceived in their purest form.

The relationship between weather and climate is rarely linear, with attempts to disentangle forcing and variability often proving challenging. It is changes in climate that can lead to changes in the rate of occurrence of extreme weather events (Cubasch *et al.* 2013, 121). Climate change, both naturally- and anthropogenically-driven, can influence and increase the probability of occurrence of extreme climate and weather events. Extreme weather events are defined as those which are rare for a particular place and time, although such a definition will vary spatially. If these events continue for a season or more, (e.g. from summer through to winter) they are defined as an extreme *climate* event, for example droughts or heatwaves (Cubasch *et al.* 2013, 134).

2.2.1. Environment

The 'environment' is a further term and concept which requires consideration, as it is within this context that climate and weather are experienced, and interacted with. In ecological spheres, the environment has been defined as one's biophysical surroundings (Evans, J. G. and O' Connor 1999, 5). Within this, three physical components of the environment may be identified; the abiotic (the physical and chemical surroundings), biotic (organisms of mixed species) and social (organisms of the same species). Human activities alter all three of these components (Halstead and O'Shea 1989, 2). The past environment rightly receives significant attention in archaeological investigations, where it stands as an important sub-discipline in its own right. Environment, then, can also be defined as a particular sphere of interaction, with both spiritual and more prosaic significance.

In the archaeological and anthropological literature, as concerns move beyond the biological niche, there is a general understanding that humans do not exist independently of their environment or vice versa. Rather, they are intertwined, with the thoughts and actions of the individual stimulated by other humans, and by their surroundings (Ingold 2011). The environment allows for the mediation of important relationships between different beings. In a scientific sense, this immediate environment is often referred to as a 'niche', the biological space in which organisms exist. On the human scale, however, Evans suggests that 'locality' may be a more appropriate term in a consideration of humans and their relationship with the environment, following the movements of the sociological fields (Evans, J. G. and O' Connor 1999, 5).

The environment is the sphere in which the weather and all relationships are played out. However, this does not mean that the environment, like the 'old landscape' was a passive backdrop against which human activity played out. Rather, it is a dynamic and constantly-developing entity which is brought into being by humans interacting with it. Neither humans nor their environments exist in a vacuum. It is created by the interaction of a number of different natural and geomorphological systems, where one cannot always exist without the other.

2.2.2. Climate, Weather, and People

Scientific observation allows an empirical understanding of climate and its conditions, and a means by which to rationalise it. The perception of climate and weather on the human scale encourages a more nuanced, culturally-grounded view. The two strands both require integration in order to develop a holistic understanding of climate and its social significance, although there is a long-standing tension between the two due to a variation in chronological and perceptual scale. Climate as a concept could be broken down into a wholly human construct, which has been used as a means of social engagement - whereby climate is created and recorded in its relevance to human activity (e.g. Evans, J. G. 2003, 117-8). Such an understanding should underlie any investigation of perceptions and significance of climate. It has already been argued here that 'climate' is not a suitable interpretative framework for any discussion of human-environment relations in the prehistoric period, due to its broad scales of occurrence in a chronological and geographical sense, and that the perceptions and impacts of 'weather' should instead be utilised for regional and site-based understandings. Rain, wind, sun and snow can all have a fundamental impact in human spheres of interaction, whether it is the shore, the field, or the house. These impacts can be both positive and negative depending on the geographical area and the primary concerns of its inhabitants.

The perception of the environment by humans is a concept which has received frequent attention in the social sciences and anthropology, and in the last thirty years has been heavily drawn upon by archaeologists looking to understand the sensory and perceptive behaviour of past inhabitants. The key structuring tenet of many of these anthropological perspectives is that people and landscape are mutually constituted and that humans are not just observers, but participants in their environment and landscapes (e.g. Ingold 2011a). This thinking has been continually applied to prehistoric theoretical archaeologies in particular, with interactions between people and their landscape featuring heavily (e.g. Tilley 1994).

It has been noted by Ingold (2011b) that weather as a specifically discussed concept which was, until relatively recently, generally absent from anthropological and archaeological works and considerations of the engagement between people and the material world (but see Pillatt 2012). Rather, concerns have been fixated on broader climatic scales, with Bronze Age climatic deterioration remaining a key research paradigm (Downes 2012). The weather is in a constant state of flux, and resultantly, so is the landscape. Ingold concludes that weather is not an object of perception, as 'landscape' used to be, but a sphere which we perceive *in*, informing our capacity to see, hear and touch: a 'weather world'. The coastline in particular may be defined as a 'weather world', in a constant state of flux and becoming, with interactions between water, wind and stone (Ingold 2011b, 130-1).

The majority of archaeological works have not broached the topic of weather, its cultural significance and its possibilities for understanding human-environment relationships (Pillatt 2012, 29). Instead, terms such as 'climate' are frequently used in an attempt to harness the important scientific data being made increasingly available, and used as a source to argue for climate as a driver behind cultural change. There is, therefore, a major gap in our understanding which requires attention: human perceptions of weather, and its impacts on everyday life. It is this gap that this thesis seeks to contribute to. This chapter has so far argued that place-based understandings of the weather (such as at the shore, and in the field) are central to how we experience it, and perceive its impact. To finish, four domains in which the weather may be experienced and interacted with will be introduced, in order to demonstrate its importance in everyday life. These domains are explored in more detail in Chapter 6, where they are discussed with specific reference to living with windblown sand.

2.2.3. The shore

Being an active and dynamic environment, the nature of the coast and the opportunities it offers can vary, and in many ways allows the most direct and embodied experience of the weather. The tides, influenced by cosmic forces, would have been a key means of structuring time and daily activities as well as bringing important economic resources. Seasons, and the weather that accompanies them, were key structuring principles in socio-economic life. Seasonality dictates the appearance of plants, birds, fish, deer (and antler) and growing periods, all of which are identifiable in prehistoric faunal assemblages and provide important insights into the economic strategies of sites and communities. Tidal action and changing sea levels are important driving forces behind the development of coastal geomorphologies and as a result, beaches, dune cordons, and their supply (see Chapter 3). Wind, sand, waves, and salt spray are all intrinsic experiential qualities encountered at the shore's edge.

2.2.4. The field

It can be argued that the concept of seasons and seasonality (reflected in the weather) became increasingly important with the advent of crop and animal domestication during the Mesolithic-Neolithic transition and beyond, as people became more physically invested in their landscapes. Domesticates would require varying levels of attention and care throughout the year, dictated by, for example, grazing and birthing. Domestication holds deep relevance across the landscape and into the homestead and accompanying social organisation, particularly during the winter months when domesticates are often moved from the agricultural landscape and into dwellings. The more you invest in your landscape, in terms of time, labour, and materials, the more weather will affect you and your material possessions, as well as your figurative possessions: your memories and psychological ties to that landscape.

Weather in an inland landscape can be experienced in a very different way to how it is experienced on a beach or shoreline. Firstly, in agricultural societies it will be experienced with economic concerns in mind, such as the impacts of adverse weather on crops and grazing. Low-lying, boggy landscapes could become wetter, the spread of peat could be a visible and relatively rapid occurrence and lochs could be inundated by sands and turn to peat bogs. It is also within the field/shore interface that one of the most complex aspects of sand and how it is mobilised becomes apparent. It has long been recognised that sand does not move alone, and is generally mobilised by a combination of three factors; weather, human activity through land use and animal activity (e.g. rabbit burrowing). During the Little Ice Age, a combination of climatic deterioration (leading to an increase in storm conditions), and the harvesting of dune stabilising marram grass for craft activity, caused an increase in aeolian movements and resulting impacts. This example demonstrates that as human populations grow and demand more of their surroundings and invested more in it in a physical sense, the situation grows more circular and complicated, and it becomes increasingly difficult to disentangle cause from effect.

2.2.5. The house

In the Atlantic Scottish context, studies of the drystone house are dominated by considerations of their role in structuring social relations, and articulations of power (e.g. Parker Pearson and Sharples 1999). The house as shelter from weather and a means through which weather can be experienced remains comparatively unexplored. Experiencing the weather from within a sheltered environment can be notably different from experiencing it in an outdoor, exposed location. Wind, temperature and sunlight, for instance, may appear more 'muted', and perceived in alternative ways. Aural experience of the weather – and gauging its severity – may become far more important, from the sound of rain hitting and draining from a roof to strong winds whistling through cracks and doorways. Changes in weather conditions may influence whether or not individuals or groups leave the domestic structure to visit others, and to attend to outdoor tasks and activities.

2.2.6. The spiritual domain

The spiritual domain is the final sphere of interaction to be considered, and indeed it may be debated whether the spiritual domain should even be treated as a separate entity from other spheres of interaction given its intrinsic significance to daily life. If there was a sudden and unpredictable downturn in the weather this would have significantly changed plans for the day. For example, perhaps there would be a meeting of communities which would no longer go ahead; a harvest would be delayed, or another event postponed. Predictability and forecasting of conditions allow for people to rationalise, understand and relate to weather on human terms, for example, sayings such as “red sky at night...”, or the sight of cows lying in a field, signifying impending rain.

The unpredictability of the weather may lead to feelings of powerlessness and a loss of control of surroundings and daily activities. Weather was likely to be related to mythology, folk stories and the spiritual sphere; higher beings and deities would be perceived as being in control of the weather. The concept of natural forces having sentient powers continues to play a key role in the social and spiritual beliefs of traditional societies. The Greenlandic Inuit looked to the weather for communication from the spirit Sila, who transmitted knowledge through snow, storms, rain, sun and sea (Leduc 2007, 241-2 in Connor 2016). Myths and parables continue to hold significance in cultures where generational knowledge transfer and the wisdom of the elders are held in high regard.

Fishing was an important part of the economic basis for prehistoric coastal settlements, and would have required extensive specialist knowledge of weather, tides and seasonality of species. It has been noted in the anthropological literature that those who engage in fishing are generally more superstitious than others in their communities (Martinez 2005, 189), and that given the dangerous and high-risk nature of fishing, it was a highly ritualised undertaking. The sea is a relatively alien environment, requiring man made devices to manoeuvre the sea when weather allows. Although it represents a quite different physical sphere, the intertidal zone also presents its own challenges, and requires different tools and equipment to undertake tasks than those required on land (Acheson 1981, 276). In Japan, Kuzaki fishermen watch the sky and sea - studying the moon phases, tides, and waves - before organising fishing ventures. Although weather reports are also consulted, science is not considered reliable. Additionally, any new boats acquired by the fishermen require ritual cleansing and elders were consulted to see if certain weather conditions had occurred in previous years (Martinez 2005, 189-91). This remembrance of the weather through older generations and through popular imagination attests to the importance of generational knowledge transfer and ancestral histories to many societies.

If someone understood or correctly predicted weather patterns they could be regarded as holding wisdom and an intrinsic connection to the world around them. They would perhaps even be seen as a medium through which a higher being could communicate, and be communicated with. This ability to understand the vagaries of the weather lends power to an individual, and this power could be used to broker social relationships and establish the exchange of knowledge and guidance, for respect and fealty in return. Such knowledge could afford an individual certain priorities and privileges not available to other members of their community (Orlove *et al.* 2010).

To predict the weather, and to predict it correctly, is as important today as it was in the past. Predictions are made in the face of collective scrutiny, and error could have significant impacts on the wellbeing of communities and their resources. In modern day society, weather prediction is generally the preserve of scientists and relayed by the media. In the past, understanding of the weather and its vagaries may also have been a specialised skill; however, given that the vast majority of prehistoric economic success was based on farming, fishing and widely distributed tasks, it may also be suggested that an understanding of the weather and the inherent risks it could bring was a more collectively-held knowledge in terms of risk and mitigation against it. Certain ramifications may be expected if weather conditions were no longer predictable in the face of a changing climate. In coastal Papua New Guinea, unpredictable rising sea levels and the resultant prospects of resettlement served to 'emasculate' male community leaders and decision makers. The ability to understand risk and mitigation are linked with gendered and fragile social relations within this community (Lazrus 2012, 291; Lipset 2011). Leduc recounts Inuit remarks concerning their fears that their knowledge of the climate no longer "worked" due to the increasingly unpredictable nature of weather and environment (Leduc 2010, 1).

2.2.7. Summary

This chapter began by introducing and defining climate, weather and environment as three governing concepts, predominantly employed and influenced by the physical sciences, which influence modern and past societies. Reconciling climatic timescales with archaeological timescales (for example, generations to centuries) continues to be one of the most problematic and challenging conceptual aspects of any attempt to explore past human-environment interactions. Although it is accepted that weather and climate are intrinsically linked in a scientific sense, it was further suggested that weather is a more important structuring principle within which human-environment interactions, and how social change developed, can be explored. Through a consideration of coastal landscapes and the way in which they were inhabited and interacted with, it concludes that a consideration of the significance of weather allows a more in-depth and personal exploration of how the environment was perceived, how it shaped and was shaped by social life, and how this may have changed over time. It has been argued that 'climate' as a modern construct has been most commonly used in a scientific sense; it rationalises occurrences and is often made sense of on a global scale. A deeper understanding of weather must therefore be developed before this can be integrated with the broader climatic scale. Climate change is a driving theme behind many Earth science endeavours and the development of environmental proxies as we seek to understand past and therefore future climate and how it may be predicted and projected.

Archaeologists have somewhat unquestioningly accepted this governing structure and applied it to their own concerns in an attempt to answer big questions which form some remaining 'grand challenges' for archaeology (Kintigh *et al.* 2014). Archaeologists endeavour to explore and explain population movement, fundamental economic and social changes from resources to burial rites, settlement patterns and house shape, and how climate may have driven these. 'Climate' is a big and emotive word and its use is accompanied by its own set of challenges. Such a top-down, broad-brush approach is unsuitable for such a wholly human pursuit and can lead to deterministic and rigid explanations which cannot be applied in a flexible and inclusive way. We must rather approach social change in the first instance on a small geographical scale, from the bottom up. The resulting themes and discussions can then be integrated with broader narratives and regional patterns. Chapter 6 expands on the themes presented in this chapter with reference to specific archaeological sites and their weather and landscape contexts. It will also examine the complex nature of chronological scales of investigation through discussion of varying elements of weather, extreme and short-term events and how and when they feed into prolonged periods of deterioration. Illustrating these concepts with anthropological and historical data, this will be used to explore the impacts and perception of weather in the case region on archaeological timescales.

Chapter 3. Processes of sand movement

Although there has been some engagement with the archaeology of dune landscapes (Griffiths, D. *et al.* 2011) and the chronology of windblown sand deposition (Sommerville 2003), few archaeologists have considered or summarised the processes by which sand is physically mobilised after it has become destabilised. This is an important factor which is intrinsically linked with local geomorphological conditions at the coast. Given that depositions through both single events and gradual accumulations can be identified at the archaeological level, it is important that the mechanisms behind these dynamics are understood. By identifying the key characteristics of sand movement, and the physical processes which drive it, a clearer picture of its environmental context can be developed. Identifying the processes that cause sand movement can contribute to discussions on the validity of windblown sand movement as a proxy for climatic deterioration.

Windblown sediments can be broadly divided into three defined types; loess, dune sand and coversand. Loess is fine-grained sediment comprised primarily of silt and can be mobilised over significant distances in cold and dry conditions. Their formation was particularly prevalent during glacial maxima. Coversands are those deflated (moved by wind) from surfaces lacking vegetation cover on retreating shorelines, till plains or river valleys. Dune sands are those deflated from a beach and deposited in coastal zones above the high tide, and can often lie a significant distance inland (Bell and Brown 2008, 1).

The beaches, coastal dune cordon and machair plains of Scotland have been created and mobilised by wind and wave dynamics over the Holocene. Two key processes drive sand mobilisation in this geographical context, both of which are forced by wind energy. Through shifting sea levels, storm surges and high waves, offshore and beach deposits can be thrown up and deposited further inland. Secondly, sand can be moved from unstable dune landforms, many of which ultimately derived from beach sediments (Bird *et al.* 2003). Beach and dune sands, and how the development of the former led to the development of the latter, are discussed below.

Windblown sand: movement dynamics

Early exploration of windblown sand dynamics was undertaken by Bagnold (1941), who identified two 'critical thresholds' which prompted sand movement. These were *fluid threshold*, namely the strength of wind required to mobilise sand over a loose, dry surface; and *impact threshold*, where if wind dropped below a certain speed, mobility ceased. Once the critical thresholds of movement have been surpassed, three modes of aeolian transport may be undertaken (Livingstone and Warren 1996, 15-17; Jiang *et al.* 2014). In order of increasing velocity these are;

Nearsurface creep. As a broad term, creep can be used to define any near-surface movement of grains. Creep is generally defined as the rolling of mostly coarser particles (Livingstone and Warren 1996, 17).

Saltation. Saltation comprises the low-hopping of grains dislodged by descending high-energy particles, which jump or skip downwind.

*Suspension***.** This movement represents the suspension of sand grains in strong upward currents of air.

These three types of movement can be identified in the Scottish coastal context, with saltation accounting for c. 57% of Scottish sand transport (Hickey 1997, 161-6). Sand movement by winds is dictated by two principle effects; topography and land/sea interfaces. A number of influencing factors on sand movement can also be identified.

1. Water. Precipitation increases the velocity threshold needed to prompt sand grain movement, as does air and sand humidity. Temperature and atmospheric pressure also influence sand dryness and resultantly, its movement. Surface albedo and solar movement are also important factors (Carter 1989)
2. Grain shape, diameter and sand density. For example, mobile dune sands are typically between 63µm and 2mm (Bell and Brown 2008, 18).
3. Wind speed and direction, which are perhaps the most important influencing factors. The velocity of the wind will dictate the type of mobilisation undergone by the sand particles, as will topography (e.g. slope) and vegetation (Wal and McManus 1993 in Hickey 1997, 163).

Hickey's 1997 study identifies two important types of coastal sand movement in Scotland, where westerly and southwesterly winds prevail; coastal dune movement and coastal sand storms. These movements vary according to their sediment sources, the process by which they are mobilised, wind speed and threshold velocity. Episodes of aeolian activity vary in duration, from significant events taking place over hours to days to a decadal or century scale, over longer periods of time where incidences of windblown sand may have increased (Hickey 1997, 185).

1. *Coastal dune movements*. These are here defined as the movement of previously existing dunes onto land which is not covered by dune forms, or sand moving within dune systems. This process is relatively slow, happening on a decadal scale or longer. Traction or creep processes prompt this movement to occur, at low velocity although an initial movement threshold has to be breached in order for the process to begin.
2. *Coastal sand storms.* Hickey defines this as the movement of sand either from a previously existing dune or a marine source onto land not normally covered by sand. Unlike coastal dune movements, this process is dependent on saltation, requiring higher wind velocities than dune movements.

Relative sea level

The creation of the majority of beaches and sand dunes we see today occurred during the later Holocene, c. 6,500 years ago. These processes were governed by changes in relative sea level as a result of isostatic adjustment. Following deglaciation, varying relative sea level curves exist at different parts of the Scottish coast according to their position beneath the ice sheet (e.g. Shennan and Horton 2002). Whereas mainland Scotland has generally experienced a falling relative sea level given its distance from the centre of the ice sheet, the outer coast, and particularly the Western Isles, have experienced a rise in relative sea level.

Effects of moisture

Moisture imposes a significant control on the movement thresholds of sand grains and the rate at which they are transported. Seasonal changes in precipitation can dictate this movement. Total saturation will slow or completely stop transport, regardless of wind conditions. As soil or sand dries, movement can begin again although it is dependent on a range of complex factors. Azizov (1977) roughly estimated that a soil must dry to c. 4% water content although it is clear that particle size, heavy rain, wind speed and organic content will complicate this process, and even destabilise sediments further, thus making them increasingly susceptible to deflation (Livingstone and Warren 1996, 19).

Vegetation

Most dunes form in the presence of vegetation, and the variable drag caused by vegetation on the movement of wind influences dune morphology (Carter 1989, 311). Vegetation can hinder sand transport either by trapping particles in the transportation process, or by preventing their movement. However, the situation is complex and the presence of vegetation does not necessarily ensure that aeolian movement ceases (Livingstone and Warren 1996, 20).

Anthropogenic activity

Sand dunes frequently become mobilised as a result of anthropogenic activity. This may include sand quarrying (for construction or agricultural improvement purposes), animal grazing, trampling, cutting, vegetation harvesting and clearance, all of which serve to deplete vegetation and destabilise dunes. In historical periods, dunes were frequently utilised as rabbit breeding grounds, an activity attested to in typical dune place names such as ‘warren’ and ‘burrows’ (Bird *et al.* 2003, 223-4).

3.1. Beaches

Beaches have been forming since the first development of the oceans and coasts, and can comprise a wide variety of materials including shingle, gravel and sand. Those that formed during the Early Quaternary period are now submerged and have for the most part been significantly reworked or hidden by later seafloor sediments. The beaches that exist in the present day in Britain first formed approximately 6,500 years ago, during the Holocene (or Late Quaternary) marine transgression. During this period, the sea level reached a point where wave action shaped the coastline, either eroding or depositing sediment on it (Bird *et al.* 2003, 203).

Beaches are mostly commonly formed on low-lying coasts, separated by headlands which allow the formation of coastal cells of sediment. These cells have a 'sediment budget'. Volumes of sediment are reducing and are no longer as plentiful as they were during the earlier Holocene. The causes of the reduction are numerous, but a significant consequence is that many beaches are now actively eroding with little in the way of sediment replenishment (Hansom and Angus 2001). Two primary sources of beach sediment can be identified in the Northern Isles; eroding cliffs and rocky shores, and the sea floor (also known as offshore deposits). The majority of beach sediments on Scotland's beaches are either partially or completely of sea floor sediments (sand and gravel) moved shoreward by waves during the Holocene marine transgression (Bird *et al.* 2003, 208). A move further shoreward drives the creation of dunes.

A broad contrast in beach and dune development can be identified in terms of their geographical location. While the coasts of western Scotland are exposed to the storm waves and swell of the Atlantic Ocean, the east coast and coastlines of the island archipelagos face narrow seas and more enclosed areas. Formation and regeneration of coastlines are controlled by tide regimes, waves, wind and fetch (the length of water over which a wind blows).

3.2. Dunes

Carter notes that of all the coastal ecosystems, sand dunes have been subject to the most significant degree of human pressure (Carter 1989, 301). Sand dunes form when beach sand is blown landwards and deposited above high tide level (Bird *et al.* 2003, 221). Dune forms include spit, bay and hindshore dunes, nesses, climbing dunes, tombolos and cuspate foreland (Radley 1994; Bell and Brown 2008, 19). Around 20% of the Scottish coastline is made up of sand-based features, with the dune area comprising some 48,000ha (Dargie and Duncan 1999, 143). Many demonstrate evidence for settlement and exploitation throughout history and prehistory. Key areas include Forvie (Aberdeenshire), Tentsmuir (Fife), Luce (Dumfries and Galloway), the Northern Isles and the Atlantic coastline of the Western Isles (Whittington and Edwards 1997, 21). Given their coastal location, potential for agricultural exploitation and their exposure to Atlantic and North Sea weather systems, it is no surprise that sand movement was a key concern in this highly dynamic zone, as well as in the hinterlands (Goldberg and Macphail 2006, 119-21).

Dune formation is dependent on local controls including topography, tidal range, wave climate, wind, tidal litter and over a longer timescale, sea level. Reduced sea level or tidal range can lead to the upper shore drying more frequently and for longer, when dunes can form during strong onshore wind movement. The movement inshore of sand by strong currents and levels of sediment supply are also important, as is grain size (which dictates transport distance); coastal dunes are typically composed of medium fine-grained sands which are well sorted (Carter 1989, 301; Bell and Brown 2008, 15; Pye and Tsoar 1990; 2009).

Windblown sediments and sands can cover and substantially bury land surfaces, leading to their incorporation beneath or within dunes. Accumulation of these sands can be remarkably rapid, and can preserve important palaeolenvironmental, archaeological and geoarchaeological remains. The mineralogy of dune sands can allow for the identification of dune sediment sources, which can include earlier dunes, outwash gravels and weathered local bedrock geology. The majority of dune sand is comprised of quartz, and can also contain whole or fragmented shells and other marine organisms such as calcareous algae. Such calcareous materials aid the preservation of faunal remains (Bell and Brown 2008; 16-18).

Dunes are formed via a process of accretion, beginning with an embryo dune upon which salt-tolerant vegetation begins to grow. Development continues until embryo dunes grow to become foredunes, many of which join to form a ridge. Stabilising vegetation continues to colonise and take hold as the dune develops, dominated by sea lyme grass and marram (Bird *et al.* 2003, 221). If a considerable amount of sediment is available and mobilised, more landward dunes can develop behind the foredunes. As dunes stabilise further, lichens, mosses and other grasses, as well as shrubs and trees, can begin to colonise (Bird *et al.* 2003, 221).

3.2.1. Dune formation chronologies

Dune formation was an episodic process, with phases of sand deposition punctuated by stabilisation and soil formation phases. These phases are often of particular significance in a cultural and chronological sense as they are often associated with archaeological remains (Bell and Brown 2008, 19). The episodic nature of dune movement has been observed in the Netherlands and Denmark (Jelgersma *et al.* 1970; Clemmensen *et al.* 2001), Northern Ireland (Wilson *et al.* 2004) and in the UK on the Formby coast (Huddart 1992), North East coast (Wilson *et al.* 2001) and the west coast of the Scotland (Gilbertson *et al.* 1999). These cycles of stability and deposition may reflect the occurrence of extreme events, such as storms, which prompted erosion. Sea level change may also influence these movements, which may have occurred during colder periods and reduced sea level when lower temperatures and increasing levels of water held in land ice are apparent (Tooley 1978; Bell and Brown 2008, 19).

Like Britain's beaches, most Scottish dune systems originated in the earlier Holocene (c. 6,500 years ago) when seabed deposits were deposited onshore. As discussed above, these early sand mobilisation processes were intrinsically linked to relative sea level change. Owing to their more complex sea level history (where isostatic rebound is evident), an earlier origin can be pinpointed for the dunes and beaches of the Western Isles (Gilbertson et al. 1999).

Episodes of later widespread dune movement are best recognised during the Little Ice Age (AD1550-1850) (Grove 2001), when coastal dunes became increasingly geomorphologically active as a result of changing climatic conditions and increased dune instability driven by intensification of anthropogenic activity in the dune landscapes. Large areas of agricultural and inhabited land from Cornwall to Scotland were inundated by drifting sands in the 15th-18th centuries (Bird *et al.* 2003, 224-5).

Earlier phases of widespread Holocene dune formation across northwest Europe at around c. 1100-400 cal. BC have been posited by Wilson *et al.* (2004), amongst others (e.g. Gilbertson *et al.* 1999). Given the erosive nature of windblown sand mobilisation, it is likely that more evidence for extensive dune building in the earlier millennia was removed during later, more dramatic episodes of sand movement, with earlier deposits being transported further inland. However, it is not certain if these earlier episodes were also associated with the apparent climatic deterioration that prompted the Little Ice Age sand mobilisation. A range of other complex local, regional and global factors must be acknowledged, and the extent to which these contributed must be determined by whether the cycles of deposition, erosion and stability are temporally aligned in different regions (Bell and Brown 2008, 19). Although more scientific dating is needed, it is already beginning to be possible to identify periods of increased, interregional sand movement.

3.2.2. Dating of dunes and sand movement

The two most widely-employed scientific dating methods employed in the dating of sand movement are luminescence and radiocarbon dating. OSL (Optically Stimulated Luminescence) dating of sand grains and their exposure to light during transport should ideally by coupled with, and thus constrained by, radiocarbon dates on organic materials from associated buried soils and peats. This can allow for age estimates for the formation and cessation of sandblow and hiatuses (Bell and Brown 2008, 20), although the definition of a hiatus is difficult as the presence of organic material does not always denote stability in a climatic or local environmental sense (Gilbertson *et al.* 1999). More consideration of the dating of windblown sand horizons will be given in Chapters 4 and 5.

3.2.3. Storminess in Northwest Europe

An increase in stormy conditions in the North Atlantic Ocean from around 4000 BC has been cited as the primary causal factor behind the widespread deposition of windblown sand horizons at coastal archaeological sites and wider landscapes (Borja *et al.* 1999; Sommerville *et al.* 2007; Dockrill *et al.* 2007; Tisdall *et al.* 2013). A storm is defined here as any significant low-pressure atmospheric disturbance to normal weather conditions, for example heavy precipitation, hail, winds strong enough to transport substances through the air, heavy rain, thunder or lightning. Wind must reach a speed between 48 and 55 knows (10 on the Beaufort Scale) (UKCP09; World Meteorological Organisation 1967). A storm surge is characterised as a coastal floor or tsunami-like activity where water rises. Storm activity demonstrates significant temporal and geographical variability at annual, decadal and millennial scales (Clarke and Rendell 2006). Beginning with a review of the various data sources for measuring levels of storminess (defined here as encompassing both the frequency and intensity of storms), studies of windblown sand as a proxy for storminess will be summarised and the complexity of North Atlantic storminess as a driver highlighted.

3.2.4. Storms and their drivers

The character and impact of storms in the North Atlantic and North West Europe are now well-documented in the scientific and historical literature (Stone and Orford 2004). Understanding the role played by atmospheric and oceanic variability is key to understanding climatic variation over large regions, which in turn impact local-scale ecosystems (Hurrell and Deser 2009). These complex systems are created by atmospheric Rossby waves (planetary waves, which are a natural atmospheric phenomena) (Holton 2004). These waves govern the interaction between jet streams, cold (polar) and warm (subtropical) air masses. Within these waves, low pressure (over the wave troughs) and high pressure (below the wave crest) pressure systems develop (for example the Azores High and Icelandic Low). These pressure gradients cause stronger westerly airflow across northern Europe (Hurrell and Deser 2009). It is within the low-pressure atmospheric systems with significant temperature and pressure gradients that storms develop (Feser *et al.* 2014). Typical characteristics of storms include high wind speeds, and often hail, thunder, lightning and heavy precipitation. Storms and their frequency can be measured and expressed either directly, via sea level pressure or wind speed (measured by the Beaufort (Bft) scale), or indirectly, by storm losses and damages or sea level change driven by storm activity. Two primary strands of evidence can be employed in the investigation past storminess and its impacts; instrumental and archival evidence (for historical storminess) and sedimentological and chronological (absolute dating) proxy evidence (for both historical and prehistoric storminess) (Clarke and Rendell 2006). Proxy data becomes vital as investigations of storminess go beyond the last millennium.

3.2.5. The North Atlantic Oscillation (NAO)

As a leading pattern of weather and climate variability over the Northern Hemisphere, the North Atlantic Oscillation (NAO) has been frequently identified as a cause behind fluctuations in precipitation, temperature and storminess (Hurrell and Deser 2009). A significant number of historic storminess studies have correlated sandblow events with positive NAO and as such it is an important process to understand in any attempt to reconstruct weather and climate patterns. The NAO process is characterised by a redistribution of atmospheric mass between the Arctic and Atlantic, with the atmospheric pressure fluctuations creating changes in the physical makeup of the ocean as well as surface air temperature, precipitation, storminess and winds over the Atlantic, as well as the ocean (Hurrell and Deser 2009). This weather phenomenon records the differences (the NAO index) between air pressure systems, namely the Azores high and Icelandic low. When an Azores high and a deep Icelandic low exist, the NAO is positive (Figure 3.1) and has been demonstrated to correspond with periods of historic storminess in the north Atlantic, which will in turn increase aeolian activity (Sommerville *et al.* 2007; Dawson, A. G. *et al.* 2003). A well-recognised climate 'see-saw' across the North Atlantic has also been linked with air temperature and pressure dynamics related to the NAO, whereby the occurrence of severe and cold winters in Western Greenland regularly coincides with mild northern European winters, and vice versa. This 'see-saw' has in recent years been linked to historic storminess in northern Europe, whereby the stormiest winters over the last century coincide with notably low temperatures in western Greenland (Dawson, S. *et al.* 2004).

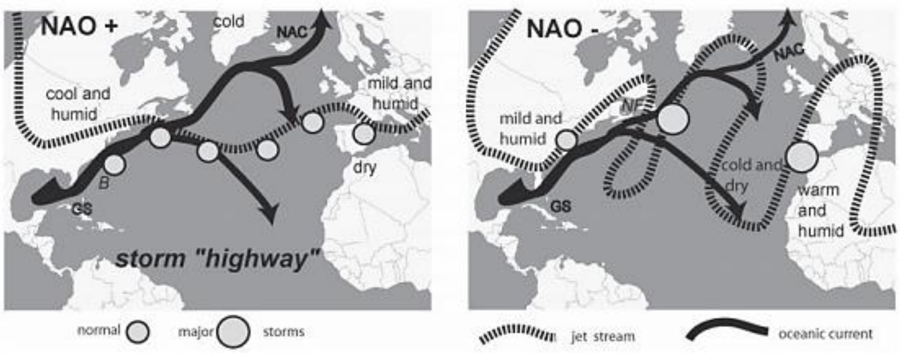

Figure 3.1. Synoptic scheme of oceanic and atmospheric circulation patterns within the positive (+) and negative (-) NAO. Van Vliet-Lanöe et al. 2014, 442.

3.3. Measurements of storminess

3.3.1. Instrumental records

Storm surge heights, sea level pressure fields and wind velocity can all be instrumentally measured to characterise Atlantic storminess. Such records can be taken over a wide and varied geographical context, from the land and near-shore, to lighthouses, vessels and their log books. The Beaufort wind scale typically defines storminess as measuring over 10 on the scale (Qian and Saunders 2003; Clarke and Rendell 2006).

Synoptic charts, summarising atmospheric conditions, and near surface pressure readings can also be used (Clarke and Rendell 2006). As demonstrated in Figure 3.2, studies display significant spatial and temporal variability in North Atlantic storminess, which may be linked to the status of the North Atlantic Oscillation (NAO). NAO indices are averaged on a monthly basis, whereas the above synoptic scale data is generally measured in daily durations leading to difficulties in correlation (Betts *et al.* 2004; Clarke and Rendell 2006).

Time period of observations	Location	Conclusions of study	Reference
1796–1999	N Ireland	Significant variations in storminess. High numbers of storms 1796–1825, 1835–1844. Decline in storms 1983–2001	Hickey (2003)
~1800–2000	Scandinavia	No robust signs of any long-term trend in storminess indices	Bärring and von Storch (2004)
1823–2005	Iceland	No increased overall storminess in the study period	Jónsson and Hanna (2007)
1875–1995	NE Atlantic	No common trend with some stations showing decreasing or increasing storminess for part of the length of record, but with some evidence of increasing trends over the last two to three decades of record in the most northeasterly part of the study area	Schmith et al. (1998)
1875–1992	SW approaches of eastern Atlantic	Decadal scale changes in storm surge data with maximum storminess detected for early 1880s and mid-1900s	Orford (2001)
1876–1990	German Bight	No significant trends in geostrophic winds	Schmidt and von Storch (1993)
1876–1996	N Scotland, NW Ireland	Strong interannual variability in gale days. Station data show both increases (Lerwick) and decreases (Stornoway) over study period	Dawson et al. (2002)
1881–1960	NW Europe	Decrease in storm frequency between 1881 and 1960	Alexandersson et al. (1998)
1881–1998	NW Europe	Decreasing trend in storminess but with an increase again in the 1980s and peaking in the early 1990s followed by a reduction in storminess in the late 1990s	Alexandersson et al. (2000)
1881–2003	N Atlantic	A significant decrease in cyclone density over the North Atlantic over the study period	Bhend (2005)
1903–1987	N Atlantic and northwest Europe	Variability of cyclonic activity on decadal timescales but no significant overall trends	Kaas et al. (1996)
1949–2004	N Atlantic (Iceland and UK)	Decrease in severity of severe storms in Iceland after 1980; increase in severity of storms over UK since 1950s	Alexander et al. (2005)
1950–1992	Eastern N Atlantic	No trends in cyclone frequency over the study period	Betts et al. (2004)
1955–1995	Iceland	Intensification of cyclone activity over the study period	Bartholy et al. (2006)
1957–2002	North Atlantic	A decrease in the frequency but increase in the intensity of mid-latitude (30–60°N) cyclones and an increase in both the frequency and intensity of high-latitude (60–90°N) cyclones	McCabe et al. (2001)
1962–2002	Netherlands	Decrease in storminess based on the analysis of near-surface wind data	Smits et al. (2005)
1965–1995	N Atlantic	Decline in the number of storms but strong interannual variability	Lozano et al. (2004)

Figure 3.2. Studies of trends in Atlantic storminess from instrumental records in Clarke and Rendell 2009, 33; Table 1).

3.3.2. Mean sea level pressure (MSLP) observations.

Mean sea level pressure (MSLP) comprises the average atmospheric pressure at sea level (Figure 3.3), and variable pressure readings have been used to track storms trends and long-term variability in storms in a number of studies over the winter and summer seasons (e.g. Hoskins and Hodges 2002; Alexander *et al.* 2011), often as a more accurate means of measuring wind speed. Proxies based on surface pressure readings such as MSLP are generally based either on long series low pressure readings from a station, or on geostrophic (air influenced by pressure gradient forces which move parallel to isobars) wind speed statistics (Feser *et al.* 2014). The method is most reliable over flat terrains, in latitudes far from the equator; the North Atlantic and Baltic Sea areas have received frequent attention from studies utilising MSLP readings for past storminess (e.g. Schmith *et al.* 1998; Bärring and von Storch 2004). As a large-scale variable, MSLP is noted to display a lack of sensitivity to local conditions or non-climatic disturbances (Feser *et al.* 2014).

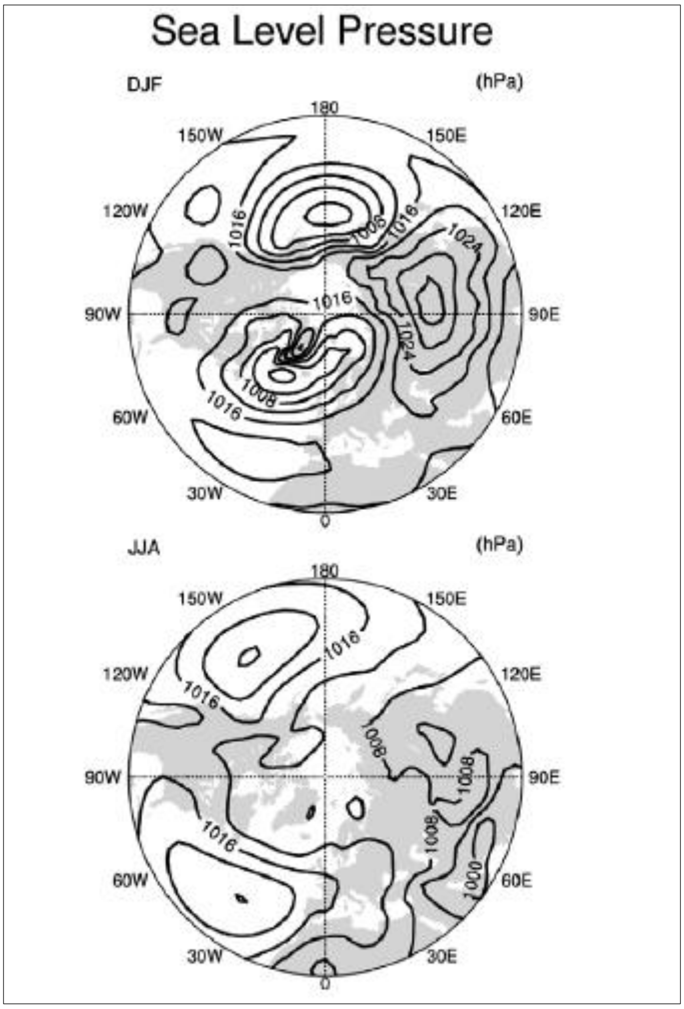

Figure 3.3. Mean sea level pressure for (top) winter (December-February) and (bottom) summer (June-August). Hurrell and Deser 2009, 29.

3.3.3. Wind speeds

Determining changes in windiness is often hampered by a lack of homogeneity of observed time series (data points listed, indexed or graphed in time order). Measurements are highly localised and depend heavily on the exposure of measurement stations and any obstacles. While wind measurements give good results for short term monitoring of current storminess, direct wind measurements are less useful for decadal or longer-term analyses (von Storch and Weisse 2008). Although wind speed is one of the most obvious means of measuring storminess, few studies have made significant use of this method owing to the inhomogeneities present in such records (Schmith *et al.* 1998).

3.3.4. Tide gauge data

Tide gauge data (measuring sea level change relative to a datum) can be used to capture information on decadal climate variability and coastal processes including tides, global mean sea level, storm surges and tsunamis (Betts *et al.* 2004). Whereas chronological resolution is finer and longer (c. 100 years +) than, say, satellite data, the spatial resolution of this data is less sharp. It has been frequently employed as a means of investigating links between sea levels and storminess in the North Atlantic, where positive correlations between storminess, sea level and atmospheric circulation have been noted, especially during the autumn and winter months (Jaagus and Suursar 2013). Drawbacks of tide gauge include the necessity of numerous corrections to raw data in order to account for atmospheric pressure, regional and local variability and vertical land motion. Additionally, there is strong variability with no global bench mark to combine and compare multiple tide gauge measurements across a large geographic area (Jaagus and Suursaar 2013; Feser *et al.* 2014).

3.3.5. Archival records.

Whether empathetic and discursive (e.g. Golinski 2001) or descriptive and objective (e.g. Naylor 2006), archival records offer detailed evidence for historic Atlantic storminess. Sources include natural and historical descriptions of counties, parishes, regions and specific weather events within them (Leask 1996), shipwreck registers, weather diaries (Hewison 1997; Golinski 2001), event accounts and lighthouse keepers' accounts (Dawson, A. G. 2009). Several weather diaries refer to the 'Great Storm' of 1703, the severe impacts of which were felt across southern and central England (Wheeler 2003; Golinski 2001).

There are a number of sources which provide information on historical coastal events around Scotland specifically, including instrumental records, estate papers, historical and geographical accounts and parish records, as well as the Statistical Accounts for Scotland. The Statistical Account (1791-1799) and New Statistical Account (1834-1845) are an important resource for exploring the impacts of last two centuries of the Little Ice Age (c. AD1300-1870), and the extent to which this information could be used as a means to understand prehistoric impacts. The Statistical Account was published in 1791, the New Statistical Account in 1832 and the Third Statistical Account in the 1990's, although it began in 1944. The Statistical Account comprised responses to John Sinclair's (an MP for Ulbster, Caithness) appeal for information from each Church of Scotland parish, and included population information, climate, provision prices and any other information deemed significant by each parish. A similar format was followed by the later Statistical Accounts. As a result, the breadth and contents of the Accounts vary in detail and theme (Leask 1996, 1).

The Statistical Accounts make frequent references to coastal sand movements. The accounts detail occurrences of high winds leading to sand movement and the burial or destruction of agricultural land, exposure of landforms, poor soil quality caused by sandblow, as well as mitigatory strategies including manuring and afforestation (see Chapter 6). An example, the Rev. Edward MacQueen describes "*a great deal of* *sand…blown one way or other with every gale of wind, so that a great part of the best corn-land [was] blown away, or covered with sand*" on the island of Barra (Statistical Account vol. 13, 329 in Leask 1996).

3.3.6. Proxy records

Since the early 1990's and the publication of Hubert Lamb's influential work on storm reconstruction and impact (1991), the theme of historic storms in the North Atlantic and their impacts on coastal margins has increased markedly in the literature (Stone and Orford 2004). The wide availability of historical data and instrumental measurements detailed above has ensured that a relatively detailed picture of historic storminess in this region has been developed and documented. The physical and societal effects of both large and small-scale sand movements are well-documented for the historic period (Clarke and Rendell 2008), but less well-understood for the previous millennia (Sommerville 2003). Palaeoclimatic data from a range of natural archives, with resolution at a variety of temporal scales present an additional form of evidence – proxy data – can further inform understandings of historic storminess. Additionally, proxy evidence provides the required perspective on storm conditions in the deeper past. Two of the most frequently-cited sources of proxy evidence specifically for storminess are the Greenland Ice Sheet Project (GISP2) data, and sand mobilisation.

3.3.7. GISP2

Data gathered from the GISP2 has for the last three decades been the principal source for climate reconstructions for the North Atlantic and northern Europe (Dawson, A. G. *et al.* 2003), as well as standing as a frequent source of comparison with other proxy data (e.g. Sommerville *et al.* 2007). Varying concentrations of Na+ ions (marine sea salt) and oxygen isotopes in the GISP2 ice core record has been widely used as a proxy for storminess for the period covering the last 1000-1400 years (Meeker and Mayewski 2002; Dawson, A. G. *et al.* 2003) (Figure 3.4). The seasonal resolution of ice core data has made it an attractive comparative method for instrumental records. High Na+ levels in the GISP2 ice cores, signifying increases in storminess, have been identified for AD1400-2000, with lower values for the preceding 500-1000 years (Meeker and Mayewski 2002).

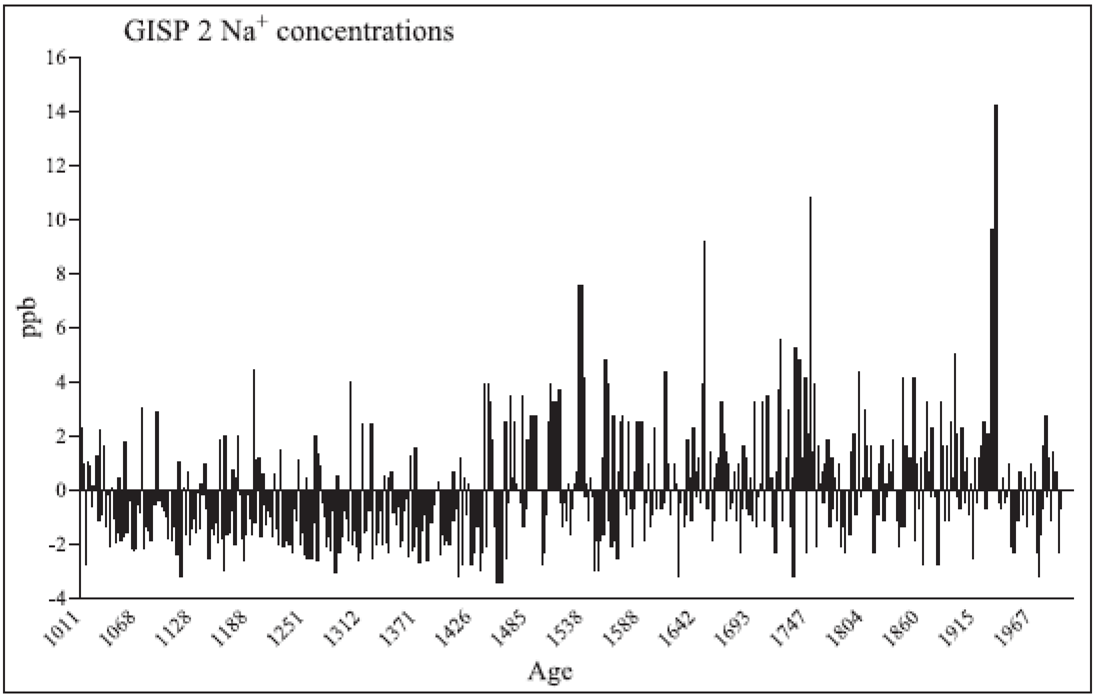

Figure 3.4. Concentrations of Na+ at the GISP 2 drill site, central Greenland, 987– 1987 AD expressed as departures from long-term average (Dawson, S. et al. 2004 after Kreutz and Mayewski 1997).

3.4. Chronologies of sand drift and dune building

The dating of periods of sand drift is one of the most frequently-employed sources of proxy data in studies of storminess in Northwest Europe (e.g. Dawson, S. *et al.* 2004; Wilson *et al.* 2004; Clemmensen *et al.* 2009; and see Table 1). For these aeolian processes to occur, strong, prolonged winds, a sediment supply and sparse vegetation cover are needed (Clarke and Rendell 2008, and see Chapter 2). This method of reconstruction requires the use of absolute dating techniques, mostly frequently Optically Stimulated Luminescence (OSL) (and/or Infra-Red Stimulated Luminescence (IRSL)) dating of minerals, typically quartz and feldspar, within sediments combined with and constrained by radiocarbon dating of organic material. In this instance, the event itself is being dated by pinpointing the last time the sediment was exposed to daylight, and thus being transported and deposited (see Appendix 2). These independent chronologies of sand deposition are then employed as proxy evidence. Systematic sand grain counting, and measurement of sediment proportions have also been applied to determine Aeolian Sand Influx (ASI) levels (Bjorck and Clemmensen 2004; de Jong *et al.* 2009). For historic reconstructions, studies are often combined with instrumental and archival data.

Archaeological period	**Location**	**Study method**	**Study findings**	**Reference**
Late Mesolithic; Late Neolithic; Early Bronze Age; Middle-Late Iron Age; Medieval.	Southern isles of the Outer Hebrides	OSL dating of sand horizons	Sand deposition at 7050-6350BC; 5550-5050BC; 4950-4450BC; 3850-2250BC (one of most notable episodes of drift in the Outer Hebrides and elsewhere in north-west Europe); 1850-1350BC; AD250-650; AD1350-1750; and AD1850. See Gilbertson et al. (1999) for full suite of dates and lab codes.	Gilbertson *et al.* 1999
Late Mesolithic	North Uist, Outer Hebrides	Radiocarbon dating of peat bracketing sand deposits	Frequent sand deposition punctuated by peat development from c. 7060-6440 cal. BC (GU-1762) to c. 4700-4230 cal. BC (GU-1761) at Cladach Mór, North Uist	Ritchie and Whittington 1994
Late Mesolithic; Middle to Late Neolithic-Early Iron Age; Medieval	South Erradale peninsula, Wester Ross, Scotland	Radiocarbon dating of peats bracketing aeolian sand deposits.	Increased sand mobilisation at 6200-6000 cal. BC (SRR-6557), between 3320-2900 cal. BC (SRR-6556) and 770-400 cal. BC (SRR-6555), and at cal. AD1460-1650 (SRR-6558). Calibrated using CALIB v. 4.1 (Stuiver and Reimer 1993).	Wilson *et al.* 2002.
Mesolithic; Late Bronze Age-Early Iron Age.	Ulfborg, Western Jutland	Radiocarbon dating of buried podsols associated with windblown sand deposits.	Large-scale sand movement at c. 6700-3700 cal. BC. Later sand movement connected to human activity with soils covered by sand at 800-600 cal. BC (no lab codes stated). Calibrated using the Seattle Calibration Program v. 3.03 (Stuiver and Reimer 1993).	Dalsgaard and Odgaard 2001.
Late Mesolithic	Morcambe Bay, NW England	Biostratigraphic analysis and Radiocarbon dating of organic materials.	Nine storm events between c. 5000-4700 cal. BC (BETA-79292) and 4700-4460 cal. BC (BETA-79294). Calibrated using the intercept method (Talma and Vogel 1993)	Zong *et al.* 1999

Late Mesolithic; Early Historic; Medieval; Modern	Breckland, East Anglia	OSL dating of dune sand horizons interleaved with organic deposits	Sand deposition phases at 4530 BC±500 (SHFD-99108), AD400-900 (SHFD-99107; 00076), AD1500±35 (SFD-02079), and AD1600-1615 (SHFD-02077; 02078)	Bateman and Godby 2004.
Early Neolithic; Late Neolithic; Early Bronze Age	Thy, Denmark	OSL dating of aeolian sand deposits	Increased sand movement beginning at c. 2200±200BC, c. 700±70BC, and AD1100±90, separated by periods of stability and soil formation (no lab codes given)	Murray and Clemmensen 2001
Early Neolithic; Late Neolithic; Early Bronze Age; Late Bronze Age-Early Iron Age; Medieval	Vejers dunefield, Denmark	Radiocarbon dating of organic deposits bracketing sand horizons	Intense windblown sand deposition dated by radiocarbon between 4040-3960 cal. BC (AAR-4604) and 2470-2290 cal. BC (AAR-4603). Further instability at 1500-1405 cal. BC (AAR-8670), c. 829-792 cal. BC (AAR-8669), and 800-520 cal. BC (AAR-8668). Calibrated using Talma and Vogel (1993). Renewed aeolian activity between AD1100-1900 dated by OSL.	Clemmensen *et al.* 2006
Early Bronze Age; Early Iron Age; Middle Iron Age; Medieval	Herm, Channel Islands	OSL dating of sand horizons interleaved with palaeosoils	Significant aeolian activity at 1210±200BC (359-6), 635±240BC (359-16.2), 290±270BC (359-18.2), and from AD1180±70 (359-17.2), until AD1660±30 (359-12)	Bailiff *et al.* 2014

Early Neolithic; Late Neolithic; Early-Middle Bronze Age	Hyltemossen, Halland, SW Sweden	Radiocarbon dating of peat and systematic quartz grain counting to ascertain Aeolian Sand Influx (ASI)	Increased ASI at 3750-3500 cal. BC (LuA-5303), 2250-2150cal. BC (LuA-5302), 1100-900 cal. BC (LuA-5301). Calibrated using IntCal98 (Stuiver *et al*. 1998).	Björck and Clemmensen 2004
Late Neolithic-Early Bronze Age; Medieval	Medoc, SW France	Historical and radiocarbon dating of organic deposits bracketing sand	Dune mobilisation c. 3050-1550 cal. BC (UQ-1991), cal. AD1450–1675 (BETA-95393). Calibrated using Talma and Vogel (1993).	Tastet and Pontee 1998
Late Neolithic	Finistère, Brittany, NW France	Radiocarbon dating of organic basal palaeosol.	Max age of 2595-2210 cal. BC (Beta-114971) for onset of sand accretion in dune systems. Calibrated using CALIB 3.0 (Stuiver and Reimer 1993).	Haslett *et al.* 2000
Late Neolithic; Early Bronze Age; Late Iron Age; Medieval	Brittany, NW France	AMS radiocarbon dating of organic deposits bracketing sand horizons.	Sand deposition initiated from c. 2467–2285 cal. BC, with dune formation from 1498–1437 cal. BC (Poz-56624; Poz-56797), with the slowing of sea level rise. Historical sand dunes developed from AD350 with major storms between cal. AD900-AD1200 (Poz-56622) and at cal. AD1313–1357 (Poz-56629). Calibrated using IntCal13 (Reimer *et al*. 2013).	van Vliet-Lanöe *et al.* 2016

Late Neolithic; Late Bronze Age; Medieval.	Lodbjerg, NW Jutland, Denmark.	Radiocarbon dating of peaty palaeosols and OSL dating of sands.	Aeolian sand movement initiated in 2280-2050 cal. BC (AAR-4606), 805-765 cal. BC (AAR-4613), and cal. AD1160-1260 (Beta-127499). Calibrated using IntCal98 (Stuiver *et al*. 1998).	Clemmensen *et al*. 2001.
Late Neolithic; Late Iron Age; Medieval	Jutland, Denmark.	OSL dating of sand deposits and radiocarbon dating of interleaved peats	Aeolian activity around 2200BC±300 (974710), 805–765 cal. BC (AAR-4613), cal. AD92-238 (AAR-7228), and c. AD1060±70 (984703). Continued vegetation removal between 4000BC-AD1850 allowed sand to move more easily.	Clemmensen *et al.* 2009
Late Neolithic; Early Bronze Age; Early Iron Age	Central Netherlands: west coast	Radiocarbon dating of shells within sand deposits as a proxy for storm surges	Storm surges across five different sites from 2465-2200 cal. BC (GrN-5853), 1880-1600 cal. BC (GrN-4566), 510-195 cal. BC (GrN-19546), and c. 410-350 cal. BC (GrN-15157). Level of storm surge elevation increases through time, reaching a maximum during the Little Ice Age. Drivers cited as a mixture of climatic and foreshore bathymetry shifts.	Jelgersma *et al.* 1995
Late Neolithic, Early Bronze Age, Late Iron Age, Late Norse/Early Medieval.	Sanday and Westray, Orkney	OSL dating of sand horizons	Increased sand movement at 2260±100BC <SUTL-602-3, 612-3, 616-7>; 1050±140BC <SUTL-884-889>; 625±185BC <SUTL-608-9, 611, 614-5, 618>; 1385 ± 45 AD; 1500 ± 15 AD; 1710 ± 15 AD; AD1900±15 <SUTL 902>	Sommerville 2003; Sommerville *et al*. 2007
Early Bronze Age	Ghyvelde, NW France	Radiocarbon and OSL dating of organic and sand deposits	Accretion of dune systems around c. 1800-1500 cal. BC (KIA-19480; KIA-19493; KIA-19498). Calibrated using IntCal98 (Stuiver *et al*. 1998).	Anthony, E. J. *et al.* 2010

Early Bronze Age; Medieval	Aquitaine coast, SW France	IRSL dating of sand deposits	Three phases of sand movement and dune development at c. 1500BC, c.AD700-1100, and c.AD1450-1750	Clarke *et al.* 2002
Early Bronze Age; Early-Late Iron Age; Medieval	Northumberland, NE England	Radiocarbon dating of peats and IRSL dating of feldspar grains	Sand accumulation and dune building after 1677-1450 cal. BC (AA-23494),750 cal. BC-cal. AD650 (BETA-109527-8), and cal. AD396-1168 (AA-23502), perhaps associated with a macroscale fall in relative sea level over the last 4-5000 years. Calibrated using CALIB 4.1 (Stuiver and Reimer 1993)	Wilson *et al.* 2001
Early Bronze Age; Late Bronze Age; Late Iron Age	Sola, SW Norway	TL and radiocarbon dating of sandy and organic sediments	Significant aeolian activity TL dated from 1550-1350 BC (T-6903A and B), 740-450 BC (T-6599), 450 BC-AD150 (see Selsing and Mejdahl 1994, 94 for full suite of lab codes) and AD150-340 (T-7042A), punctuated by periods of stability, with some less severe aeolian activity.	Selsing and Mejdahl 1994.
Early Bronze Age; Late Bronze Age-Early Iron Age; Medieval; Modern	Mill Bay, Stronsay, Orkney	Radiocarbon and OSL dating of peats and sands from a coastal section	Increased windblown sand deposition at 1450-1150 cal. BC (BETA-300344) and 850-310 cal. BC (BETA-300342; SUERC-26654) dated by AMS radiocarbon. Calibrated using IntCAL09 (Reimer *et al.* 2009). Sand inundation at AD1360±75 <SUTL-2321>, AD1865±20 <SUTL-2322>, and AD1960±5 <SUTL-2323> dated by OSL.	Kinnaird *et al.* 2012; Tisdall *et al.* 2013
Middle Bronze Age; Middle Iron Age; Medieval; early 20thC.	Underhoull and Lund, Shetland.	OSL dating of sand deposits	Onset of sand activity at 1210±290BC <SUTL2861>, and AD30±150 <SUTL2863> at Underhoull with continued sand movements during AD1380±60 <SUTL2866> and into the early 20thC AD at Underhoull and Lund.	Kinnaird *et al.* 2017.
Middle-Late Bronze Age-Early Iron Age; Medieval	N coast of Northern Ireland	OSL dating of sand horizons	Widespread dune instability from 1150-450BC <SHFD-00095>, and AD1300-1900 (see publication for full suite of determinations and lab codes)	Wilson *et al.* 2004

Early Iron Age	SW Scandinavia	Systematic quartz grain counting in radiocarbon-dated peat bog deposits to ascertain levels of aeolian Sand Influx (ASI)	Strong increase in aeolian activity after c. 550 cal. BC (LuS-6540), coinciding with drier conditions. Calibrated using IntCal04 (Reimer *et al.* 2004).	de Jong *et al.* 2009
Middle Iron Age; Medieval	Co. Donegal, Ireland	Radiocarbon dating of organic deposits bracketing sand horizons	Dune development from 170 cal. BC-cal. AD55 (SRR-5072) and c. cal. AD1350-1450 (SRR-5073; SRR-5067A; SRR-5424). Calibrated using CALIB 3.3 (Stuiver and Reimer 1993).	Wilson and Braley 1997
Medieval	NW Spain, NW France, western Ireland	Radiocarbon dating of peats and sandy organic deposits	Sand deposition at cal. AD1280-1400 (Beta-56073), and cal. AD1650-1770 (Beta-53928)	Devoy *et al.* 1996
Medieval	Dingle Bay, SW Ireland	IRSL dating of feldspar grains from aeolian sand deposits	Dune formation at c. AD1400±52-1500±44 (no lab codes given)	Wintle *et al.* 1998.
Medieval	Outer Hebrides (Lewis-Barra)	Radiocarbon dating of 13 peat deposits bracketing sand layers	Increased sand movement after cal. AD1400 (see publication for full suite of dates)	Dawson, S. *et al.* 2004
Medieval	Aberffraw, Anglesey	OSL dating of aeolian sand deposits	Increased sand movement from c. AD1320±140 (AB5-5), and from AD1480±80 (AB1-3).	Bailey *et al.* 2001
Medieval	Lake Hosta, North Uist, Outer Hebrides	210Pb (lead isotope) dating of Ca/K (Calcium/Potassium) ratios in lake cores measured by Micro x-ray fluorescence (µXRF). Calcium represents the presence of calcareous sands	Increased storminess and sand movement from AD1400-1900	Orme *et al.* 2016.

Table 1. Table listing studies using aeolian sand deposits as a proxy for increased storminess in Northwest Europe.

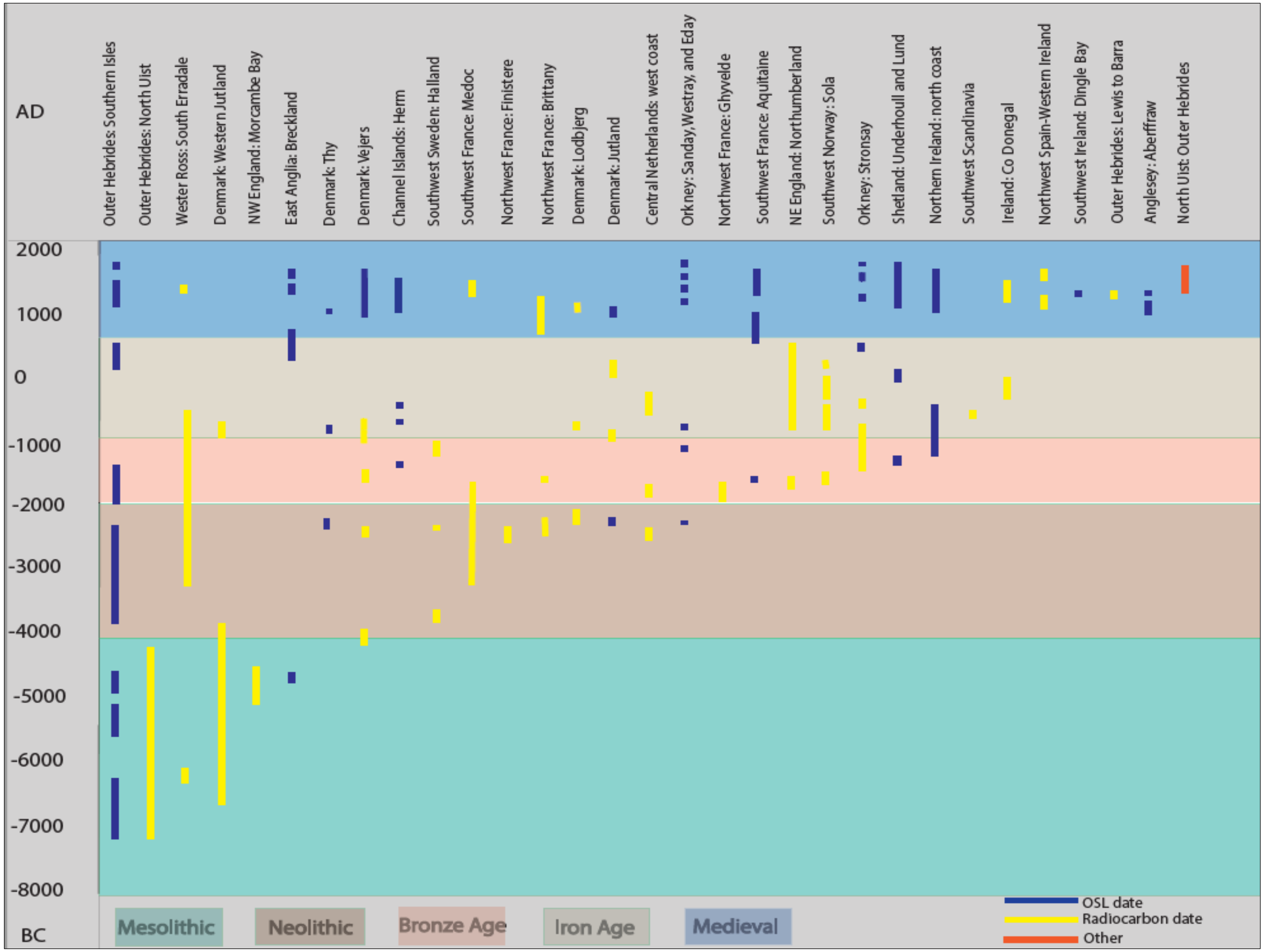

Figure 3.5. Summary figure of chronological data presented in Table 1.

3.4.1. Discussion: Sand drift and storminess on the coastlines of Northwest Europe

Table 1 contains selected scientific studies which make use of sand movement as a proxy for storminess in northwestern Europe, using absolute dating of either sand or organic deposits stratigraphically related to sand. Independent dating evidence for the earliest records of sand deposition varies geographically and chronologically. The earliest instances of earlier Holocene sand movement have been identified along the western coasts of the Outer Hebrides during the Mesolithic (from c. 7000BC) (Gilbertson *et al*. 1999), and at the dunefields at Ulfborg, Denmark (Jutland) at c. 6700-3700 cal. BC (Dalsgaard and Odgaard 2001) (no lab codes). Other early dates for dune building followed in northeast England from c. 5000-4700 cal. BC (BETA-79292) and at c. 4530±500BC (SHFD-99108) (Bateman and Godby 2004; Zong *et al*. 1999). Late Mesolithic and Neolithic episodes followed on the Danish coast from 4040-3960 cal. BC, 2470-2290 cal. BC during periods of both relative sea level change, and the Early Bronze Age and Early Iron Age from 1500-1405 cal. BC and c. 800-520 cal. BC (AAR-4604, 8670, 8669, 8668 respectively) (Clemmensen *et al*. 2006).

Overall, the table demonstrates broad agreement between many early luminescence and radiocarbon ages for sand deposition across Denmark, Britain, France and Ireland. The majority of studies correlate their results chronologically with large-scale climatic proxies (e.g. GISP2) as well as aligning themselves with other recorded incidents of northwest Atlantic storminess in the literature. Holocene cooling events associated with the southward extension of North Atlantic sea ice have been suggested to have taken place at 9.5, 8.2, 5.9, 4.3, 2.8 and 1.4ka by Bond, G. C. *et al.* (1997), and have been linked as drivers behind increased Holocene storminess. The 8.2ka event in particular has been linked to sand mobilisation in Scotland and Denmark (Clarke and Rendell 2009; Tipping *et al.* 2012).

Sand mobilisation dating to the later prehistoric period is also relatively frequent, perhaps aligning with a purported late Bronze Age climatic decline as well as increasing agricultural investment in fertile coastal landscapes (Tipping *et al.* 2012). As expected, the vast majority of studies present dates concurrent with the Little Ice Age, during the Medieval period, where widespread sand movement activity is evidenced by both historical records and independent dating. Sand invasion was frequent throughout the period (Lamb, H. H. 1991; Brown, P. 2015), with Scottish examples including inundations in the Outer Hebrides in AD1400-1800, AD1696, and AD1500-1700 and Orkney and Shetland between AD1492 and AD1500 (Sommerville 2003; Gilbertson *et al.* 1999; Clarke and Rendell 2009).

Unlike instrumental records, which frequently demonstrate interannual or decadal scale variabilities in climatic conditions, the 8-10 % errors attached to luminescence dates ensure that sand movement can only really be pinned down to specific centuries. Resultantly, identification of specific storms or series of storm events relies on probabilities rather than certainties (Clarke and Rendell 2009). Radiocarbon dating of rapidly-formed palaesols and peats can help to improve chronological precision. Although broader patterns of environmental change that correspond with absolute age estimates from sands and organic materials are frequently interpreted as drivers behind sand mobilisations, it has been noted that these ages demonstrate only a coincidence of timing between environmental shifts and movement, and are thus suggestive as opposed to conclusive indicators of causal factors (Ballantyne 1991).

3.4.2. Study locations and sand sources

Given the proliferation of suitable study sites, sampling locations for the sites described above are predominantly westerly or southwesterly, and therefore Atlantic-facing and particularly exposed. Sampling locations vary from Holocene sand dunes (Tastet and Pontee 1998; Wilson 2002) to palaeoenvironmental sections on eroding coastlines (Kinnaird *et al.* 2012), hinterland sites (Sommerville *et al.* 2007), lakes (Nielsen *et al.* 2016), and archaeological sites (Bailiff *et al.* 2014; Sommerville *et al.* 2007). Where two or more sampling locations are contained within the same study, it is notable that there is significant variation in the dates for sand deposition over relatively short distances (e.g. Ritchie and Whittington 1994; Wilson *et al.* 2002). This demonstrates the highly-localised nature of sand movement and sediment supply, and the importance of erring on the side of caution when it comes to broad correlative studies.

Variations in grain and inclusion size in sampled sands can be used to identify differences in source and event type. For instance, the presence of larger, unbroken shells may indicate a powerful storm surge and the mobilisation of marine deposits (e.g. Jelgersma *et al.* 1995, and see chapter 3 for more discussion on provenance). As well as single events such as storm surges and tsunamis, changes in relative sea level is also interpreted as having had a significant influence on sediment supply in the early coastal zone. Much of the early dune building episodes prior to 5,000 years ago was strongly influenced by regional sea level change by supplying sediment to beaches which in turn were transported further inland to form dune systems (Clarke and Rendell 2009) (Figure 3.6). By the later prehistoric period, relative sea level change was no longer a major driver in sand deposition, with dune building and episodes of sand mobilisation increasing rapidly as a result of alternative environmental, and cultural drivers.

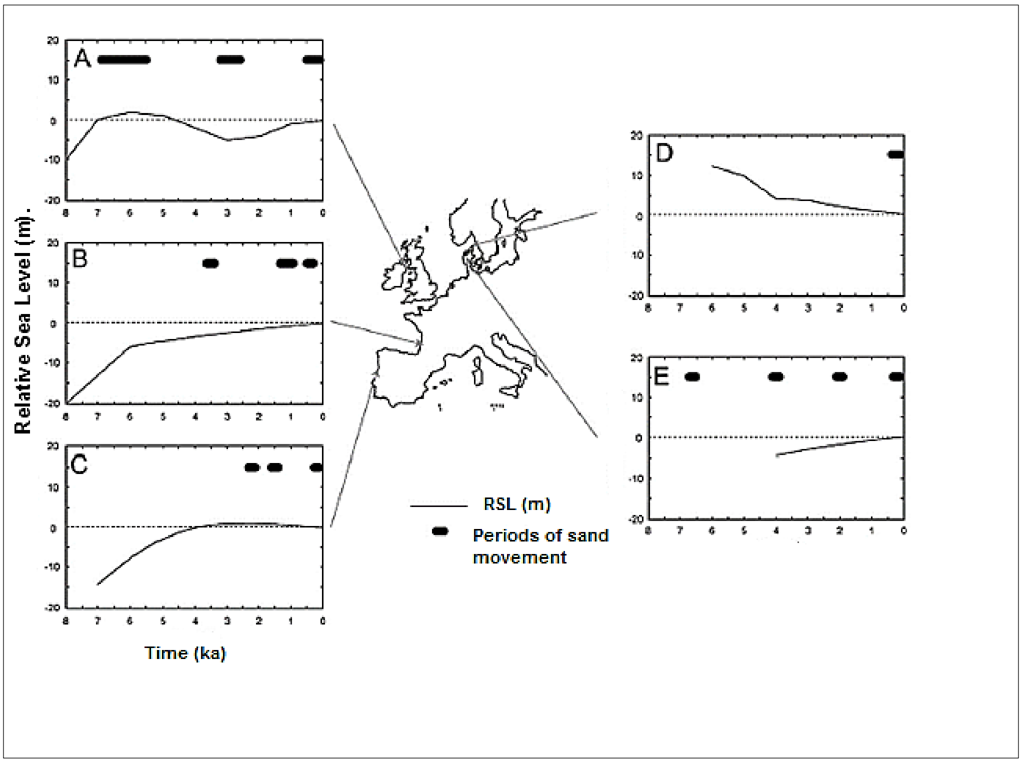

Figure 3.6. Relative Sea Level (RSL) curves over the last 8ka, with sand movement timings marked with a heavy line for A. Northern Ireland, B. Aquitaine, SW France, C. Portugal, D. Skagen, Denmark, E. Jutland, Denmark. Adapted from Clarke and Rendell

Chapter 4. Windblown sand in Orkney

4.1. Introduction

Chapter 4 comprises a descriptive summary of the archaeological evidence for windblown sand in specific landscapes within Orkney (Figure 4.1). The islands are divided into a series of regions; Mainland Orkney (Bay of Skaill and Birsay Bay, West Mainland, and Deerness, East Mainland), Papa Westray, Westray (Grobust Bay and Pierowall Links), and North Sanday. Significant dated archaeological sites in these regions containing archaeological windblown sand layers are discussed in turn. Sites with a lack of detailed archaeological information (for example, many of the actively-eroding and recently identified sites compiled by the Coastal Zone Assessment Survey and The SCAPE Trust) are contained in Appendix 1. Although the thesis discussion is concerned primarily with the evidence for prehistoric incidents of windblown sand incursion, historic and undated incidences are recorded for clarity and breadth. Archaeological windblown sand layers are here defined as any sand layer which can be identified as having been naturally deposited within an archaeological context. This can be identified in three primary contexts:

i. A sand layer or multiple layers found in the direct vicinity of an archaeological site, which appear to have been deposited during the occupation of a nearby site.
ii. A sand layer or multiple layers deposited directly on or over a site and/or its associated managed landscape (e.g. middens, infields and gardens)
iii. Frequent sand inclusions in occupation deposits indicative of repeated sand movement in the immediate environment of the site.

Chapter 4 contains information on phasing, dating and the nature of windblown sand deposits (including sand composition and dimensions) for excavated sites in these regions. It summarises relevant radiocarbon dates and their stratigraphic relationship with blown sand horizons, some of which have also been directly dated by Optically Stimulated Luminescence. Between the radiocarbon dating of bracketing deposits, and direct dating of the sand layers, where possible the date of sand deposition, and therefore its relationship with occupation (or a hiatus) at each site can be posited. Where they exist, discrepancies between the radiocarbon dates and OSL dates are highlighted and the possible explanations for these discrepancies discussed.

The formatting of these discussions, and the way in which the archaeological and chronological information is presented, varies across the sites depending on their character. In discussions of sites investigated via tapestry excavation methods, or smaller sites investigated within the context of a large site or landscape area, frequent use is made of tables in order to present large amounts of information concisely. In some examples, enough information is present to develop an understanding of what living with sand at these sites may have entailed; at others, this is not the case. For some larger sites there is the opportunity to critically assess the methods by which they were excavated and interpreted. A key aim of this thesis was to develop a better understanding of the chronology of sand movement and as such, critical consideration of the scientific dating of the sites is key. It is important to consider pertinent issues including;

a. Whether bone samples were comprised of bulk material (which can contain residual bone, rendering determinations only useful for a *terminus ante*- or *post quem* for the development of the deposit being dated), single entity, or articulated (suggesting the bone is located at its original point of deposition;

b. Whether wood samples comprised a single entity or mixed species (with mixed samples creating the possibility of old charcoal interference);

c. The marine dietary input on shells and bones, whereby an older or younger bias is created (although published dates generally already have a correction of 200-500 years to account for this).

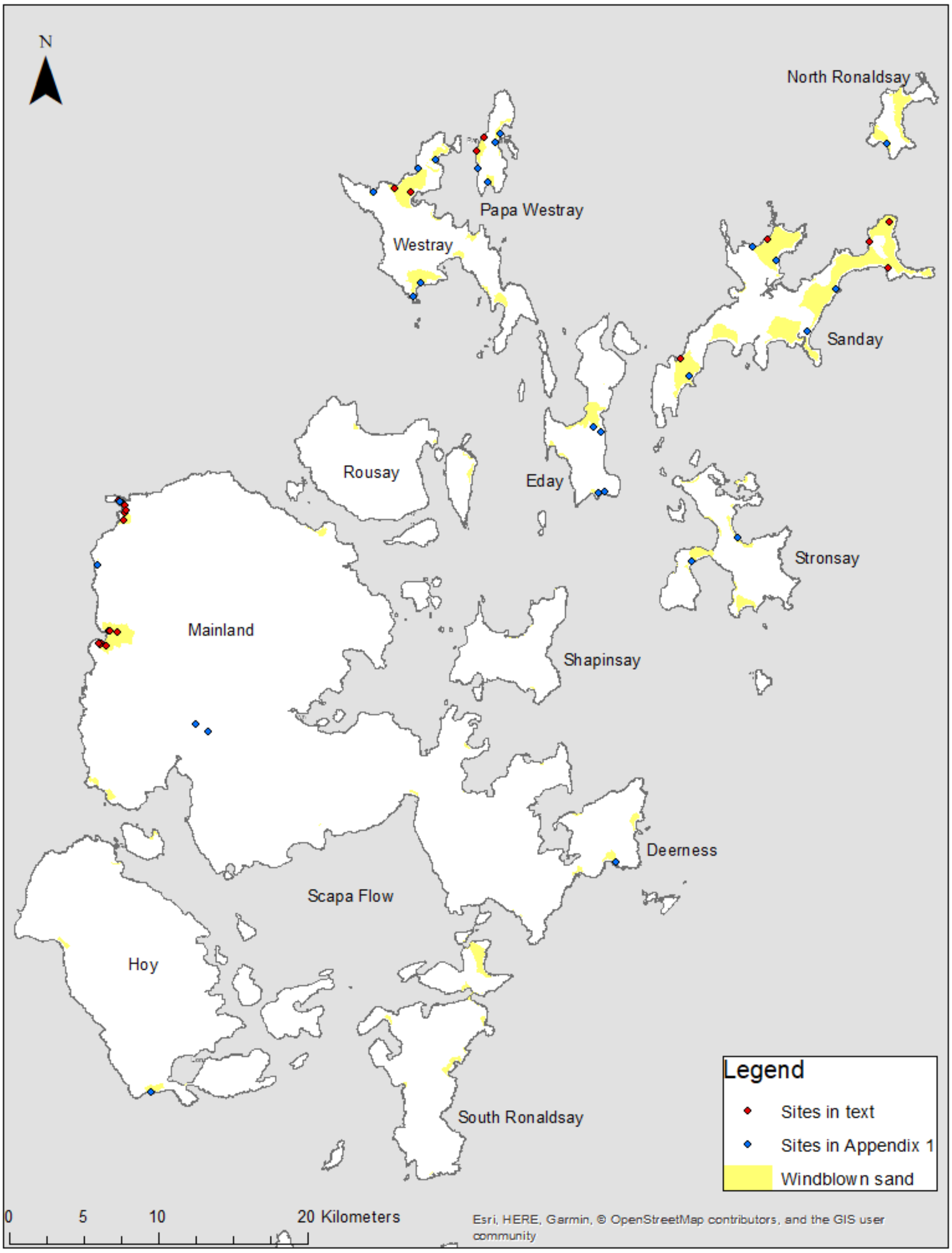

Figure 4.1. Windblown sand sites mentioned in Chapter 4 (red) and in Appendix 1 (blue).

4.1.1. Methods

The methods comprised the study of the Coastal Zone Assessment Surveys for Orkney (Moore and Wilson 1997; 1998; 1999), drift geology surveys, the Soil Surveys of Scotland (1981), historic OS maps and the SCAPE Sites at Risk Map (available at scharp.co.uk/sites-at-risk). During map consultation, an area which extended from the mean high-water spring (MHWS) tides, leading inland to where windblown sand ceased to be the dominant drift deposit. The Historic Environment Record, unpublished data structure reports, the Scottish radiocarbon database, published site monographs, unpublished doctoral theses, and historical documents were also consulted to identify archaeological sites containing, or associated with, windblown sand deposits.

The information populates a Microsoft Access database (see Supplementary Data Disc), containing records for every archaeological site in the Orkney archipelago with evidence for sandblow horizons stratified within archaeological deposits. Where appropriate, it details: CANMORE record details (NUMLINK, radiocarbon hyperlink); HER site number; Radiocarbon hyperlink, the availability of OSL and radiocarbon dates, island, site name, local authority, parish, grid coordinates (eastings/northings); NGR, site type, century, period, designation, and references. Shapefiles for the Sand Dune Vegetation Survey of Scotland 2012 (SDVSS) were used to map the windblown sand deposits in ArcGIS (provided by Scottish Natural Heritage under an Open Government Licence), over Ordnance Survey 1:25000 and 1:50000 raster basemaps (Crown Copyright 2019).

4.2. Mainland Orkney

Mainland is the largest island in the archipelago, with an underlying geology of Old Red Sandstone with Eday beds to the south and east, and Stromness Flags to the North. Unlike the more northerly islands (e.g. Sanday and Westray), Mainland displays comparatively discrete pockets of windblown sand drift geology, most notably in the Atlantic-exposed West Mainland, where extensive drifts are located at the Bays of Skaill and Birsay between high-cliff coastlines. Smaller pockets can be found to the lower-lying southeast of the island, at St Peter’s Bay, Newark Bay, and Sandside Bay (Figure 4.2). The drift sand deposits of Mainland Orkney total approximately 546ha of land cover (Dargie 1998b, 66; Table 1a). Much of the island is low-lying and fertile, and under cultivation (Moore and Wilson 1998, 3). Most sites with identifiable windblown sand horizons are located on the north coast of the West Mainland. This is unsurprising given that this western-facing, soft-sediment coastline is highly susceptible to erosive processes (Stapf 1998, 64), leading to more frequent sand movement and archaeological discoveries. This is compounded by a comparative lack of coastal survey on the east coast, with the Coastal Zone Assessment Survey (Moore and Wilson 1998) focussing only on the West Mainland given its high-risk status. It is worth noting, however, that the Coastal Zone Assessment Survey (1998) of Mainland Orkney focussed only on the more sheltered southwest coast.

West Mainland Orkney has been the focus of significant archaeological attention, with the group of Neolithic monuments (the Heart of Neolithic Orkney) being assigned UNESCO World Heritage status in 1999. Important landscape-scale projects undertaken at the Bay of Firth (the Cuween-Wideford Landscape Project (Richards and Jones 2016)), Birsay Bay and the Bay of Skaill (Morris 1989, 1996; Griffiths, D. *et al. forthcoming*) have vastly improved understanding of the archaeological landscapes of the West Mainland. The Statistical Accounts for Scotland refer to windblown sand in certain pockets of the West Mainland in particular, namely in the Parish of Sandwick (Rev. Charles Clouston, 1839. New Statistical Account Vol. 15, 42 in Leask 1996, 124). In the more recent past, at the Bay of Evie (northeast Mainland) sands encroached on cultivated land behind the coastline in the 1920's (Rev. Dr. A. J. Campbell, Third Statistical Account 1952, Vol. 20a. 32 cited in Leask 1996, 122). Twenty-three separate sandblow sites have been recorded (Table 2), many of which (for example, at Birsay Bay) comprise parts of a larger composite site. Five sites at Bay of Skaill, five at Birsay, and one at Deerness are discussed here. Detail from the remaining sites are contained in Appendix 1.

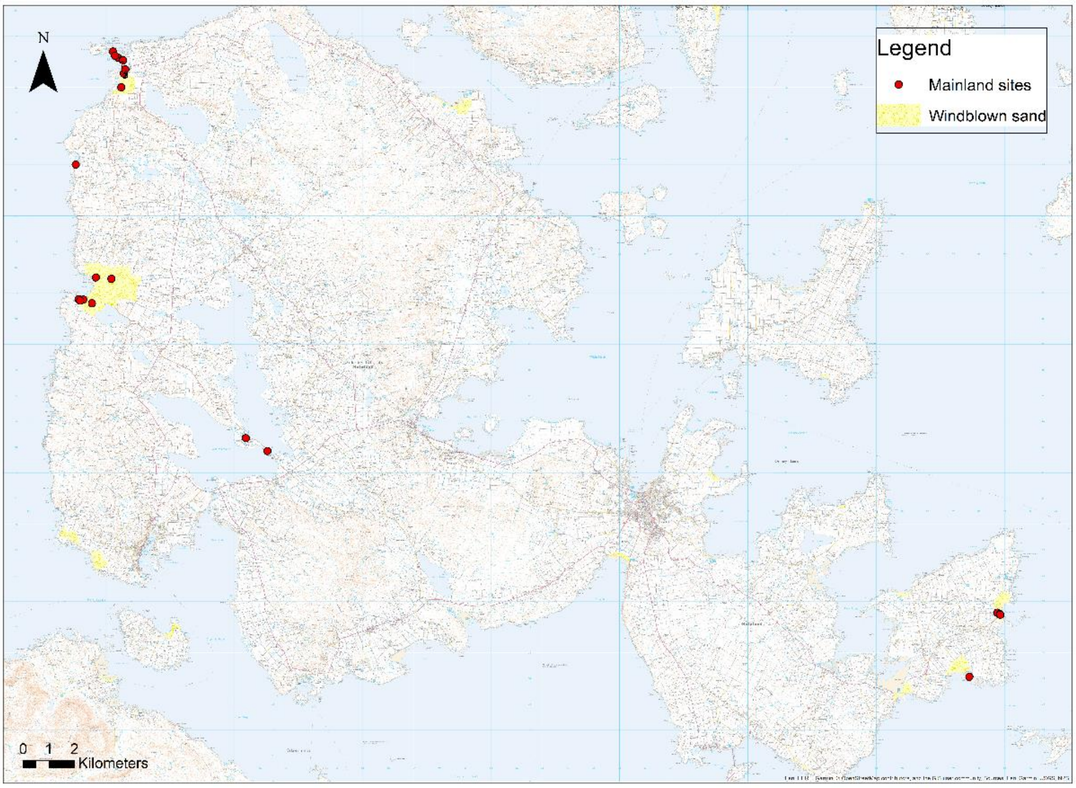

Figure 4.2. Mainland Orkney sandblow sites.

Bay of Skaill				
Site	**Site type**	**Period of human activity**	**Sandblow period**	**Reference**
Skara Brae	Settlement	Late Neolithic; 2920-2885 cal. BC - 2545-2440 cal. BC (*central_phase_1_start; central_phase_2_end*)	Early-Middle Neolithic (before 3350-3020 cal. BC (SUERC-12717 (GU14731)); Late Neolithic (at c. 2920-2690 cal. BC (SUERC-12733 (GU14741)); from c. 2870–2815 cal. BC to c. 2840-2685 cal. BC (*central_phase_1_end; central_phase_2_start*); at c. 2620-2460 cal. BC (SUERC-12470 (GU14686)); after 2545-2440 cal. BC (*central_phase_2_end*).	Clarke, D. V. 1976a and b; Simpson *et al.* 2006; Bayliss *et al.* 2017
Skaill	Cist burial and palaeoenvironmental section	Late Iron Age-Pictish; c. cal. AD550-680 (GU-7245)	Between 765±620 BC <SUTL-621> and cal. AD550-680 (GU-7245)	Sommerville 2003; James *et al.* 1999
Sand Fiold	Cist burial	Bronze Age (from c. 2900-2500 cal. BC (UT-1483; UT-1485) to c. at c. 1000-800 cal. BC (UT-1560).	Unknown (post- 1000-800 cal. BC (UT-1560)).	Dalland 1999
Marwick	Settlement	Viking	Viking, Medieval	Griffiths, D. 2009
Snusgar	Settlement	Viking	cal. AD489-774 cal. BC at 95.4% probability (GU-17851); c. cal. AD900-1050 at 94.5% probability (GU-23601–23618)	Griffiths, D. 2016
Snusgar East Mound	Settlement	Viking	c. AD1395±125 (lab ID unavailable)	Griffiths, D. 2015
Skaill House	Cemetery	Late Viking-Medieval (from at least cal. AD1043-1290 (GU-7244) to cal. AD1220-1392 (GU-7243), and into 17th century	Before c. cal. AD1043-1392 (GU-7244; GU-7243); between cal. AD1043-1392 and the 17th century AD (no date)	James *et al.* 1999

Brodgar				
Ring of Brodgar	Monument	Completion of ditch at 2750–2210 cal. BC (*Ring of Brodgar*)	Late Neolithic-Early Bronze Age; c. 2191±200 BC <SUTL-2281>	D. Sanderson *pers. comm.*; Sanderson *et al.* 2010; Bayliss *et al*. 2017 [Supplementary material], 88; Table S4)
Ness of Brodgar	Settlement	Late Neolithic; from c. 3065-2950 cal. BC (*start_NoB*) until c. 2285-2100 cal. BC (*end_NoB,*)	?Late Neolithic (no dating)	Card *et al.* 2017, 35-6; Table 3); D. Sanderson *pers. comm.*
Birsay Bay				
Point of Buckquoy: Area 6	Settlement	Late Neolithic-Early Bronze Age (from at least 2630-2180 cal. BC (GU-1557)); Pictish-Modern (c. 9^{th}-10^{th} centuries AD to 18^{th}-19^{th} centuries AD)	Late Neolithic-Early Bronze Age (around 2630-1690 cal. BC (GU-1557; GU-1640) Pictish-Modern (between the c. 9^{th}-10^{th} centuries AD and 18^{th}-19^{th} centuries AD)	Morris *et al*. 1989
Point of Buckquoy: Cuttings 5 and 6	Midden	Late Neolithic-Early Bronze Age (from at least c. 2150-2000 cal. BC (*Boundary start_cutting_6*)); unknown historic	Late Neolithic-Early Bronze Age (before c. 2150-2000 cal. BC (*Boundary start_cutting_6*) to c. 1600-1400 cal. BC (*Boundary end_cutting_6*; Marshall *et al.* 2016, 14). After c. 1600-1400 cal. BC (*Boundary end_cutting_6*)	Morris *et al*. 1989 Marshall *et al.* 2016
Brough Road Cutting 1	Inhumation s	Late Iron Age (from at least cal. AD230-570 (GU-1550).	Unknown prehistoric; before cal. AD230-570 (GU-1550)	Morris *et al.* 1989
South of Red Craig Area 1	Settlement	Late Iron Age (from at least AD550-570 (GU-1554) to c. cal. AD880-1140 (GU-1552).	Unknown prehistoric (before AD55-570 (GU-1554)); Iron Age-Norse (between c. cal. AD55-585 (GU-1554, 1551) and c. cal. AD620-1035 (GU-1956, 1957) (Morris *et al*. 1989) Pictish-Norse (after c. cal. AD880-1140 (GU-1552).	Morris *et al.* 1989
South of Red Craig Area 2	Settlement	Late Iron Age-Norse (from at least cal. AD625-895 (GU-	Norse (around cal. AD855-1050 to cal. AD885-1245 (GU-1980, 1667)); Norse	Morris *et al*. 1989

		1955) to cal. AD885-1245 (GU-1667)).	(after cal. AD670-1020 (GU-1555) to cal. AD885-1245 (GU-1667).	
St Magnus' Kirk	Burials, church	Pictish-Norse; Medieval; Modern. (from at least cal. AD800-1030 (GU-1631) to the 17th-19th centuries AD).	9th-11th centuries AD.	Morris *et al*. 1996
Beachview Burnside Area 2	Settlement	Norse (from at least c. 1020-1280 cal. BC (GU-2280, 2281).	Norse (around 1020-1280 cal. BC (GU-2280))	Morris *et al*. 1996
Beachview Burnside Area 3	Settlement	Norse-Early Medieval (from at least cal. AD1020-1320 (GU-2279)).	Norse (around, and after, cal. AD1020-1320 (GU-2279) (Morris et al. 1996, 292-3)	Morris *et al*. 1996
Beachview Studio	Settlement	Norse-Early Medieval (from c. cal. AD980-1206 (GU-2272) to at least cal. AD1020-1280 (GU-2269))	Norse (around cal. AD980-1206 (GU-2272) to c. cal. AD1030-1280 (GU-2268); Norse-Early Medieval (from cal. AD1020-1280 (GU-2269)	Morris *et al*. 1996
Saevar Howe	Settlement	Pictish-Norse (from at least cal. AD540-720 (GU-1401), to at least cal. AD660-990 (GU-1400)).	Pictish-Norse (from at least cal. AD660-890 (GU-1402) to at least cal. AD660-990 (GU-1400)).	Hedges, J. W. 1983
Buckquoy	Settlement	Iron Age; Pictish; Norse	?Pictish-Norse	Ritchie 1977
Deerness				
Skaill, Deerness	Settlement	Early Bronze Age-Middle Iron Age (Site 5) (Between 1949-1752 cal. BC (OxA-1716) and 370-1 cal. BC (Birm-413)); Early Iron Age-Pictish (Site 6) (from at least c. 700-200BC (no scientific dating) to c. AD600-770 (Birm-765)	Later Prehistoric (Sites 5 and 6) (between 1513-1392 cal. BC (OxA-1437) and the 8th-10th centuries AD) Late Iron Age-Pictish (Site 6) (c. cal. AD420-775 (Birm-592, 763, 765) Norse (Site 2) (c. AD800-900) Norse-Medieval (Site 4) (c. AD900-AD1600) Medieval (Site 1) (c. AD1100-1200)	Buteux 1997

		Pictish-Norse (Site 2) (9th-11th centuries AD – no scientific dating) Norse-Medieval (Sites 1-4) (c. AD900-1600 – no scientific dating)		
Newark Bay	Chapel, inhumations	Bronze Age; Medieval	Unknown	Card *et al.* 2015

Table 2. Mainland Orkney windblown sand sites showing periods of occupation and sand movement.

4.3. Bay of Skaill

A total of eight sites (with Sandwick, Skara Brae amalgamated with Skara Brae) containing windblown sand deposits are clustered around the wide, semi-circular Bay of Skaill, on the Atlantic-exposed coast of West Mainland Orkney (Figure 4.3**Error! Reference source not found.**). The bay is located within the western end of a depression likely to have been eroded and further deepened by Devensian glacial activity. The lochs of Stenness and Harray to the east and southeast of the Bay of Skaill also occupy this depression (Mather *et al.* 1974, 19). The bay and its sandy foreshore are backed by a steep, swash-aligned (where waves break parallel to the shore) cobble storm beach, the height of which varies from c. +5.1m OD and +9.3m OD. This is in turn backed by an extensive machair deposit. This comprises a key source for the blown sand deposits which characterise this landscape, with sand extending at least 2km inland with the most extensive deposits to the north of the Bay. The thickness of the sand deposits reaches up to 4m in depth (Mather *et al.* 1974, 20), with a total land cover of c. 298ha (Dargie 1998b, 66; Table 1a). The vegetation of this landscape is today comprised of short pasture, grassy sedges and perennial herbs. Typical machair vegetation predominates, including plantago species (*Plantago maritima*), carex (*Carex flacca*) and fescue (*Festuca rubra*) (Keatinge and Dickson 1979, 594-5; de la Vega Leinert *et al.* 2000, 510).

The geological significance of the old red sandstone deposits in the bay have led to its designation as a Site of Special Scientific Interest (SSSI). Intertidal peats have also been observed (see below). High human pressures on the stability of the machair landscape derive from the large numbers of visitors to the Neolithic site of Skara Brae and in the recent past, sand extraction. The continued risk to the archaeological site and its surroundings from dynamic coastal change has recently been reiterated by the Historic Environment Scotland Climate Change Risk Assessment (Harkin *et al.* 2018, 110).

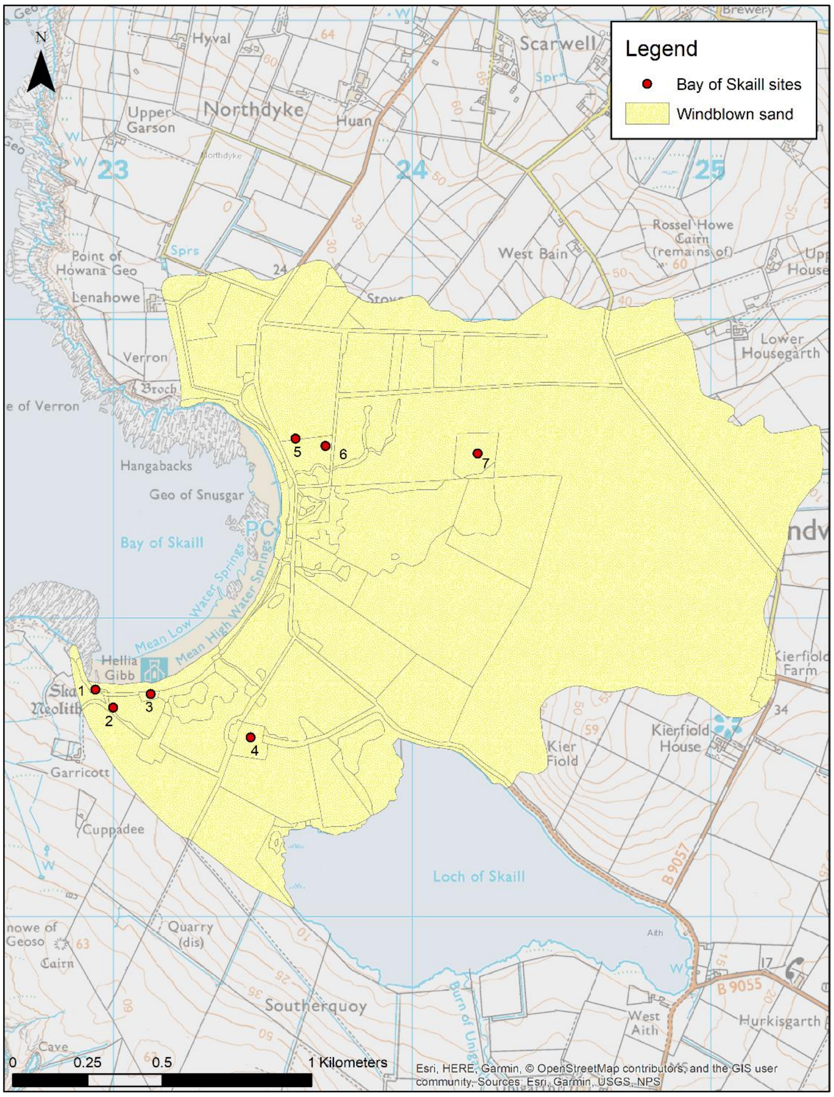

Figure 4.3. Bay of Skaill sites. 1. Skaill; 2. Sandwick, Skara Brae; 3. Skara Brae; 4. Skaill House; 5. Snusgar; 6. East Mound; 7. Sand Fiold.

Environmental history

Unlike the other regions discussed, Skaill Bay benefits from comparatively detailed palaeoenvironmental studies. The palaeoenvironmental research context is currently dominated by data pertaining to the middle Holocene. An early study of the Bay of Skaill's palaeoenvironmental history was undertaken by Watt (1820), who observed and described and intertidal peat deposit containing plant macrofossils which he identified as deriving from fir (*pinaceae*) and willow (*salix*) (Watt 1820, 101). Later notable palaeoenvironmental studies have been undertaken in the Bay of Skaill environs. A stratigraphic environmental study of the Loch of Skaill to the southwest of the Bay of

Skaill, Pow fen to the east, and the intertidal zone below Skara Brae, formed part of a wider study of Mainland Orkney by Keatinge and Dickson (1979). An integrated sedimentological and stratigraphical study of environmental change was later undertaken by de la Vega Leinert *et al.* (2000). Despite a fuller understanding of the environmental history of the Bay of Skaill being highlighted as a research priority (Downes 2005), these studies continue to provide the most detailed environmental data currently available. They radiocarbon-dated environmental sequences offer important contextual information for the occupation of Skara Brae (see below). A chronological summary of the findings is presented here.

The earliest radiocarbon dates for environmental change at the Bay of Skaill are offered by de la Vega Leinert *et al* (2000), who took samples from the far north of the bay. All determinations were calibrated using the Pretoria curve (Vogel et al. 1993). From c. 5590-5305 cal. BC (Beta-90824) (dated on humified peat), a freshwater marsh developed in the coastal depression at the Bay of Skaill. The identification of *phragmites* grass peat in the intertidal zone suggests that the Bay of Skaill was formerly a freshwater loch, with the original coastline lying further west. Marly sediments sampled by Keating and Dickson (1979) from the loch of Skaill yielded a determination of c. 3750 cal. BC-3050 cal. BC at 93% probability (SRR-978) for the formation of the bay and beach – as a result of marine incursion and sand mobilisation inland by strong onshore winds (Keatinge and Dickson 1979, 604). This is slightly earlier than the date posited by de la Vega Leinert *et al.* who place the formation of the present Bay to shortly after c. 3325-2900 cal. BC (Beta-104795, on humified peat) (2000, 525) (Keatinge and Dickson 1979, 610).

During the formation of the Bay of Skaill and its sandy beach, machair developed in the hinterland from at least 5235-3540 cal. BC (Beta-90822 and 90823, on humified peat and organic marl respectively). This derived from blowouts at the outer edge of a dune ridge to the west of the Bay and infilled the freshwater marsh and ponds (de la Vega Leinert *et al.* 2000, 509). As these deposits moved up to 2km inland, pasture developed and sand covered the hills of Kier Fiold (57m OD) and Sand Fiold (42m OD) (de la Vega Leinert 2000, 526). Dimensions of the sands recorded by de la Vega Leinert *et al.* vary from thin lenses to tens of centimetres in thickness. The thickest *dated* sand layer in the sequences (c. 0.30m) was located at the northernmost point of the Bay of Skaill and dated to c. 3790-3115 cal. BC (Beta-104796-Beta-104797, on humified peat and organic silt respectively). Although the authors do not make clear whether these were a single deposit as opposed to an accumulation, the lithostratigraphy presented does appear to suggest that this was a single deposit (de la Vega Leinert *et al.* 2000, 513; Figure 3). A dearth of organic matter in the sand units attests to the presence of bare, deflation-prone sand units.

Multiple episodes of calcareous sand mobilisation and deposition, punctuated by less dynamic periods, took place until c. 3325-2900 cal. BC (Beta-104795, on overlying peat). This is the latest radiocarbon date recorded by de la Vega Leinert *et al.*, although sand continued to be periodically mobilised into the later prehistoric periods and beyond. Changes in particle size of the sands and variation in thickness are indicative of irregular aeolian dynamics or changes in sediment supply. Coarsening of the sand into the later part of the mid Holocene may have been indicative of either stronger winds, or a change in the proximity of the sand source (de la Vega Leinert 2000, 526).

Some temporal discrepancies in the data presented by de la Vega Leinert *et al.* (2000) for episodes of sand deposition highlight the highly localised nature of such coastal dynamics. Despite two sampling sites (SK94 and SK134) lying only 30m apart at the north of the bay, the authors observed significant differences in chronology and sedimentation between the two sites. The dates for the organic silt overlying the upper contact of the first sand layer range by over 1000 years, from 3925–3540 cal. BC (Beta-90822) in SK94 to 4490–4140 cal. BC (Beta-104800) in SK134. The thickness of the sands also varied from 0.49m in SK94 to 0.5m in SK134. This is demonstrative of the distinct variation in depositional histories within a relatively small area, and the authors explain this in two ways. Firstly, the discrepancy in age may be due to a hiatus in an already slow sediment accumulation in the locality of SK94. Alternatively, given the relatively short distance between them and the variation in thickness, differing lateral (horizontal) sedimentation may have taken place. This as favoured as a more reasonable explanation by the authors (de la Vega Leinert *et al.* 2000, 513), and can be driven by the underlying topography as well as remobilisation of sands following their deposition.

It is worth noting that the discrepancy in the radiocarbon dates for SK94 (peat) and SK134 (marl) may be due to the hard-water effect known to produce a considerable older bias on radiocarbon dates. The effect can occur when old carbon is recycled by aquatic plants, and in areas where the underlying bedrock is carbonate-rich – as is the case with the Stromness Flags which underlie the Bay of Skaill (de la Vega Leinert 2000, 513). If the deposit being dated accumulates under these conditions, then an older bias may occur. This was an issue noted in previous work in the area (Keatinge and Dickson 1979, 609), resulting in the application of a c. 965-year correction to the radiocarbon dates for the Loch of Skaill (Harkness in Keatinge and Dickson 1979, 609-12). This correction not undertaken by de la Vega *et al.*, and this must also be borne in mind when considering the age discrepancy.

Early anthropogenic activity between c. 4370-3115 cal. BC (Beta-104796 - Beta104798, on peat and silt) is evidenced by pollen and charcoal records (de la Vega Leinert *et al.* 2000, 509). Decline in open birch-hazel woodland, and a transition to more herbaceous vegetation thriving in open environments and pasture took place at the Loch of Skaill and Pow at c. 3900-3600 cal. BC (SRR-978) (Keatinge and Dickson 1979, 610). Land mollusc data from dune sections sampled to the south of Skara Brae supports this conclusion (Spencer, J. 1975). Such changes also appear to have also occurred in other areas of West Mainland, at Quoyloo Meadow at c. 3950 BC (dated by tephrochronology) (Bunting 1994) and Glims Moss at c. 3500 cal. BC (SRR-976) (Keatinge and Dickson 1979, 590; Farrell 2009, 122).

The fourth millennium BC change in vegetation at Skaill was associated with a purported increase in wind speed from the south west, leading to the sand accumulations in the bay and inland to the Loch of Skaill. This is likely to have initiated the development of the machair pasture, with an increase in *plantago maritima* species, which thrive in sandy soils (Keatinge and Dickson 1979, 599). The increase in levels of salt spray and sand abrasion would have had damaging effects on tree growth and development, and is a pattern which has also been noted in the Outer Hebrides. This change from woodland to pasture, grasses and scrub is estimated to have occurred over a period of 200 years, with the lack of regeneration of young saplings, and therefore trees, probably due to grazing (Dickson and Dickson 2000, 64-5). The possibility of dating inaccuracies from the hard water effect led the authors to use the traditionally-accepted elm decline at c. 3000 cal. BC to infer dates for the vegetational changes observed in the pollen diagrams for the Loch of Skaill. Further studies have more recently highlighted that this elm decline was not synchronous across the region (Tipping 1994; Farrell 2009, 123). The formation of blanket peat across Skaill and West Mainland was then dated to c. 1830-1620 cal. BC (SRR-981, SRR982) (Keatinge and Dickson 1979, 585).

Further palaeoenvironmental investigations have revealed more information about later prehistoric aeolian dynamics at the Bay of Skaill. OSL dating and micromorphological studies were employed to investigated sediments in an eroding coastal section 100m west of Skara Brae. These deposits comprised dark basal organo-mineral deposits, bracketed by windblown sand horizons (Cluett 2007, 256; 265). The organic deposits were insubstantial and did not warrant the use of radiocarbon dating, thus necessitating the use of OSL dating of the bracketing sands.

The results of the OSL dating programme revealed that calcareous sand deposition continued to dominate environmental dynamics in the Bay of Skaill in c. 1000±80BC, with a second notable period of sand mobilisation at c. AD310±190 (Cluett 2007, 274-7) (no lab codes). The lack of precision in the OSL dates from Orkney more generally necessitates that caution should be exercised when attempting to pinpoint specific sand deposition episodes or events within this data. The organic horizons were interpreted as stabilisation layers forming during periods of comparatively weaker periods of aeolian mobilisation. Given the continued presence of calcium carbonate and the limited organic matter, however, it is clear that aeolian deposition continued to stand as the dominant environmental dynamic in this area (Cluett 2007, 265), with only partial stabilisation and vegetation colonisation occurring.

4.3.1. Skara Brae

Located on the low-lying west coast of Mainland Orkney at the south of the Bay of Skaill (one of three large bays on the west coast of the Mainland) and northwest of the Loch of Skaill, the Neolithic site of Skara Brae represents one of the earliest of the Orkney sandblow sites to have been excavated. The site lies within an extensive area of calcareous windblown sand deposits (Figure 4.3), and sand was frequently mobilised and blown into the settlement during its occupation. Indeed, the site was first revealed by a destructive storm in the winter of 1850, when the dune covering the site was stripped of its vegetation and began to deflate (Clarke, D. V. 1976b, 233).

After a series of small-scale explorations prompted by storms through the 1860's and 1920's, the first extended archaeological excavations at the site took place in from 1928-1931 under the direction of Vere Gordon Childe for the Ministry of Works. The emphasis of these excavations was on consolidation and preservation (Richards 1991, 452). The majority of Skara Brae's later phases were excavated by Childe, during which well-preserved settlement remains including houses and passageways were revealed (Childe 1931). The underlying, earlier deposits received limited attention, with the exception of 13 exploratory test pits (Childe 1931, 83-91) (Figure 4.5). These test pits were located within the houses, as well as in the paved areas, passageways, and at the limit of excavation to the northwest.

Childe's investigations revealed a series of drystone structures joined by passageways, which developed incrementally over at least two phases of occupation. The remains lay beneath an extensive windblown sand deposit. Two intrusive cist burials, interpreted as being of Norse origin, were later inserted into the sand (Childe 1931, 143-4). The structures were surrounded by extensive drainage systems and occupation deposits. Although these occupation deposits were previously described as 'midden' by Childe during his excavations, Shepherd suggests that this is a blanket misnomer given the variety of materials represented in these deposits, combining sand, consolidation and stabilisation layers over sand, and occupation deposits. These deposits comprised construction material (predominantly clay) with ash, humic material, refuse, habitation residues and sand (Shepherd 2016, 221-2; A. Shepherd *pers. comm.*). The use of clay, midden and other anthropogenic sediments as a construction material was an important facet of site development at Skara Brae and other Neolithic sites (Simpson *et al.* 2006).

Each house contained similar furnishings, including 'dressers', box beds and hearths. Approximately ten structures were investigated and recorded during several excavations, with parallels in their construction, and use of Grooved Ware pottery highlighted at Rinyo (Rousay), Barnhouse and Ness of Brodgar (Mainland), Knap of Howar (Papa Westray) and Pool (Sanday) (Childe 1931; Clarke, D. V. 1976b). The first structure to receive significant interpretative attention was House 7, which came to form, and illustrate, Childe's interpretation of the settlement having been 'abandoned' following an episode of significant sand mobilisation (Childe 1931; 37; 62-3); Richards 1991; and see Chapter 6). Childe's excavations contributed a great deal to an early understanding of material culture in Neolithic Orkney, and its preservation conditions have ensured it has stood the test of time as an iconic Scottish Neolithic 'type site' with a significant material culture assemblage. Unfortunately, the level of contextual detail from Childe's excavations is mixed, with his interpretations of Skara Brae described as "well dealt with in narrative, but not in detail" (Brophy and Sheridan 2012, 7).

Figure 4.4. View of Skara Brae in its immediate landscape context, and modern-day agricultural activities on the sandy pasture. RCAHMS Aerial Photography Digital collection. SC 1691575

Excavations by Gordon Childe: Phasing and chronology

No scientific dating techniques were available during the time of Childe's excavations and instead, he relied purely on his own experience and knowledge when it came to the chronology of the site. He stated that the settlement at Skara Brae dated to the Pictish period, although he recognised the Neolithic character of many of the remains (Richards 1991, 453). Childe divided phases of occupation at the site into four 'Periods' (Periods I-IV). These periods were preceded by what Childe termed the 'original land surface', upon which Skara Brae's early inhabitants first settled (Childe 1931, 90-1). These periods and their defining characteristics are summarised below, and more detail should be sought in Childe's most expansive publication on the site: '*Skara Brae. A Pictish Village in Orkney*' (1931).

The original land surface

Childe excavated 13 Test Pits (labelled I-XIII) (Figure 4.5) to investigate the original land surface at Skara Brae. Beginning at a height of c. 5.3m OD, the land surface is described as sloping upwards towards the southwest. Many of the Period I deposits were found to overlie blown sand (composition not stated), which in turn overlay natural basal clay (Childe 1931, 88-9; Clarke, D. V. 1976a, 11). The original land surface, then, comprised a sandy plain, and drifted sand being exposed in many of Childe's Test Pits. The depth of these deposits varied topographically, from c. 0.60m-0.80m at their deepest in the east and west at the shoreline, to c. 0.12m-c. 0.40m towards the south (Childe 1931, 90-1). In some areas of the site, (such as at Test Pit XII at the far south of the site) no basal sand deposits were present and occupation lay directly on the clay old land surface. The presence or absence of sand was therefore influenced by variations in the underlying topography, according to the presence of inclines and depressions which could be filled (A. Shepherd *pers. comm*.).

Period I

Childe defined Period I as a series of midden deposits deriving from occupation activity as well as scant structural remains. Waterlogged midden deposits (termed 'black midden') were also noted (Childe 1931, 84). The Period I stratigraphic sequence from Test Pits I-XIII generally comprised natural clay at the base, overlain by the light clean sand (c. 0.30m-0.60m thick) of the original land surface. This sand was overlain by brown midden which in some test pits was then further overlain by a waterlogged 'black midden'. These midden deposits ranged from c. 0.05m-c. 1.20m in depth (Childe 1931, 87-90).

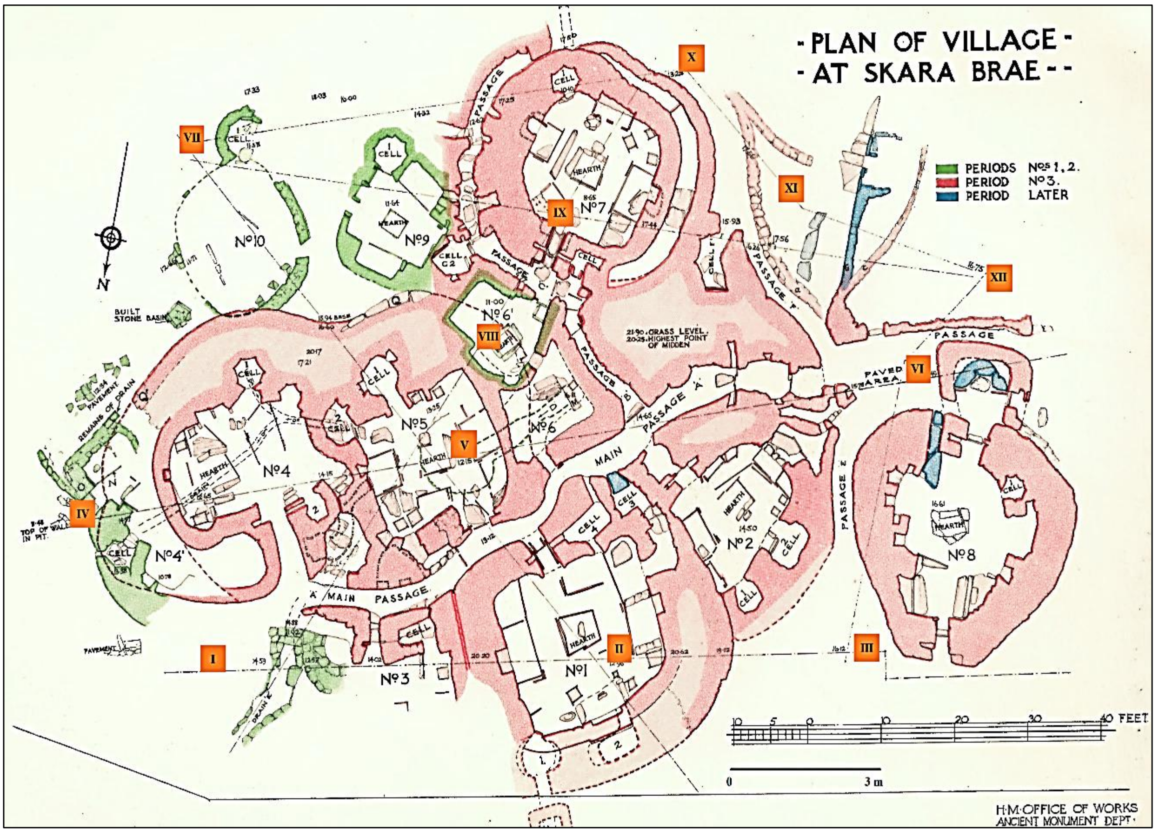

Figure 4.5. Gordon Childe's plan of Skara Brae showing Test Pits I-XII in orange. Test Pit XIII is located c. 27m west of Test Pit III, against the sea wall. After Childe 1931, 209.

Period II

This period marked the construction of four furnished houses in the excavated area: 4, 6, 9, and 10. These houses overlay the midden accumulations of Period I. Fragmentary remains of additional structures were also identified. All structural remains from Childe's Period II (highlighted in green in Figure 4.5) stood at the north and east of the settlement. The remains of the Period II Houses 4 and 6 were incorporated and rebuilt in Phase III. The houses were in a state of general disrepair, lacked roofs, and contained substantial sand deposits interleaved with midden. They demonstrated close architectural agreement with the Period III houses (Childe 1931, 93). Test Pits VI, XI, and XII, excavated to the west of the settlement in the paved 'market place' south of House 8, revealed accumulations of midden interleaved with layers of sand. This midden ranged from depths of c. 2.07m to c. 2.25m and was interpreted by Childe as being associated with Period II settlement activity (Childe 1931, 72). Following the occupation of the Period II houses, Childe identified a period of hiatus, during which sand infilled many of the houses – which appeared to have been dismantled or demolished.

Period III

Childe’s Period III comprised the construction of the bulk of the structures (Houses 1, 2, 3, 5, 7 and 8) which formed the village as it is currently seen, the interlinking passages, the continued occupation of other houses, and the continued accumulation of occupation deposits interleaved with sand layers. Many of the houses were constructed upon blue clay bedding, which overlay the remains of Period II.

Period IV

Period IV saw the continued occupation and restructuring of the houses built in Periods II and III, and the accumulation of occupation deposits and sand around the houses. The end of period IV at the site was marked by Childe as the deposition of 0.90-1.00m of blown sand which extended across the settlement. Four ‘re-occupation levels’ following the ceasing of occupation activity at the site were noted in House 7, overlying c. 0.90m of sand which covered the earlier floor deposits (Figure 4.6).

Figure 4.6. Later sand deposits overlying House 7. Childe 1931, Plate XXXII.

Excavations by David Clarke et al.

The restricted nature of the information provided from Childe's excavations prompted further excavations by David Clarke and Anna Ritchie from 1972-3 (Clarke, D. V. 1976a) and David Clarke and Alexandra Shepherd in 1977 (Shepherd 1996, 97; Shepherd 2016). It is these excavations which have elucidated much of what we now understand about the chronology of the site and its environment. A full monograph detailing the results of these excavations, as well as aspects of Childe's excavations, is forthcoming (Clarke and Shepherd *forthcoming*). Until this time, a limited number of preliminary, small-scale, publications are relied upon (Clarke, D. V. 1976a, 1976b; Shepherd 1996; Shepherd 2000; Shepherd 2016).

Excavation was undertaken within four trenches (1-4) in 1972-3 to recover environmental evidence, radiocarbon dating samples, and to clarify and expand Childe's early interpretations of the site sequence. Trench 1 was positioned towards the centre of the settlement, over the final phase occupation deposits which had accumulated against House 7, with the aim of exploring the relationship between the undisturbed occupation deposits and structural features. Trench 2 was located to the east of the settlement, and included waterlogged occupation deposits (Clarke, D. V. 1976a, 8; Simpson *et al.* 2006) (Figure 4.7). Trenches 3 and 4 were located c. 25m west of the settlement, and contained field boundaries with extensive sand deposits (N. Sharples *pers. comm.*). Clarke simplified Childe's phasing into three phases: 0, 1, and 2 (Figure 4.7, Table 3). Given that the definitive monograph is forthcoming, many of Clarke's interpretations – published in the 1976a interim report – may be subject to change in the near future.

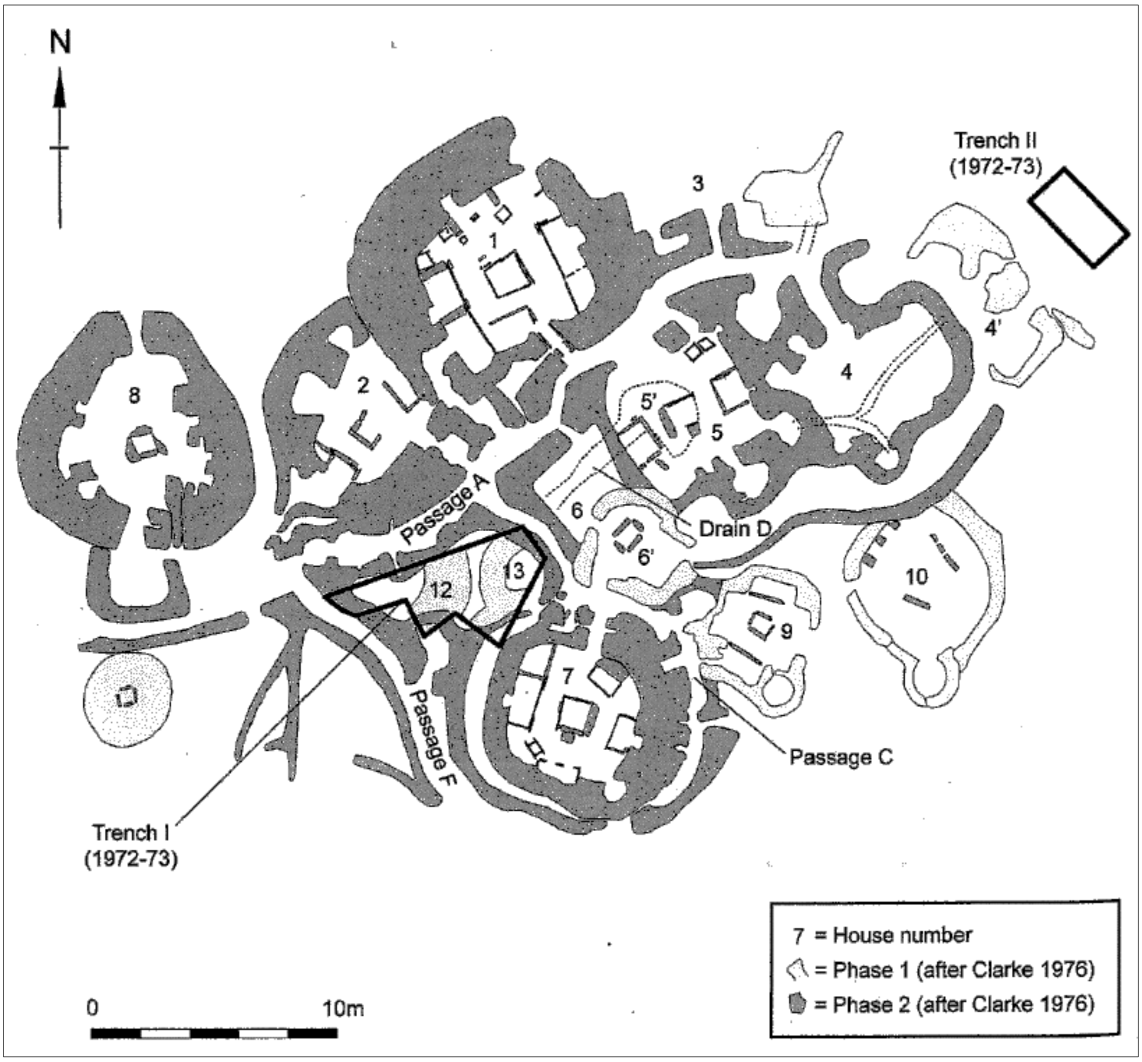

Figure 4.7. Plan of Skara Brae according to phasing devised by Clarke (1976). Thomas 2016, 94 after Shepherd 2000, 140; Figure 12.4.

Trench 1 (1972-3)

Trench 1 was located toward the centre of the surviving settlement, delimited by passages A, B, and F (Figure 4.7) and placed with the intention of leaving the previously-revealed structures undisturbed. The aim of Trench 1 was to excavate the undisturbed midden deposits in this area, in order to ascertain the relationship between these deposits and the existing structures and their associated passages (Clarke, D. V. 1976a). The information was intended to be collated and compared with that gathered by Childe, and the results of this collation are expected in Clarke and Shepherd (*forthcoming*). Over 4.5m of stratigraphy was excavated in Trench 1. The earliest midden in this sequence was deposited above the c. 0.25m-c. 0.60m of sand which had accumulated over the old land surface. As the ashy-clay midden accumulated and increased in depth (reaching a total of c. 0.75m), three early structures (11-13) were built upon it (Clarke, D. V. 1976a, 11; Shepherd 2016, 223). The remains of these structures comprised a portion of an earlier recessed house cut into earlier midden, the remains of a possible later house, and a curved wall which appeared to follow the outer limits of Phase 2's House 7. It may be that this represented an earlier construction phase of House 7 which featured a casement wall (Clarke, D. V. 1976a, 13). The descriptions currently available for these structures is confusing and piecemeal, and at present it is difficult to ascertain which numbered house is which.

Outwith the remains of this wall lay a paved area which was revealed throughout the trench, and overlain by c. 0.30m of sand. Midden had continued to be deposited on top of this sand. Clarke notes that towards the beginning of this stratigraphic sequence of continued midden deposition, only small layers of midden were deposited – intermingling between small layers of sand. Thicker midden deposits with less observable sand layers characterised the upper units of this sequence (Clarke 1976a, 14). This appears to indicate a fairly short early period of midden accumulation and stabilisation of periodical small-scale sand ingresses took place. This midden continued to accumulate to some depth (c. 1.00m) and indeed characterised the rest of the sequences excavated in Trench 1. Only partial evidence for structural remains was recovered from the uppermost sequences of Trench 1. This structure was located at the northeastern end of the trench, partially overlain by passage F (Clarke 1976a, 17).

Trench 2 (1972-3)

Trench 2 was located to the east of the site outwith the revealed structures, northeast of House 4. Like Trench 1, the Trench 2 stratigraphy encompassed Clarke's simplified Phases I and II (Clarke, D. V., 1976a). While the uppermost, latest stratigraphic units consisted of alternating deposits of sand and midden, the lower, earlier deposits comprised the waterlogged midden first identified by Childe in his Test Pit IV, overlying the sand which had accumulated over the original ground surface (Clarke D. V. 1976a, 17). A large quantity of organic remains was recovered from this wet midden, including fragments of wood and wooden objects, and rope fragments (Clarke, D. V. 1976a, 23-5). The excavated stratigraphy was not associated with any notable structural activity.

Trenches 3 and 4 (1977)

Little information is currently available for Trenches 3 and 4, with a full report expected in Clarke, D. V. and Shepherd (*forthcoming*). Lying approximately 25m west of the settlement, two trenches were opened following a storm which revealed archaeological remains. Two phases of field boundary wall construction were revealed, suggested by the excavators to be contemporary with the settlement (N. Sharples *pers. comm.*). Two separate walls running inland (southwest) were recorded, with further walls running at right angles from these main walls. Although no significant midden deposits were recorded, large quantities of windblown sand were observed, with the walls appearing to have been rebuilt higher as the sands accumulated (Clarke, D. V. 1977, 24; N. Sharples *pers. comm.*).

Excavations by David Clarke et al.: Phasing and chronology

Clarke and Ritchie's 1972-3 excavations led to the simplification of Childe's original phasing – reducing them to Phases 0, 1 and 2. These have since been further subdivided – details of which are included in Clarke, D. V. and Shepherd (*forthcoming*) (Thomas 2016, 93). Phase 0 represents the early land surface beneath a layer of calcareous windblown sand, and precedes two core occupation phases (Phases 1 and 2). Phase 1 combined Childe's Periods I and II, and comprised the construction of Houses 4-6, 9-13, and Houses 11-13 which were revealed during Clarke's Trench 1 excavations. This phase also saw the construction and incremental development of Passages B and C (Figure 4.9), and the accumulation of over c. 1m of midden deposits. Phase 2 (combining Childe's Periods III and IV), contains the construction of the remaining structures excavated by Childe (Houses 1-3, and 8) and the continued occupation and remodelling of Houses/Structures 4-6, and 9-13. Passages A, E, F were constructed, and Passages B and C continued to develop, while midden deposits reaching c. 2m deep accumulated around the structures. A schematic diagram of Clarke's phasing for Skara Brae as observed in section within Trench 1 is presented below (Figure 4.8), while Table 3 summarises Childe and Clarke's respective phasings.

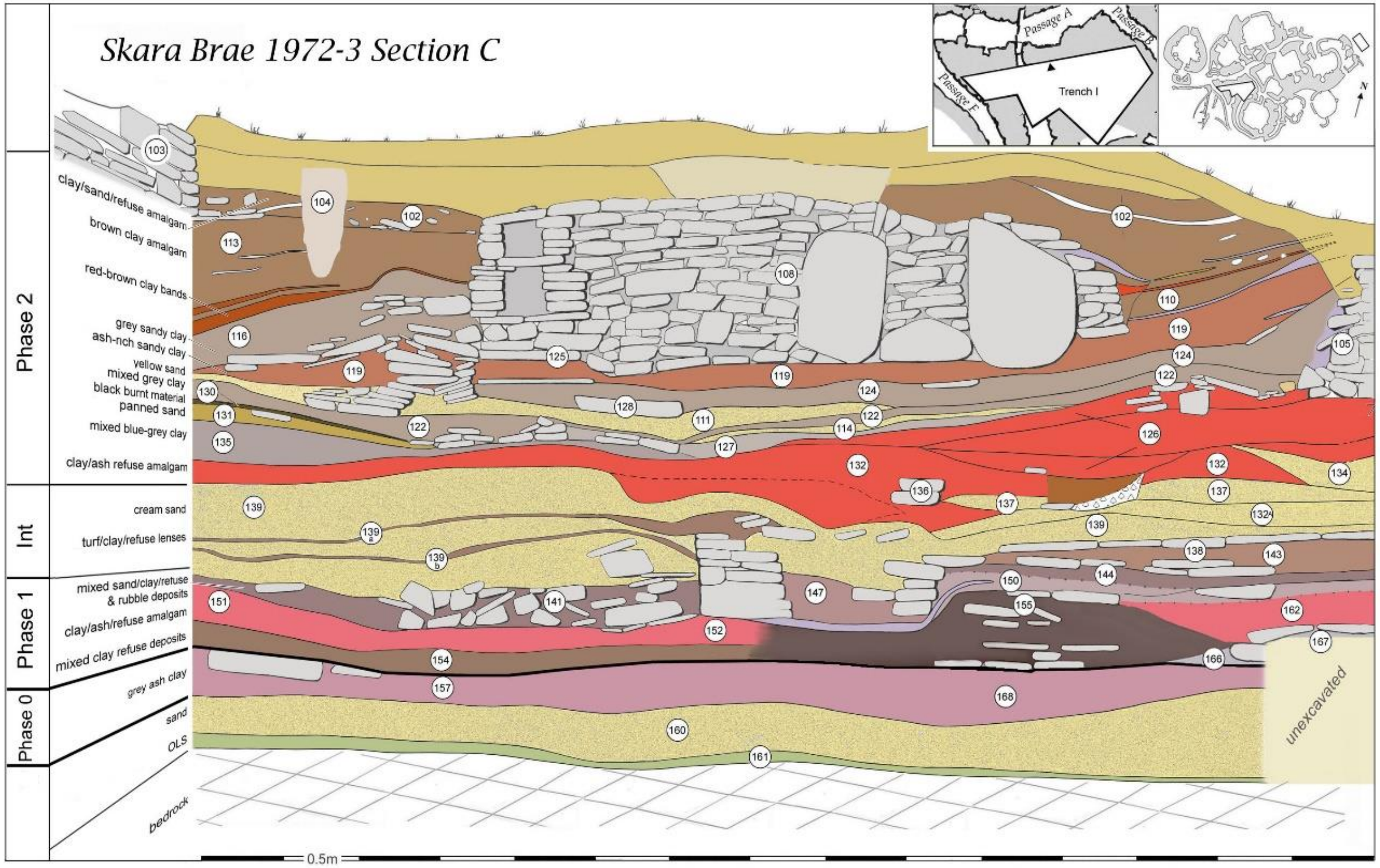

Figure 4.8. 1972 excavation north Section C through Trench 1, displaying contexts and phasing. Shepherd 2016, 223.

Childe 1931		Clarke 1976a	
Phase	**Activity**	**Phase**	**Activity**
Period 0	Original land surface	Phase 0 (c. 3360-3160 cal. BC) (Table 6)	Original land surface and small-scale activity comprising ashy clay deposits, prior to settlement proper
Period I	Midden, sand, fragmentary occupation remains	Phase 1 *Combines Childe's Periods I and II.* c. 2920-2885 cal. BC to c. 2870–2815 cal. BC (Table 7)	Construction of Houses 4-6, 9-13 (with 11-13 discovered during Clarke's 1972-3 excavations). Construction and development of Passages B and C
Period II	Construction of Houses 4, 6, 9, 10, all of which were then dismantled and filled with windblown sand		
		Hiatus	Partial demolition/disrepair of Phase 1 houses. Accumulation of sand deposits and turf horizons
Period III	Bulk of settlement constructed, including Houses 1, 2, 3, 5, 7 and 8, and continued occupation of above	Phase 2 *Combines Childe's Periods III and IV.* From c. 2840-2685 cal. BC to c. 2545-2440 cal. BC (Table 7).	Construction of remaining Houses 1-3, 7, and 8. Continued occupation and remodelling of Houses/Structures 4-6, and 9-13. Passages A, E, F constructed; continued development of Passages B and C
Period IV	Continued occupation and restructuring of the houses built in Periods II and III, and 'Reoccupation period'		

Table 3. Simplified summary of the differences in Childe's occupation 'Periods' and Clarke's reappraised 'Phases'. After Childe 1931, 61-95 and Clarke, D. V. 1976a.

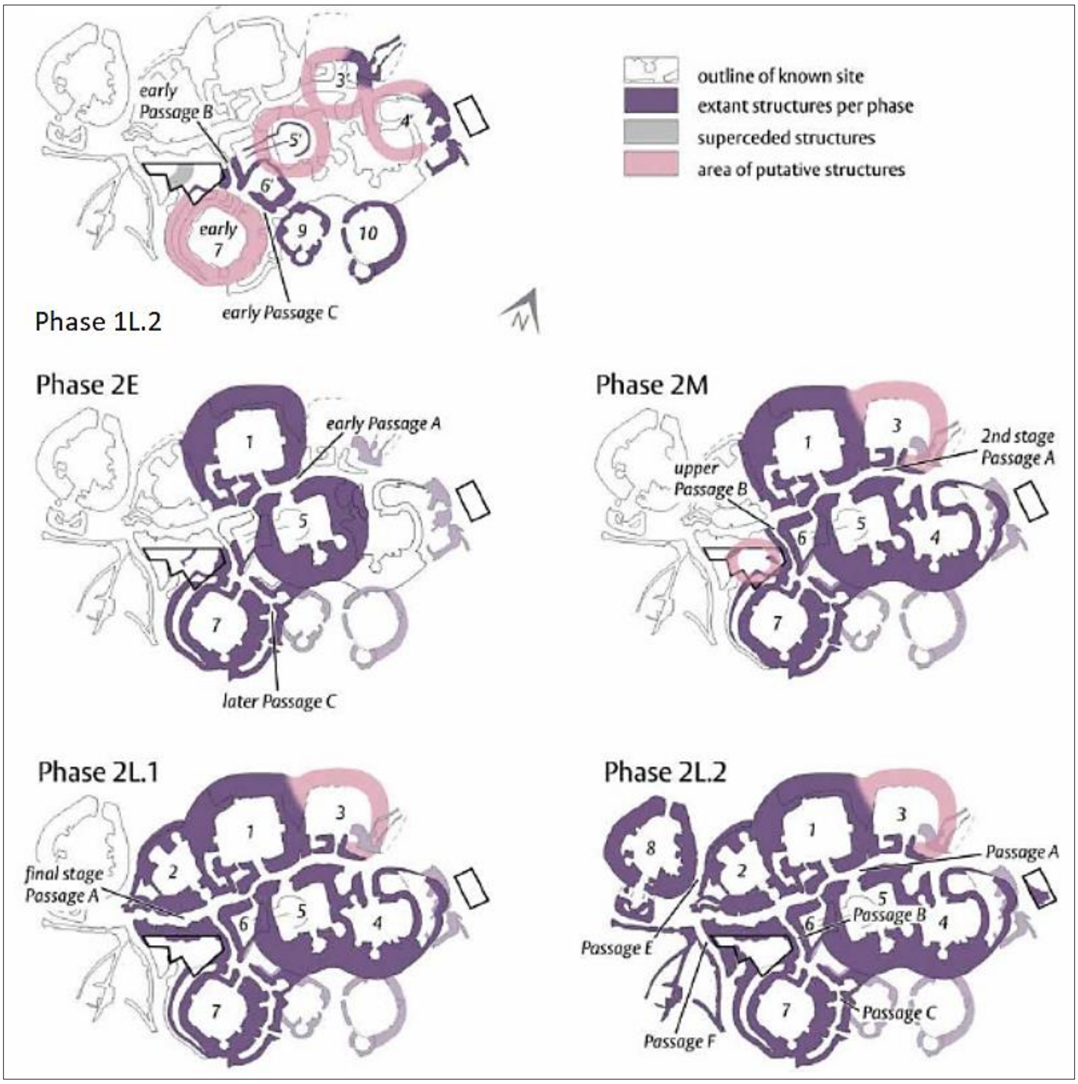

Figure 4.9. Phased plan of Skara Brae showing development of the houses and passages. After Shepherd 2016, 218.

Chronology and phasing

At present, 149 radiocarbon dates have been published for samples from Skara Brae, in various guises (Table 4). The dated material includes charred grain, animal bone, and mollusc shell.

Year dated	**Number of determinations**	**Material**	**Reference**
1972-3	24	Mixed animal bone	Renfrew and Buteux 1985
1993	8	Cattle bones, limpets	Reimer *et al.* 2002
1994	1	Horse tooth	Ashmore, P. J.; pre-2005 Radiocarbon Database; Thomas 2016
2003-2005	20	Cereal grains, cattle bone, marine molluscs	Ascough *et al.* 2007
2006	74	Single cattle bones	Sheridan *et al.* 2012
2012	1	Horse tooth bead	Thomas 2016 Sheridan *et al.* 2012
2013	7	Common vole bones	Martínková *et al.* 2013
2013	4	Human bone	Thomas 2016
2015	10	Unknown	Thomas 2016; Clarke and Shepherd *forthcoming*

Table 4. Skara Brae radiocarbon date numbers and references.

Bayesian chronologies

An initial 14 radiocarbon determinations on bulk animal bone recovered in 1973-4 (calibrated using the CALIB curve (Pearson *et al.* 1986)) (Figure 4.10) were employed in what was a pioneering study into the efficacy of Bayesian modelling of radiocarbon dates by Buck *et al.* (1991) (Table 5). It attempted to estimate settlement duration at a site where a complex stratigraphy could not be employed alone to interpret time lapse. The model did not take ages from Phase 0 into account, but placed the advent of village settlement at Skara Brae to somewhere within an age range of c. 3300-2900 cal. BC, with the multiple possibilities presented in Table 5 reflecting ‘wiggles’ in the calibration curve.

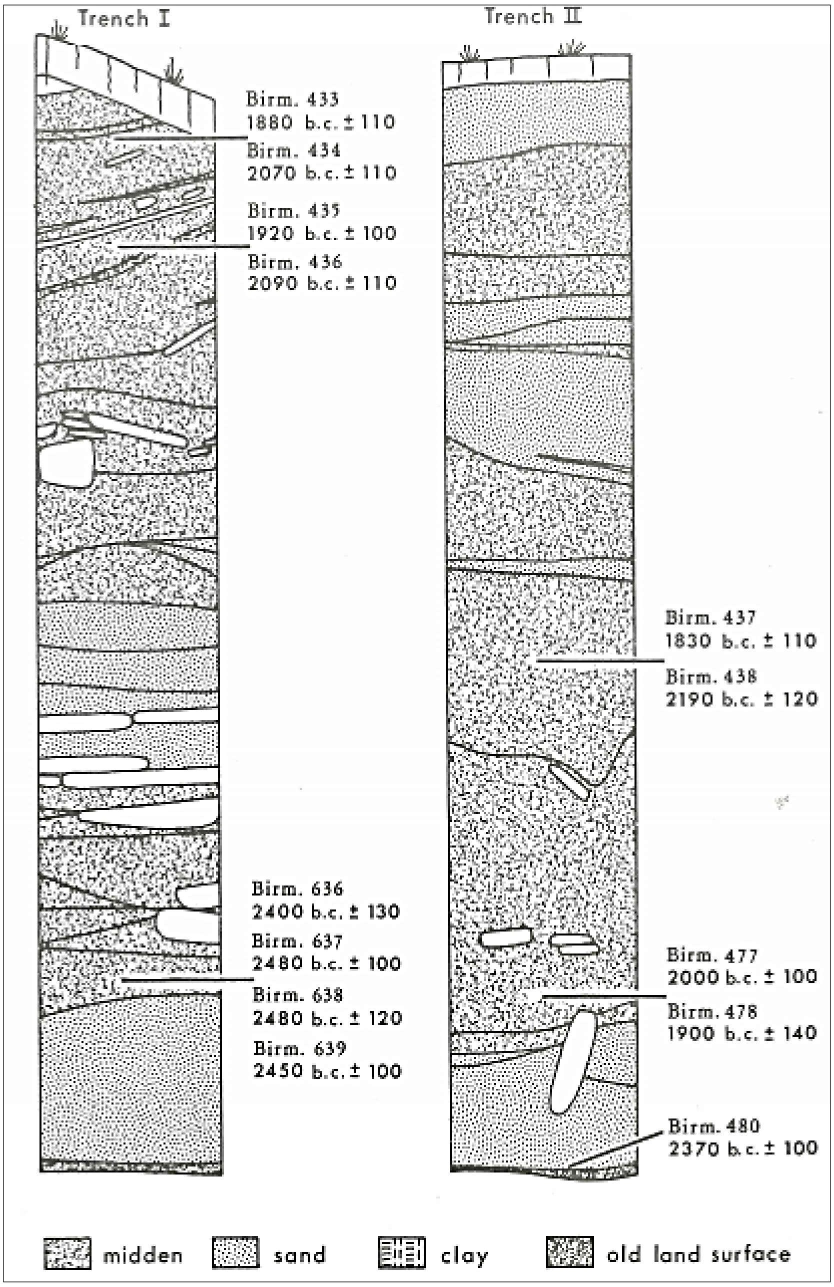

Figure 4.10. Sections from Clarke and Ritchie's Trenches 1 and 2 with radiocarbon determinations (Clarke, D. V. 1976b, 239).

<table>
<tr><th>Event</th><th>Radiocarbon determinations</th><th>Duration</th><th>Posterior probability estimate cal. BC (95% probability)</th></tr>
<tr><td>Beginning of Village (Phase) 1: Event 1</td><td>Birm-637.
3550-2650
Birm-638.
3700-2600
Birm-639
3500-2600
Birm-636.
3600 to 2400</td><td rowspan="2">Up to 390 years</td><td>3320-3220
or
3180-3160
or
3140-2920</td></tr>
<tr><td>End of Village (Phase) 1: Event 2</td><td>Birm-790. 3700-2400
Birm-789. 3500-2400
Birm-791. 3100-2600</td><td>3090-2870
or
2800-2780</td></tr>
<tr><td colspan="2">Hiatus</td><td>Up to 340 years</td><td></td></tr>
<tr><td>Beginning of village (Phase) 2: Event 3</td><td>Birm-788. 3500-2400
Birm-786.
3500-2400
Birm-787.
3400-2200</td><td rowspan="2">80-530 years</td><td>2930-2850
or
2830-2650
or
2640-2610</td></tr>
<tr><td>End of village (Phase) 2: Event 4</td><td>Birm-436.
3050-2050
Birm-434.
2950-2000
Birm-435.
2900-1900
Birm-433.
2900-1700</td><td>2610-2330</td></tr>
</table>

Table 5. Posterior probability estimates in the Bayesian study by Buck et al. Original estimates were presented in cal. years BP; these have been converted. After Buck et al. 1991, 817-8.

An additional 74 radiocarbon determinations on single cattle bones recovered from the 1972-3 trench and 1977 Trenches 3 and 4 were commissioned in 2006. These spanned the stratigraphic sequences excavated in the trenches (Sheridan *et al*. 2012, 204-5). All were calibrated using OxCal 4.1.7, and the IntCal09 dataset (Reimer *et al*. 2009), and were rounded to the nearest decade. The ranges calculated from these dates are shown in Table 6. These determinations will be discussed in more detail, as they provide an important chronological context for the windblown sand deposits excavated in Clarke's Trenches 1 and 2.

Phase	Date cal. BC (at 95% probability)
0	c. 3360-3160
1	c. 2910-2880 to 2860-2840
2	c. 2800-2700 to 2550-2420

Table 6. Skara Brae phases and associated radiocarbon dates after Sheridan et al. 2012, 204-5 and Shepherd 2016, 223.

Following the greater number of radiocarbon determinations available for Skara Brae, a new Bayesian model (Table 7) for occupation at the site based on the 149 available radiocarbon determinations (with 63 dates excluded) was created (Bayliss *et al.* 2017, 1176; Table 1). Phase 0 was also not factored into this model; rather, it presents only the main occupation phases. These dates currently form the most recent chronological dataset for the site, developed in collaboration with the more recent excavators. They form part of a larger chronological model due to be presented in Clarke and Shepherd's forthcoming monograph.

Parameter name	**Parameter description**	**Posterior Density Estimate cal. BC (95% probability unless otherwise stated)**	**Posterior Density Estimate cal. BC (68% probability unless otherwise stated)**
central_phase_1_start	Boundary parameter estimating the start of the activity associated with the first phase of settlement in the central area	2920-2885	2910-2890
central_phase_1_end	Boundary parameter estimating the end of the activity associated with the first phase of settlement	2870–2815 (92%) or 2795–2760 (3%)	2860-2835
central_phase_2_start	Boundary parameter estimating the start of the activity associated with the second phase of settlement	2840-2685	2785-2705
central_phase_2_end	Boundary parameter estimating the end of the activity associated with the second phase of settlement	2545-2440	2530-2455

Table 7. Chronological model for Skara Brae showing key parameters for cultural activity at the settlement. After Bayliss et al. 2017 [Supplementary Material]. Table S4 (83-96).

The Bayesian model suggests that Phase 1 occupation at Skara Brae began at c. 2920-2885 cal. BC (*central_phase_1_start*) (Bayliss *et al.* 2017 [Supplementary Material, 89]), with the construction of the earliest known buildings at the site. These buildings were occupied for less than 80 years, and following their occupation, a hiatus of 1-160 years of windblown sand accumulation and turf horizon development is postulated (Thomas 2016, 94). Phase 2 began at c. 2840-2685 cal. BC (*central_phase_2_start*) (Bayliss *et al.* 2017 [Supplementary Material, 89]) and lasted for c. 150-410 years until c. 2545-2440 cal. BC (*central_phase_2_end*) (Thomas 2016, 94; Bayliss *et al.* 2017 [Supplementaty Material, 89).

This model enhances and displays strong agreement with the age ranges published by Sheridan *et al.* (2012), as well as broad agreement with the Bayesian model initially developed by Buck *et al*., which is improved by a much larger suite of radiocarbon dates. The date ranges provided by Bayliss *et al.* (2017) have been added to the summary in Table 8.

<table>
<tr><th colspan="2">Childe 1931</th><th colspan="3">Clarke 1976a</th></tr>
<tr><th>Phase</th><th>Activity</th><th>Phase</th><th>Activity</th><th>Date range cal. BC (at 95% probability unless otherwise stated)</th></tr>
<tr><td>Period 0</td><td>Original land surface</td><td>Phase 0 (c. 3360-3160 cal. BC)</td><td>Original land surface and small-scale activity comprising ashy clay deposits, prior to settlement proper</td><td>c. 3360-3160</td></tr>
<tr><td>Period I</td><td>Midden, sand, fragmentary occupation remains</td><td rowspan="2">Phase 1
Combines Childe's Periods I and II.

c. 2920-2885 cal. BC to c. 2870–2815 cal. BC</td><td rowspan="2">Construction of Houses 4-6, 9-13 (with 11-13 discovered during Clarke's 1972-3 excavations). Construction and development of Passages B and C</td><td rowspan="2">From c. 2920-2885 to 2870–2815 (92% probability)</td></tr>
<tr><td>Period II</td><td>Construction of Houses 4, 6, 9, 10, all of which were then dismantled and filled with windblown sand</td></tr>
<tr><td colspan="2"></td><td>Hiatus</td><td>Partial demolition/disrepair of Phase 1 houses. Accumulation of sand deposits and turf horizons</td><td></td></tr>
<tr><td>Period III</td><td>Bulk of settlement constructed, including Houses 1, 2, 3, 5, 7 and 8, and continued occupation of above</td><td rowspan="2">Phase 2
Combines Childe's Periods III and IV.

From c. 2840-2685 cal. BC to c. 2545-2440 cal. BC</td><td rowspan="2">Construction of remaining Houses 1, 2, 3, and 8. Continued occupation and remodelling of Houses/Structures 4-6, and 9-13.

Passages A, E, F constructed; continued development of Passages B and C</td><td rowspan="2">From 2840-2685 to 2530-2455</td></tr>
<tr><td>Period IV</td><td>Continued occupation and restructuring of the houses built in Periods II and III, and 'Reoccupation period'</td></tr>
</table>

Table 8. Clarke and Childe phasing summary with Bayesian model by Bayliss et al. (2017).

Windblown sand at Skara Brae

As described in the introduction to the Bay of Skaill, episodes of windblown sand mobilisation and deposition were identified by de la Vega Leinert *et al.* (2000) before the earliest-known settlement at Skara Brae took place. Significant sand mobilisation took place prior to c. 5235-4855 cal. BC (Beta-90823), within a broader phase of machair development between c. 5235–3540 cal. BC (Beta-90822) (de la Vega Leinert *et al.* 2000, 525). This is an occurrence supported by the excavated evidence at the site, with its earliest phases developing over extensive sand deposits. A decision was therefore made to settle and occupy in a machair landscape which was already a dynamic environment, punctuated by regular sand mobilisation as well as periods of stabilisation. In any case, the benefits of occupying this location – such as low-lying pasture and proximity to marine resources – may have outweighed the negative implications of an increasingly dynamic sand dune environment.

The sand dunes and machair plain surrounding the settlement at Skara Brae were also in a frequent state of mobilisation during the occupation of the site. This is attested to by the presence of sand layers and lenses within the extensive occupation deposits which accumulated around the houses. Indeed, influx of windblown sand appears to have been a continuous occurrence at the site throughout many periods of its occupation, given that to a greater or lesser degree, most excavated sediments contained sand as a component (A. Shepherd *pers. comm*.). Many of the sand deposits are identifiable only as such components, or as thin lenses. Despite this, it is possible to identify specific deposits in certain areas of the site represented by thicker layers of sand. These are likely to represent lengthier periods of sand influx in more intense concentrations within the broader context of continuous sand movement. In these areas - which were mainly on the fringes of the inhabited settlement and within abandoned or disused structures - the sand accumulated against deposits and structures (A. Shepherd *pers. comm*.).

Two sources of information are key to the understanding of the nature of windblown sand at Skara Brae; Gordon Childe's narratives offer an insight into the deposits encountered in the hiatus and second phase of settlement, while the excavated sequences in Clarke *et al*.'s Trenches 1 and 2 – and their corresponding radiocarbon dates – allow for these deposits and those which followed to be contextualised chronologically. At present, only radiocarbon dates from Clarke's Trenches 1 and 2 have been published (Sheridan *et al*. 2012; Bayliss *et al.* 2017), with a more extensive chronological model encompassing more chronological data expected in the forthcoming monograph. These trenches did not re-excavate the remains described by Childe, and as such chronological information must be extrapolated from the radiocarbon data recovered during Clarke's excavations of Trenches 1 and 2.

The evidence for windblown sand deposits in the phases defined by Clarke *et al.* (0-2) are discussed below. Childe's phasing will be integrated with that of Clarke's to avoid confusion. The stratigraphy recorded during Childe excavations are discussed first, followed by summaries of evidence recorded by Clarke *et al*. (and any radiocarbon determinations).

Phase 1 windblown sand (c. 2920-2885 cal. BC to c. 2870-2815 cal. BC (central_phase_1_start; central_phase_1_end).

The low-lying machair plains characterising Skara Brae's early landscape context had already formed before sustained occupation at Skara Brae began, with pollen and charcoal records placing transitions from open woodland to pasture and herbaceous vegetation from c. 3900-3600 cal. BC (SRR-978) (Keatinge and Dickson 1979, 610). The Bay of Skaill and its beach formed by a combination of marine incursion and inland sand mobilisation around c. 3325-2900 cal. BC (Beta-104797), during the occupation of Skara Brae. Their development, and the change in vegetation cover to species which thrived in sandy soils, attest to a possible increase in wind speed from the southwest, driving sand mobilisation (Keatinge and Dickson 1979, 599).

Clarke's Phase 1 (=Childe's Periods I and II) comprised the construction and initial occupation of Houses 4-6, and 9-13, the accumulation of associated occupation deposits, and the construction and development of Passages B and C between the structures (Shepherd 2016, 217) (Figure 4.9). The revealed remains of the Phase 1 settlement are largely located to the east of the excavated area (Figure 4.7). Based on the stratigraphic information currently available it may be suggested that comparatively less sand ingress occurred during the Phase 1 occupation in particular areas of the site. Micromorphological evidence and drawn sections from Clarke's Trenches 1 and 2 (Figure 4.11; Figure 4.12) suggest that larger, identifiable sand ingresses in the central and western areas did not take place until later in the occupation sequence; during the hiatus period, and throughout Phase 2.

During his excavations, Childe devoted much of his time to the deposits he considered as belonging to later phases of settlement, only exploring earlier phases through a series of test pits. Test Pits VI, X, XI, and XII (located in and around the paved 'market place' south of House 8) revealed early accumulations of midden interleaved with layers of sand at the western fringes of the settlement, all overlying the original land surface. This midden ranged from depths of c. 2.07m to c. 2.25m and although it was interpreted by Childe as being associated with Period II settlement activity (Childe 1931, 72), this period is now incorporated into Clarke's Phase 1. Little mention is made of the character of early sand and midden deposits beyond that summarised above.

Samples from the deposits excavated in Clarke *et al*.'s 1977 trenches (1 and 2) have produced a suite of radiocarbon dates (see above; Sheridan *et al*. 2012) which provide an important insight into the chronology of the early windblown sand deposits. Trench 1 comprised a series of midden and windblown sand accumulations, and early structural remains. The earliest deposit encountered in Trench 1 comprised a pale-yellow calcareous windblown sand measuring c. 0.25-0.50m, identified as the early land surface discussed elsewhere. This was overlain by a grey ash clay material, labelled Phase '0' by Clarke and Shepherd, and represents early, pre-settlement activity. A cattle phalanx from this grey deposit yielded a determination of 3350-3020 cal. BC (SUERC-12717 (GU14731)), providing a *terminus ante quem* for the accumulation of the sand below. The development of the grey clay is coincident with increased sand mobilisation in the Bay of Skaill from c. 3325-2900 cal. BC (Beta-104795) (de la Vega Leinert *et al.* 2000), contemporary with occupation at the site. The exact level of stability of the early land surface upon which early settlement at Skara Brae was founded is unclear, but as no mention is made of the presence of turf lines (indicative of colonising vegetation on the sand surface) it may be that the sand was in a state of destabilisation. If this is the case, the early grey anthropogenic deposits may have served to stabilise the sands below, forming an important foundation for what was to become an extensive settlement.

A similar basal deposit of 0.30-0.50m of windblown sand – lying between glacial till and the earliest midden accumulations – was observed in Trench 2 (Clarke 1976a, 17). Although the matrix was predominantly comprised of windblown sand, this deposit also contained incorporated ash residues and other anthropogenic deposits (Simpson *et al.* 2006). Three comparatively late determinations were yielded on samples from this deposit; an ulna produced a determination of 2880–2620 cal. BC (SUERC-12742 (GU14747)), while determinations on a metacarpal (SUERC-12743 (GU14748)) and humerus (SUERC-12744 (GU14749)) yielded determinations of 2910–2670 cal. BC (Sheridan *et al*. 2012, 204-5). In the Bayliss *et al.* model, these determinations fall within late Phase 1, hiatus or early Phase 2 - indicating that later anthropogenic material was incorporated into the sand, and cannot be readily employed as a direct chronological indicator for the deposition of the early sand layer.

As Phase 1 settlement developed, extensive midden deposits accumulated. The c. 3 early structures were built into these deposits (Clarke, D. V. 1976a, 11; Shepherd 2016, 223). A cattle metatarsal from the midden infill of the earlier House 12 yielded a determination of 2870–2500 cal. BC (SUERC-12696 (GU14712)). A phalanx and a humerus from the infill of House 13 yielded determinations of 2900–2670 cal. BC (SUERC-12701 (GU14717)) and 2880–2620 cal. BC (SUERC-12497 (GU14718)) respectively, all providing a *terminus ante quem* for their use and cessation (around c. 2900-2600 cal. BC). An area of paving analogous to Childe's 'market place' at the west of the settlement was also constructed during Phase 1, and recorded in Trench 1. It post-dated the construction and use of the Phase 1 structures recorded in the trench, and was associated with a small amount of walling. The remains of this paving are just visible to the right-hand side of the southeast-facing section (Figure 4.11).

Micromorphological sampling of the Phase 1 occupation deposits recovered from Trench 1 (contexts (168) – the early occupation layer of grey clay and ash, and (152) – the Phase 1 midden accumulations) (Figure 4.11) curiously revealed no evidence for calcareous windblown sand components. Rather, the samples contained peat and turf fuel residue and midden (Simpson *et al*. 2006, 226-8). Both of these deposits yielded radiocarbon determinations. As previously stated, the grey clay (168) yielded a determination of 3350-

3020 cal. BC (SUERC-12717 (GU14731)), while a radius and phalanx from (152) yielded determinations of 2920-2700 cal. BC (SUERC-12705 (GU14722)) and 2880–2620 cal. BC (SUERC-12706 (GU14723)) respectively (Sheridan *et al.* 2012, 205). If the micromorphology is truly representative of the situation, these determinations provide a chronological context for this period of reduced sand mobilisation into the settlement itself. The lack of evidence for large accumulations of windblown sand in the deposits contemporary with the Phase 1 structures may indicate that during the life of the Phase 1 settlement there was comparatively less sand accumulation than that observed during the 'hiatus' and Phase 2.

This situation is complicated when the early deposits encountered by Childe (above) are considered. His description of interleaved sand and midden deposits at the west of the site in Test Pits VI, X, XI and XII (if they do indeed belong to Phase 1) suggest that the micromorphology at one area of the site does not reflect the situation within the wider site. This is further emphasised by the Phase 1 micromorphological sediments analysed in Trench 2 at the northeast of the site, which yielded dates ranging from 2920-2690 cal. BC (SUERC-12733 (GU14741), on cattle radius) to 2900-2670 cal. BC (SUERC-12736 (GU14744); SUERC-12737 (GU14745) on a tibia and metacarpal (Sheridan et al. 2012, 205). This deposit contained high levels of calcareous windblown sand (Simpson *et al.* 2006, 230). It may be that any significant sand ingress into frequently-utilised, open-air activity areas in the vicinity of Trench 1 was regularly cleared by the Phase 1 inhabitants and thus may not be archaeologically visible. Alternatively, sufficient shelter was created at the centre and west of the settlement to ensure that little windblown sand was able to blow in and settle.

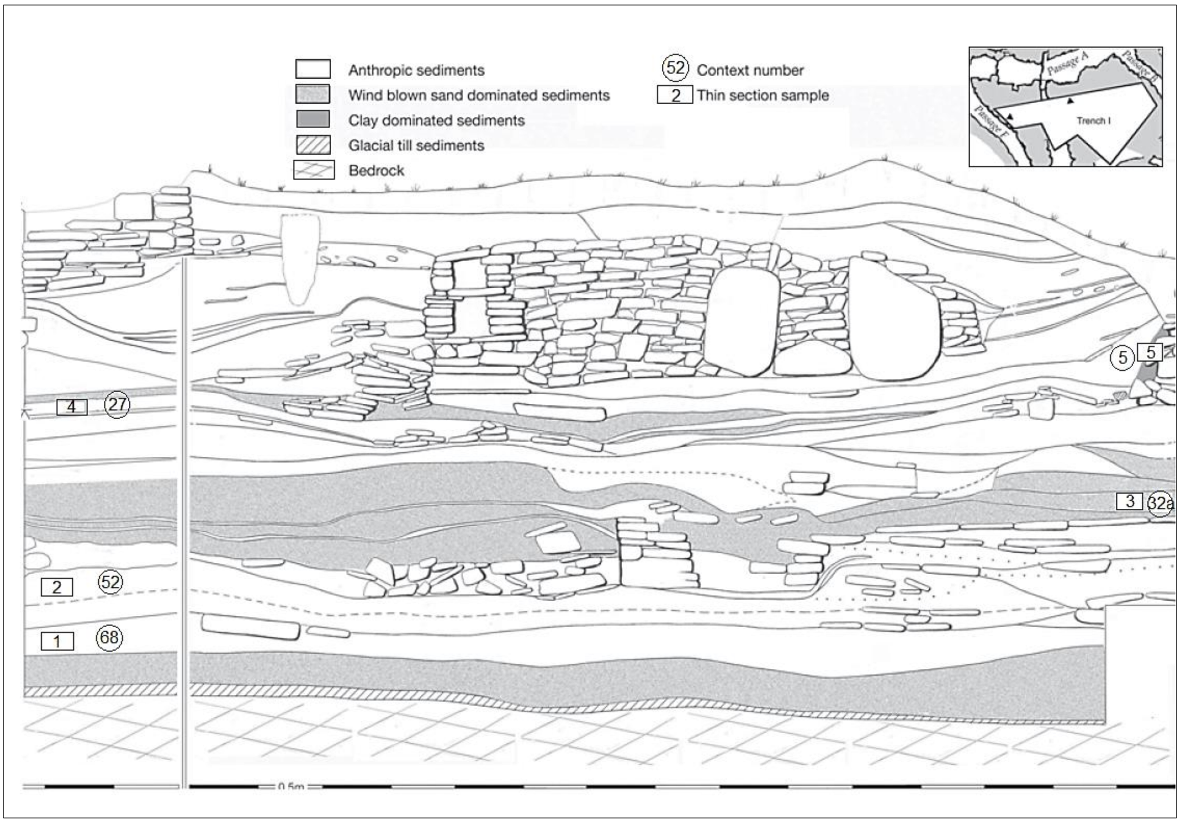

Figure 4.11. SE-facing section through Trench 1, with contexts and micromorphological samples studied by Simpson *et al*. highlighted. After Simpson *et al*. 2006, 225.

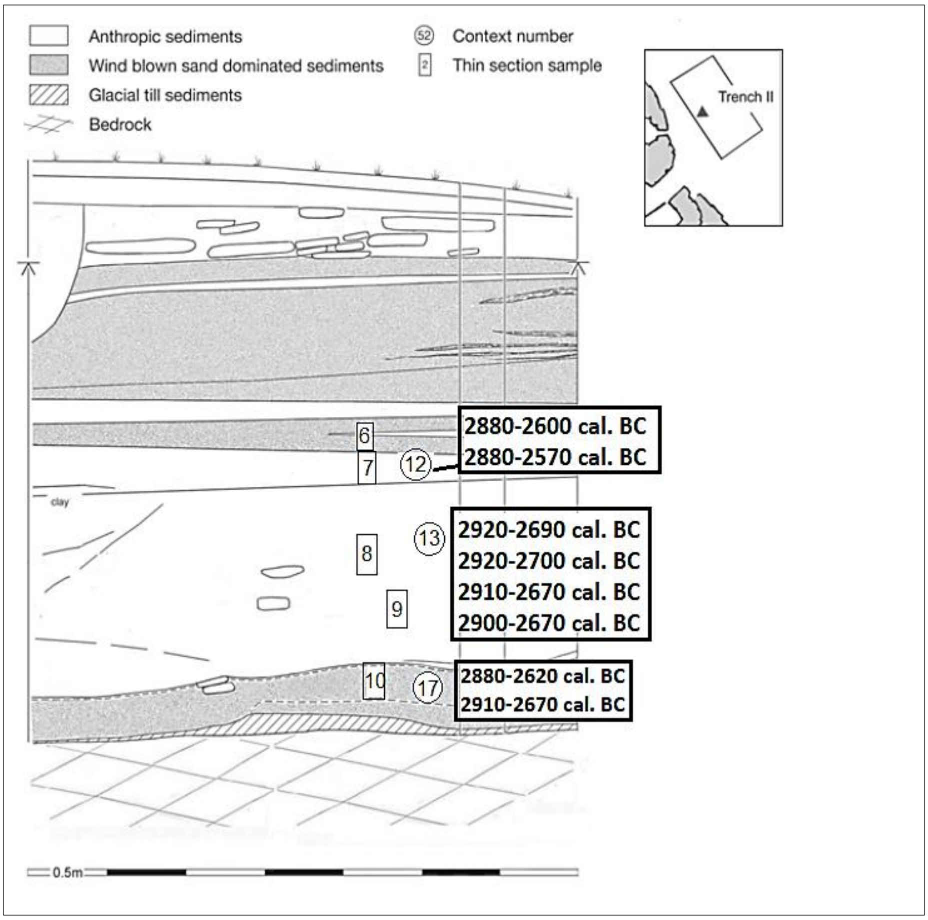

Figure 4.12. Northeast-facing section through Trench 2, with radiocarbon determinations, contexts, and micromorphological samples studied by Simpson *et al.* 2006. After Simpson *et al.* 2006, 226. Radiocarbon lab codes are listed in the text.

The hiatus. From 2870–2815 cal. BC to c. 2840-2685 cal. BC

It is at the end of Phase 1 where larger preserved sand accumulations can be observed. Termed the 'hiatus' by Clarke and Shepherd, this phase comprised the ingress of windblown sand across the settlement site following an apparent cessation of use. The sand forms a clear horizon between Clarke's Phases 1 and 2 in Trench 1, and measured between 0.40m-0.80m in depth. During their occupation, the Phase 1 houses at Skara Brae were freestanding and windowless, with roofs which were probably thatched (Shepherd 2016, 218-20). After cessation of activity in Phase 1, the settlement seems to have fallen into a state of some disrepair, allowing sand to accumulate inside houses and activity areas.

During Childe's excavations, interleaved sand and midden deposits were found to be blanketing the interiors of the early Houses 4, 6, 9, and 10 to the east of the settlement. The interior and paved floor in front of the northeast-facing doorway of early House 4 were filled with c. 0.50-0.60m of sand, overlain by 0.60m of red ashy midden which contained a further layer of sand within it (Childe 1931, 70-1). The dimensions of this sand are unknown. It was upon this deposit that the walls of the Phase 2, remodelled House 4 were built. Similarly, the remains of House 6 at the southeast of the settlement are described as being filled "to the brim" with sand measuring some 0.60m (Childe 1931, 71; 74). "Thin layers" (with no specific dimensions given) are also described as infilling Houses 9 and 10. In House 10, more sand was banked against the outer face of its west and southeast walls, as well as against the outer walls of a cell to the south of the house (Childe 1931, 76-77).

Sand also banked against the exteriors of the houses, notably against the west wall of House 10 and against the walls of House 4 (Childe 1931, 73) perhaps suggesting that the sand was mobilised by a westerly wind. A "deep sand drift" of c. 0.60m depth was also noted to be banked up against an earlier wall exposed in Childe's Test Pit III, which lay to the northeast of House 8 (Childe 1931, 72). Neither Childe nor Clarke were able to explore the remains of the walling exposed in Test Pit III in any detail so its exact relationship to the Phase 1 structures is unclear, but this again would appear to attest to sand being blown in from the west during the hiatus in occupation at the site.

Radiocarbon determinations from Clarke *et al*.'s excavations allow an insight into the length of this hiatus. In Trench 1, the Phase 1 structural remains and paving were overlain by fine-medium grained calcareous windblown sand which accumulated to a depth of c. 0.30-1.00m, interspersed with small quantities of midden comprising turf, clay, and refuse (Clarke 1976a, 14; Buck *et al.* 1991, 813). This deposit therefore represents a series of accumulations deposited periodically as opposed to during a single event. A talus and metacarpal from the uppermost sandy deposit (139) from the 'hiatus horizon' (Figure 4.8) yielded determinations of 2860–2480 cal. BC (SUERC-12490 (GU14711)) and 2870–2500 cal. BC (SUERC-12696 (GU14712)) respectively. Extensive midden accumulation then resumed, marking Phase 2 occupation.

Bayliss *et al.* (2017)'s model places the end of Clarke's Phase 1 to 2870-2815 cal. BC at 92% probability (*central_phase_1_end*), and the beginning of Phase 2 to 2840-2685 cal. BC (*central_phase_2_start*) (Bayliss *et al.* 2017 [Supplementary Material]. Table S4 (83-96)). If the larger sand accumulations were indeed deposited after the partial demolition of the Phase 1 houses, during a proposed 'hiatus', then this provides a possible chronological bracket for its deposition, to the two centuries between c. 2870-2685 cal. BC.

Phase 2 windblown sand (2840-2685 cal. BC to 2545-2440 cal. BC).

Multiple important sequences of sand and occupation debris were noted by the excavators in the Phase 2 occupation deposits (Childe's Periods III and IV). Phase 2 comprised the construction of the remaining buildings at the settlement (Houses 1-3, and

8) and Passages A, E, and F, as well as the continued use or remodelling of Houses 4-6, and 9-13, and Passages B and C. There is less palaeoenvironmental information available for the Late Neolithic period in the Bay of Skaill to provide a broader context for windblown sand deposition in Phase 2 of occupation, with the major and most sustained study relating to this area only presenting radiocarbon data for sand mobilisation up to c. 2900 cal. BC (Beta-104795) (de la Vega Leinert *et al*. 2000). Nevertheless, stratigraphic evidence from Childe's and Clarke's excavations appears to indicate that increased and sustained periods of windblown sand accumulation took place at Skara Brae during the Phase 2 occupation. The micromorphological evidence from the Phase 2 samples obtained from Trenches 1 and 2 appears to provide strong agreement, with windblown sand represented as both a large and well-sorted component throughout anthropic deposits (as seen in Samples 3 and 4 (Figure 4.11)), and as standalone lenses and layers (Simpson *et al.* 2006, 229).

Childe's observations of sand-rich midden deposits surrounding Clarke's Phase 2 structures support the interpretation of increased sand influx into the settlement. Interleaved sand and midden deposits (with each thin layer of sand measuring c. 0.02m thick) were noted outside the west and front wall of the remodelled House 9 at the centre-south of the settlement, between wall Q and passage C. The midden deposit continued to slope southwards, where it become thinner and sandier while in turn, the sand layers became thicker (measuring up to c. 0.15m). This midden was overlain by a further 0.30m of sand, as was the area south of Childe 'market place' (Childe 1931, 68). This sequence would appear to be characteristic of periodic midden dumping at the peripheries of the settlement, where thicker sands were able to accumulate. It is worth considering whether the level, compact midden within the settlement was being curated more closely, whether for construction or as a stabilising agent, than the sloping midden immediately outwith the excavated limits of the settlement.

The area bounded by passages A, B, and C held a thick (c. 1.5-2.00m) midden deposit interspersed with multiple layers of sand, the dimensions for which are again not stated). Six layers of midden separated by five layers of sand (each measuring c. 0.02m) were also identified by Childe between wall Q and passage C, across the west of House 9 (Childe 1931, 67-8). The sand layers also grew thicker as they extended away from the houses. In contrast to the compact and level occupation deposits located between passages A and C, the deposits south and east of House 4 were less confined, tipping and sloping into a seemingly open area (Childe 1931, 69). These deposits banked against the structure and sloped downwards towards the south and east, and were interspersed with sand layers which grew thicker and deeper away from the houses. This suggests that in this area of the settlement, sand was also blowing in from the south east.

Again, Clarke's Trench 1 provides important chronostratigraphic information for sand mobilisation at the settlement. The earliest occupation deposit to accumulate after the hiatus was c. 0.12-0.60m of a clay/ash refuse deposit (marked in red on Figure 4.8, contexts 126 and 132). Six determinations were yielded on bone from this deposit, ranging from 2890-2630 cal. BC (SUERC-12687 (GU14701) to 2680-2480 cal. BC (SUERC-12488 (GU14706)) (Sheridan *et al.* 2012, 204-5). They provide a *terminus ante quem* for the underlying sands which accumulated during the hiatus. The material overlying this deposit comprised a series of sandy clay occupation layers interleaved with thin layers of windblown sand.

The thickest sand observed in these accumulations was calcareous sand (111) observed at the southwest of the Trench 1 section, measuring c. 0.10-0.25m in depth, and deposited prior to the construction of Passage A (Figure 4.8). Although no material from this deposit has been directly dated, four radiocarbon determinations from above and below the sand allow for its deposition to be constrained. A metacarpal and metatarsal from a thin band of grey clay (context (122), marked in grey on the section), which *underlay* the sand yielded determinations of 2880-2580 cal. BC (SUERC-12485 (GU14697)) and 2880–2600 cal. BC (SUERC-12684 (GU14698)) cal. BC respectively. These dates offer a *terminus post quem* for the deposition of sand (111). An ash-rich sandy clay (119) partly *overlay* the sand, and yielded two similar determinations on phalanxes of 2880–2620 cal. BC (SUERC-12479 (GU14694)) and 2880–2580 cal. BC (SUERC-12480 (GU14695)) (Sheridan *et al*. 2012, 204-5). This set of four bracketing determinations suggest that the sand and its surrounding occupation deposits accumulated relatively rapidly at the start of Phase 2, between c. 2800-2600 cal. BC.

After sand (111), no distinct or visible sand horizons are recorded in Clarke *et al*.'s section for Trench 1 with the exception of the overlying deposit which was to cover the settlement after occupation ceased. Instead, the uppermost deposits largely comprise various sandy clay midden accumulations around the walls of Passage A, from which a range of determinations on bone were recovered ranging from 2840-2460 cal. BC (SUERC-12469 (GU14685); SUERC-12471 (GU14687)) to 2620-2460 cal. BC SUERC-12470 (GU14686)) (Sheridan *et al*. 2012, 204-5). The uppermost deposits in Trench 2 also comprised alternating layers of sand and midden (which, in the case of Trench, was waterlogged), from which three very similar determinations for their accumulation were yielded on metatarsals; 2880–2600 cal. BC (SUERC-12727 (GU14738)), 2880–2570 cal. BC (SUERC-12731 (GU14739)), and 2880–2600 cal. BC (SUERC-12732 (GU14740)) (Sheridan *et al*. 2012, 204-5).

Increased amounts of anthropic sediment material in the Phase 2 samples were identified in the micromorphological samples from Trenches 1 and 2, indicative of the systematic incorporation of household waste material into the increasingly-present windblown sands, likely as a means of stabilisation and consolidation (Simpson *et al*. 2006, 229-30). The Trench 2 samples – recovered from deposits not directly associated with structural remains – also contain significant amounts of animal manure. This may be indicative of the zonation of activities, with animal waste being composted at the edge of the settlement while household wastes (particularly fuel residue) accumulated closer to the structures where they formed an important construction and stabilisation material (Simpson *et al.* 2006, 232).

Post-Phase 2 settlement

Childe marked the end of his Period IV (now Clarke's Phase 2) as the deposition of 0.90-1.00m of blown calcareous sand across the settlement. The currently-available information from Trenches 1 and 2 gives little detail of the uppermost windblown sand deposits which appear to have accumulated in the settlement following cessation of occupation. As such, Childe's accounts become a prominent source of information here. The excavator makes mention of numerous windblown sand deposits found to be filling the excavated Phase 2 houses. In House 1 to the west of the settlement, skeletal remains were noted as lying above c. 0.60m of sand. Further sand deposits (dimensions not stated) were noted in House 6, overlying collapsed roof slabs and midden (Childe 1931, 65).

For the sand to have been able to infiltrate and cover the structures to the extent it did suggests that the structures were already in a state of decay or abandonment as presumably the roofing could not have been intact. Childe, however, proposed "a natural agency, namely a hurricane from the north-west" which partially deroofed the still-occupied houses while destabilising and mobilising the nearby sand dunes (Childe 1931, 64). Childe asserted that the high volumes of material culture recovered from the site are indicative of a quick desertion, perhaps driven by the postulated weather event (Childe 1931, 64). This is a narrative which is critically considered in Chapter 6.

Four 're-occupation levels' in House 7 south of the site were also contained in Childe's Period IV activity, overlying c. 0.90m of sand which covered the earlier floor deposits. The first (lowest) reoccupation deposits comprised 0.10-0.15m of shell, ashy floor deposits and antler as well as a hearth and kerb stones. These deposits were overlain by a further c.0.30m of sand, followed by another three occupation layers, each of which being separated by windblown sand layers. The third of these occupation deposits contained a complete red deer skull with antlers attached (Childe 1931, 61-2). The latest deposit in the sequence comprised a further 0.30m of sand beneath collapsed stone – perhaps representing the collapsed upper wall course of the house. Alternating layers of ashy occupation deposits (interpreted as further reoccupation deposits) and sands were also noted in other structures in the settlement, including House 9 (Childe 1931, 62-3) (Figure 4.13).

Figure 4.13. Occupation deposits and sand layers in the vicinity of House 9 at Skara Brae. Childe 1931, Plate XXIV

The stratigraphy within House 7 was to become a key strand of evidence employed by Childe to argue for an immediate desertion of the village, followed by piecemeal reoccupations where survivors of the catastrophe sheltered in the remains of the house. Increased significance was conferred by Childe on the basis of the presence of artefacts within its interior, in contrast with the other excavated houses which contained fewer in-situ artefacts (Childe 1931, 64). More recent consideration of the artefactual assemblages indicates that historic clearance prior to Childe's excavations may explain any perceived dearth of artefactual material in some of the other houses. Additionally, houses which were not subjected to historic clearance (Houses 2, 9, and 10) also contained rich artefactual assemblages (Shepherd 2017, 225-6).

Childe's interpretation of the 'great sand storm' which wiped out the settlement has continued to dominate many writings on windblown sand deposition. More recent scrutiny of the stratigraphic sequences by Alexandra Shepherd and David Clarke (*pers. comm.*), however, has suggested that the deep blanket of sand over the site that was encountered by Childe doesn't represent a final, single, inundation event (either in Childe's Phase IV or Clarke and Shepherd's Phase 2 – see below). Rather, it represents a sequence of repeated episodes of sand deposition and deflation which took place over the four and a half millennia since the site ceased to be occupied (A. Shepherd *pers. comm.*).

A large inundation of perhaps ‘tsunami proportions’ would have been required for an immediate abandonment of Skara Brae. Far more of the settlement would have been preserved in the event of such an occurrence (in a Pompeii-esque fashion), and the excavators note that this is not the case (A. Shepherd *pers. comm*.).

It is important to bear in mind that the two phases of occupation at Skara Brae comprised extensive and continuous building and rebuilding of the structures at the settlement. This could have been partially driven by the increasing influx of windblown sand into the settlement and its environs. Alternatively, the frequently rebuilding may have led to large areas of the settlements and houses being dismantled for periods of time, providing open areas, periodically out of use, in which sand could accumulate. Such an occurrence can be noted during the hiatus period (Clarke *et al.* 2017, 75 and see Figure 4.11).

Excavation methodology

Despite the availability of radiocarbon determinations, the interpretation of the nature and extent of windblown sand deposition at Skara Brae is challenging for several reasons. Firstly, as previously described Childe’s descriptions of the site phasing are essentially in the style of a blow-by-blow narrative with little contextual detail. Although some dimensions are given for the sands, their composition is not stated. While Clarke *et al*.’s excavations of Trenches 1-2 provide welcome chronological data with which to partially constrain the sand deposits, they essentially present a ‘keyhole’ view of the occupation deposits which extended far further than the confines of the trenches. Occupation at Skara Brae is characterised by widespread and continuous building and rebuilding of the structures at the settlement, and this complicates any understanding of the relationship between the sand accumulations and the site inhabitants. Only the piecemeal remains of 2-3 structures were investigated during Clarke *et al*.’s excavations, and as such much of the contextual information for the ways in which sand was deposited in the remains is unavailable.

Economy

The wide range of artefacts (comprising personal ornaments and a diverse range of tools) and raw materials recovered from Skara Brae is representative of the diversity of the environmental context in which many Orcadian Late Neolithic settlements were located. There is a lack of evidence for a struggle for survival, as originally posited by Childe (1931). Despite a decline in tree cover, these environments continued to contain rich resources, particularly in the coastal cordon. The light sandy soils at the Bay of Skaill were easily ploughed, with rich pasture for grazing. Excavation of the waterlogged midden by Clarke and Sharples revealed waterlogged wood and wooden artefacts (Clarke and Sharples 1985, 72).

As the final monograph is still forthcoming, most of the discussion of the subsistence economy at Skara Brae remains within Clarke and Sharples (1985). The food sources identified at Skara Brae were largely agricultural in nature. The predominance of grass heath, and cattle and sheep bone, has been used as evidence for a pastoral economy, while the recovery of carbonised cereals (hulled barley and wheat) from early midden phases attesting to grain cultivation (Shepherd 1996, 106-7) with barley grains dated from 3640-3370 cal. BC to 3010-2700 cal. BC (Ascough *et al.* 2007, 442). A decline in cereal pollen in the later phases of occupation has been noted by Clarke, but as yet remains unexplained (Dickson and Dickson 2000, 50). Faunal remains were dominated by sheep and cattle, followed by pig (McCormick and Buckland 1997, 91). A large proportion of the cattle bones recovered during Childe's and Clarke's excavations appeared to indicate slaughter at the end of their first year, perhaps representative of either a lack of winter foddering supplies or dairying (Clarke and Sharples 1985, 75).

Wild resources (birds, deer, fish, and shellfish) are also represented in the faunal assemblages. The deposition of red deer remains (both articulated and disarticulated) at Skara Brae and Links of Noltland has remained a subject of continued interest (e.g. Clarke, D. V. *et al.* 2016) and it has been suggested that while their distinctive presence does not represent evidence of husbandry (Clarke and Sharples 1985, 75). Fish bone and marine molluscs were also recovered in large quantities, contrary to Childe's earlier estimations (Clarke, D. V. 1976b, 240; Childe 1931; Dickson and Dickson 2000, 49). Limpets proved the most numerous shellfish assemblage. If not eaten in significant quantities, then it is more likely that limpets were used as bait. Most fish species were small and near-coast dwelling. Stone mortar filled with crushed fish bone was recovered during the 19th century excavations, perhaps indicative of the use of fish meal for cattle (Clarke and Sharples 1985, 77). Fuel sources at Skara Brae were thought by Childe to have been dominated by peat, although later palaeoenvironmental studies suggest that substantial peat development in the landscape only took place after occupation at the settlement had ceased (Keatinge and Dickson 1979, 605). Dung and seaweed are likely to have been significant fuel sources, although usage and availability would have varied through the seasons (Clarke and Sharples 1985, 65).

Skara Brae (Sandwick)

In discussions of later sand movement at Skara Brae, it is also worth considering the Late Neolithic butchery remains recovered c. 100m north of Skara Brae. Erosion of sand dunes in 1992-3 revealed the remains of a wall running NE-SW, and deposits of animal bone (predominantly comprising articulated red deer remains including a complete skull with antlers) and stone tools (Skaill knives) on each side. The remains projected from the face of the dune which was eroding c. 4-5m from the coast edge. The site was excavated in 1993-1994 by Colin Richards, and was deemed to be of particular interest due to its proximity to Skara Brae (perhaps functioning as a location for offsite butchery activities), and its related stratigraphic position. Beneath the collapsed dune material, an area of 12.5 x 3m was excavated.

The deposits on either side of the wall were subjected to different preservation conditions; while the articulated red deer remains to the east lay within a relatively dry, sandy matrix, the spread of the faunal remains and stone tools to the west were located within a flooded deposit. The remains lay on the surface of a compact grey clay with flaked stone inclusions, identified as an old land surface, (c. 0.07-0.10m thick), which overlay glacial till. The compact grey clay was sealed by windblown sand. The location of the Skaill knives and cobble tools, which were angled into the clay, as well as their chemically-degraded condition, suggested that the depositional context may have been soft, wet and marshy at times (Richards *et al.* 2015, 93). The deposits continued beneath the sand dune, beyond the excavated area. To the east of the wall, the remains of a hearth scoop which cut into the grey land surface, with two episodes of use, was identified. Associated with the secondary episode of use of the hearth was stone paving to the south of the hearth (Richards *et al.* 2015, 95). Bayesian modelling of two radiocarbon determinations on red deer antler west of the wall (SUERC-4850 (GU-124808); SUERC-4851 (GU-12481)) (Richards *et al*. 2015, 96) place the deposit in the later third millennium BC at 2300–2140 cal. BC (*Skaill Bay*; (Marshall *et al.* 2016, 14; 33; Table 7), slightly later than the last recorded occupation at Skara Brae.

The environmental location in which the butchery remains were situated was prone to sand accumulation. The remains, pressed into a grey clay matrix, lay directly above glacial till. Their position has been interpreted in two ways; firstly, the old land surface was deturfed, with the turf utilised for construction. A second possibility is that one of the significant sand mobilisation events known to have taken place during this period eroded the organic turf horizon prior to the butchery activity (Richards *et al.* 2015, 97). Richards *et al.* also note that Childe's 'reoccupation period' at Skara Brae comprised a series of ephemeral hearths sealed by sandblow deposits, one of which also contained a complete deer skull (Childe 1931, 61-4; and see 'Skara Brae' above; Richards *et al.* 2015). The sand dune deposits overlying the remains have not been directly dated, and as such the radiocarbon date for the faunal remains provides only a *terminus post quem* for the deposition of the sand. No dimensions for the sand deposit overlying the remains have been offered by the excavators but given that this deposit represents a dune truncated by coastal erosion and storm activity, any measurements would be unlikely to be accurate. It is possible that the sandblow deposit which covered the butchery remains could be Neolithic in date, and therefore linked to those which were deposited at Skara Brae at a number of points. At the very least, if the erosion hypothesis suggested by Richards *et al.* is correct, then it can be suggested that an earlier sandblow eroded and then inundated the old ground surface prior to the butchery activity. The users of this area may have then cleared the sand prior to its use.

Figure 4.14. Articulated red deer remains to the east of the drystone wall at Sandwick. Richards et al. 2015, 98; Illustration 5.

4.3.2. Sand Fiold

The cist burial at Sand Fiold, Sandwick, Orkney, was discovered during sand quarrying in 1989. The site is located on the slopes of a low hill, c. 1km from the shore at the east of the Bay of Skaill. The cist is particularly unusual and significant in that it was cut into the underlying bedrock, and was constructed with a means of re-opening the chamber.

Phasing and chronology

The interment of adult male and foetal cremation and inhumation remains span a significant period of time. All dates are calibrated using IntCal (Pearson *et al*. 1986). An inhumation was interred in c. 2900-2500 cal. BC (UT-1483 and UT-1485, with dates coming directly from bone), an urned cremation between 2900-1900 cal. BC (UT-1484, UT-1486, UT-1487, UT-1559, with dates yielded from human bone and plant fibres), and a later un-urned cremation deposited at c. 1000-800 cal. BC (UT-1560, yielded from plant fibres) (Dalland 1999, 373).

Before descending into the bedrock, the cut for the cist chamber was made through c. 0.30m of boulder clay. The cist, capstone and a load-bearing capped passage were overlain by c. 18 tonnes of soil. In three locations in the cist, preserved plant fibres were found to have survived. The earlier unburnt bone was covered by a mat of fibrous material, as were the later cremated bones. The urn also held the remains of basketry fibres originating from the sedge grass (*cyperaceae*) family, which generally grow in damper, wetland environments (Tomlinson in Dalland 1999, 393-8).

When the chamber was constructed, it was excavated through bedrock and a shallow overlying soil (Dalland 1999, 402). After its construction and use, the flagstone bedrock into which the chamber was cut was overlain by a shallow soil deposit (c. 0.20-0.30m) beneath a deposit of calcareous windblown sand of "varying thickness" (no dimensions given) which was to form the parent material for the modern surface soils (Dalland 1999, 380; Carter in Dalland 1999, 402). This windblown sand also directly overlay bedrock in places where the soil appears to have been eroded (see below). The lack of a developed soil over the till may be indicative of a phase of erosion of the soil before the windblown sand deposition, and may indicate a relatively rapid onset of windblown sand deposition, before which there was little time for a substantial soil to form.

The fill of the cist chamber itself was comprised of redeposited clay and soils contemporary with the backfilling of the chamber. Both fill contexts (2 and 3, with 2 overlying 3) contained the remains of a soil A horizon (the topsoil), identified by clods of topsoil or turf. Thin sections taken from the soil A horizon deposits did not include any calcareous windblown sand, indicating that there were no windblown sand components in the subsoil during backfilling. The A horizon had been broken down, potentially reflective of increasing activity around the cist and its re-openings. The arrival of a period of sand inundation following the use of the cist, however, is also evidenced in the thin sections (Carter in Dalland 1999, 404). A date for the deposition of the windblown sand, and the period of time between the deposition of the final interment within the cist at c. 1000-800 cal. BC (UT-1560) and the initial inundation by windblown sand is unclear. Additionally, it is unclear as to whether the original till-derived soil eroded prior to this initial sand inundation or during a subsequent sandblow episode (Carter in Dalland 1999, 404).

Windblown sand at Sand Fiold

What the chronological data from this site provides is evidence for the deposition and reworking of windblown sand in the area following the cessation of activity at the cist, as opposed to a specific date for sand accumulation there. All that can be said with some confidence is that some sand accumulated in this area after c. 800 cal. BC. The initial construction of the chamber through bedrock and shallow soil suggests that unlike Skara Brae, activity here took place over a ground surface which was not comprised of windblown sand deposits (Dalland 1999, 402). This suggests that if sand did make up the superficial deposits here in the Bronze Age (which seems plausible), it was either removed by hand or eroded by natural processes during the construction and use of the cist.

4.3.3. Skaill

A coastal erosion survey of the Bay of Skaill (see Morris *et al.* 1989) revealed an eroding mound containing a cist and stretches of walling at the very south of the Bay of Skaill. The cist was found to be cut through a dark sandy humic layer 0.40m thick, which in turn overlay windblown sand (Figure 4.15). The cist was sealed by a further sand layer c. 0.20m thick, forming a mound. Above this windblown sand layer, a layer of stones and gravel overlying the grave was noted – thought to represent the remains of a low cairn (James *et al.* 1999, 771). Northwest of the cist, a v-shaped arrangement of stones was also excavated. These were sealed by the dark sandy layer cut by the cist. Remnants of drystone walling were also recovered. All structural features overlay clean windblown sand (James *et al.* 1999, 772). A date of cal. AD550-680 (GU-7245) was yielded for the skeleton, placing its deposition in the Pictish period (James *et al.* 1999, 773; calibrated using the University of Washington Quaternary Isotope Radiocarbon Dating Program, 1987 (Stuiver and Becker 1993)). This offers a *terminus ante quem* for the deposition of the windblown sand below the Pictish grave.

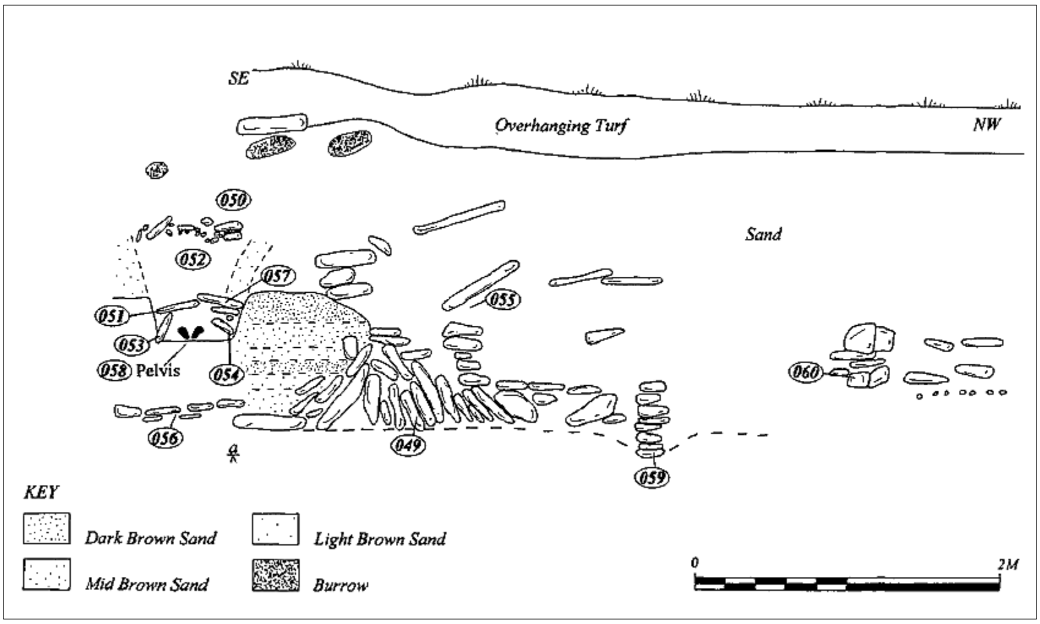

Figure 4.15. Section through the eroding cliff face at Skaill. James et al. 1999, 772.

Windblown sand at Skaill

Sampling for OSL dating of the sands from either side of the cist was undertaken by Anne Sommerville. Samples were taken from beneath the walling mentioned above which extended some 10m to the east of the cist (Section 1) and from sands approximately 10m west of Section 1, close to the cist and beneath another set of walling (Section 2). Dating the sand deposits directly beneath the walled structures provided a *terminus post quem* for their construction, thus dating when the sands were exposed as opposed to when they were deposited. Results suggest that the walled structures were constructed in the

Late Iron Age and Viking period respectively (Sommerville 2003, 356). The lower sands, however, were undisturbed by anthropogenic activities and were thus taken to reflect an episode of windblown sand deposition. A sample from this sand, <SUTL621>, yielded a date of 765±620BC – suggesting deposition in the Bronze Age (Sommerville 2003, 356). The error on this date is considerable, and has been attributed to the low sensitivity of the samples to artificial irradiation during the laboratory process (Sommerville 2003, 326).

4.3.4. Snusgar and East Mound

Sandblow sites which contribute to an understanding of the early historic period in the Bay of Skaill are highlighted by Oxford University's Birsay-Skaill Landscape Archaeology Project (Griffiths, D. *forthcoming*), which develops a landscape and environmental context for Viking and Medieval settlement at the Bay of Skaill, Marwick Bay (Appendix 1), and Birsay Bay. Mounds at Snusgar, Bay of Skaill were investigated through geophysical survey, auguring, trial trenching and full excavation, and are summarised below. Frequent inundations of windblown sand in these settlement landscapes are suggested to have led to widespread abandonment of agricultural land and settlements in the 14th and 15th centuries AD (Griffiths, D. 2015).

The settlement at Snusgar (also referred to as Castle of Snusgar) lies to the north of the Bay of Skaill (Figure 4.3) within a wider complex of five large sandy mounds, of which one other, the East Mound, was also investigated in detail. Snusgar comprises a rectangular structure formed of 1.5m thick double-faced walls and orientated east-west. The mound itself comprises accumulations of calcareous windblown sand, as well as midden, ash and flat stone spreads used to stabilise the windblown sand layers (Griffiths, D. and Harrison 2011b, 15) (Figure 4.16).

Chronology and phasing

Radiocarbon dating of charred cereals places the formation of these deposits to a relatively short period, from c. cal. AD900-1050 (GU-23601–23618) (Griffiths, D., and Harrison 2011b, 15; Ashmore, P. J. C14dates.mdb. 15 June 2003). This chronology is supported by a series of as-yet-unpublished OSL dates (Griffiths, D. 2015, 223; Griffiths, D. *forthcoming*). On the north-east side of the mound, a Late Iron Age-Pictish radiocarbon date of cal. AD489-774 (GU-17851) was yielded by a cormorant bone from a buried land surface bracketed windblown sands (Griffiths, D. 2015, 223). This provides a *terminus post quem* for the formation of the Viking Age mound.

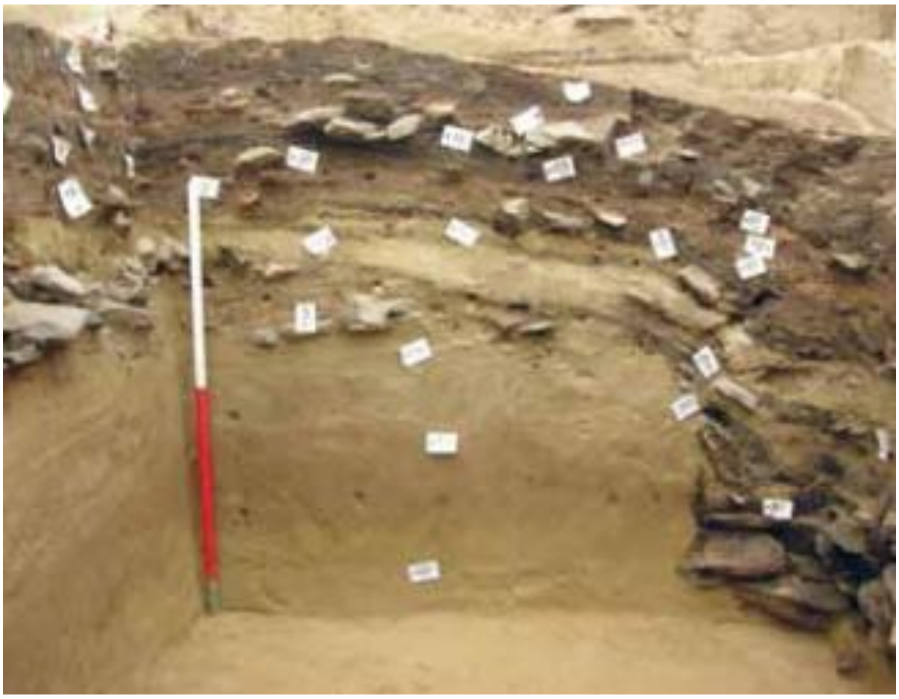

Figure 4.16. Sand and midden deposits under excavation at Snusgar. Griffiths, D. and Harrison 2011b, 15.

East Mound

Further survey and excavation were undertaken at a mound c. 100m east of Snusgar, termed the East Mound. Beneath c. 1.5m of windblown sand, excavation revealed extensive midden deposits, an east-west orientated bow-sided longhouse (comparable to that of the later phases at Pool, Sanday), an associated cluster of ancillary structures to the south of the building, metalworking residues, a yard area, and windblown sand and midden accumulations dating to the Viking period (Griffiths, D. and Harrison 2011a, 3, and Figure 4.17). Short-lived wood and charred grain specimens yielded a series of radiocarbon dates which placed the construction and occupation of these structures to cal. AD980-1230, with a peak in activity at c. AD1000 (Griffiths 2015, 224; Ashmore, P. J. C14dates.mdb. 15 June 2003).

Figure 4.17. Aerial view of the East Mound longhouse, facing east. Griffiths, D. and Harrison 2011a, 6.

Windblown sand at Snusgar and East Mound

Radiocarbon dates suggest that occupation of Snusgar and East Mound overlapped in the late 10th and early 11th centuries, with activity at the East Mound largely beginning after that at Snusgar (Griffiths, D. 2015, 224). Their formation took place relatively rapidly (over a few centuries), comprising a series of constructional episodes, windblown sand accumulation, and midden accumulations serving as stabilising deposits (Griffiths, D. 2015, 229). The accumulation of windblown sand deposits within and outwith the structures at both mounds attests to the continuing dynamism of windblown sand mobilisation in the landscape before, during, and after their occupation. Precise chronologies of windblown sand movement at the sites, and detailed phasing, are expected in the forthcoming monograph (Griffiths, D. *forthcoming*). In the meantime, some preliminary conclusions on the nature of the sand mobilisation and influx at Snusgar and the East Mound may be drawn.

The Snusgar structure overlay approximately 1.5m of yellow and grey windblown sands predating the main phases of Viking activity at the mound. These in turn overlay two organic topsoil horizons separated by a thin layer of windblown sand. The lower soil also overlay a further 0.90m of sand layers (Lewis 2006, 2). Radiocarbon and luminescence dates for the formation of these horizons are forthcoming (D. Griffiths *pers. comm*.). A cormorant bone from a deeply-stratified soil (with windblown sand above and below it) at the north-east edge of the Snusgar mound yielded a Late Iron Age date of cal. AD489-774 cal. BC (Griffiths, D. 2015, 223 (GU-17851); D. Griffiths *pers. comm*.). Sand then continued to accumulate around the structure throughout its century-long occupation, from cal. AD900-1050 (GU-23601-23618) (Griffiths, D., and Harrison 2011b, 15; Ashmore, P.J. C14dates.mdb. 15 June 2003).

The East Mound similarly overlay buried soils and windblown sand accumulations, with sand continuing to accumulate against the structures throughout their occupation. Within the longhouse itself, a series of three clay layers (each c. 0.02-0.04m thick), representing floor or structural deposits, were found to be interleaved with lenses of brown sands. The uppermost clay band was separated from the next band by a sand measuring c. 0.08-0.10m in thickness (Figure 4.18). The next two (lowermost) clay bands were separated by a sand measuring c. 0.02-0.03m in thickness (Lewis 2007, 1). During the occupation of the East Mound (Phases 2-6) such sand appears to have been used as part of an admixture with organic materials and deliberately deposited on – and as part of – floors and wall fills (D. Griffiths *pers. comm*.). Outwith the structures, successive layers of windblown sand accumulated against the walls in the latest phases (7-9), and continued to accumulate over the structures after occupation ceased (D. Griffiths *pers. comm*.; Lewis 2007, 5). Particular concentrations of sand were identified at the northeast of the east-west orientated longhouse, indicative of winds dominating from the north and east.

Figure 4.18. Clay bands separated by brown sands at the East Mound, Snusgar. The lower bands are marked by the Kubiena tin at the base of the section (Lewis 2007, 3).

Information available from preliminary reports suggests that Viking occupation at Snusgar and the East Mound had largely ceased by the 11th and 13th centuries AD respectively. The deroofed remains of the East Mound settlement were filled by c.2m of windblown calcareous sand accumulations in the 14th century, dated by OSL to c. AD1395±125 (lab ID unavailable) (Griffiths, D. 2015, 231). Similar occurrences were noted at Snusgar, but the chronological data for the cessation of activity here is currently unavailable. Sand inundations and smaller accumulations became increasingly common in the area from the 14th-16th centuries AD (Griffiths, D. and Harrison 2011b, 19).

Soil improvement which utilised the mixing of burnt peat and seaweed were identified by archaeobotanical evidence at both mounds. The cultivation of oat and barley standing as the dominant arable strategies, as well as the growth of flax – likely to have taken place in the nearby dune slacks (Griffiths, D. 2015, 227). The improvement of agricultural soils with high sand content using admixtures of organic material is a frequently-identified practice across the Northern Isles from the Neolithic period (see Chapter 6). Preliminary investigations revealed possible prehistoric deposits and earlier windblown sands, but investigation did not continue in order to preserve the overlying Viking Age structures (Griffiths, D. 2015, 223; D. Griffiths *pers. comm.*), before Viking settlement in the landscape commenced.

4.3.5. Skaill House

Skaill House is located approximately 270m east of the mean high-water mark at the Bay of Skaill, and north-west of the Loch of Skaill (Figure 4.3). Parts of Skaill House itself (the north wing) date to at least the 17th century. The discovery of six inhumations during drainage works at the house prompted a salvage excavation of additional inhumations (totalling 12 adults and 15 infants or juveniles, including the six originally identified) within a Medieval cemetery dating to the 11th-14th centuries. The cemetery is likely to extend some 30m north/south of the house, and c. 25m east/west (James *et al.* 1999, 753). Three areas were excavated during these investigations: A, B, and C (Figure 4.19). Areas A and C were located to the south and southwest of the house, while Area B lay at the east of the front wall of the house. The east-west orientated graves were located at a depth of 0.90-1.3m beneath windblown sand (here taking the dimensions of the grave cuts into account) and were cut into a lower deposit of windblown sand of unknown depth with sandy fills. The composition of the sand is not stated by the excavators but is likely to comprise the calcareous dune sand which characterises the superficial deposits of the Bay of Skaill and Sandwick.

Chronology and phasing

Radiocarbon samples from the bones yielded dates spanning from cal. AD1043-1290 (GU-7244) to cal. AD1220-1392 (GU-7243), thus falling within the 11th-14th centuries AD (James *et al.* 1999, 761). All dates were calibrated using the University of Washington Quaternary Isotope Radiocarbon Dating Program, 1987 (Stuiver and Becker 1993). Due to the deep deposit of windblown sand which blew in after the cemetery went out of use, there was a lack of local knowledge and memory of the existence of the cemetery (James *et al.* 1999, 770). Wall remnants likely to post-date the cemetery and windblown sand deposit overlying the cemetery were also recorded – a 17th century date has been posited for the wall (James *et al.* 1999, 770) suggesting that the sand overlying the cemetery must have been deposited between the 14th and 17th centuries AD. That the graves were cut into an earlier sand deposit suggests that sand mobilisation also took place here prior to the earliest recorded burials in the 11th century.

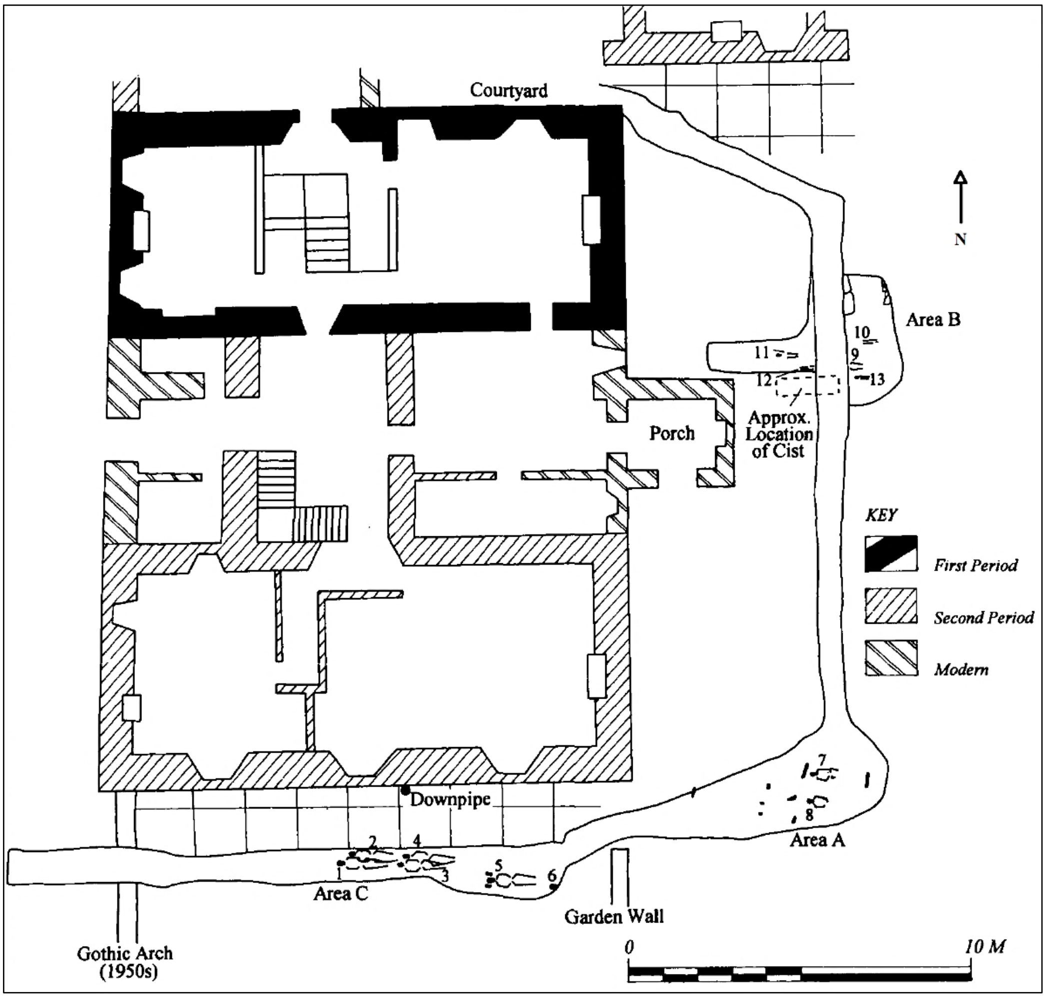

Figure 4.19. Plan of Skaill House showing the excavated areas A, B, and C, and the suggested development of the house from the 17th century ('First Period'). After James et al. 1999, 757.

The dimensions of the windblown sand over the burials vary between Areas A and C to the south, and Area B to the north. The sand in Areas A and C reached a depth of 0.6m, while in Area B the sand was 0.3m deep. It is suggested by the excavators that this differing lateral thickness was due to the old ground surface sloping upwards to the north (James *et al.* 1999, 770), leading to a thinner deposit of windblown sand in this raised area. No definitive remains of a church or chapel associated with the cemetery were recovered. The author speculates whether the original church was moved northwards around the bay to its current location after it was inundated by windblown sand in the later Medieval period (James *et al.* 1999, 771).

4.3.6. Discussion: windblown sand at the Bay of Skaill

A total of eight archaeological sites containing windblown sand have so far been identified in this landscape, dating from the Neolithic through to the Medieval period. The archaeological context is dominated by the Neolithic site of Skara Brae, which continues to offer the earliest known evidence for occupation at the Bay. The settlement record of the Bay comprises Neolithic and Viking settlements, Bronze Age, Pictish, and Medieval funerary remains at Sand Fiold, Skaill, and Skaill House respectively. The palaeoenvironmental and archaeological evidence both demonstrate the continued dominance of windblown sand deposition at the Bay of Skaill over the last four millennia, but the light sandy soil and proximity to coastal resources would have proved attractive to incoming settlers. Three additional sites with less secure dating (Ring of Brodgar, Ness of Brodgar, and Marwick) lie outwith the Bay of Skaill and are discussed in Appendix 1.

The Neolithic

Palaeoenvironmental evidence indicates that windblown sand was moving from at least 5040-4855 cal. BC (Beta-90823), with the sandy beach forming by c. 3325-2900 cal. BC (Beta-104795) (de la Vega Leinert *et al*. 2000, 525). This sand continued to move – punctuated by periods of relative stability – throughout the fourth and third millennia cal. BC. The development of early anthropogenic deposits over the calcareous sand surface at Skara Brae yielded a determination of 3350-3020 cal. BC (SUERC-12717 (GU14731)), confirming that windblown sand was mobilised in this area prior to c. 3350 cal. BC. Micromorphological studies appear to suggest that a period of reduced sand mobilisation (at least in the immediate vicinity of Trench 1) took place during the early settlement, from at least c. 2900-2600 cal. BC (SUERC-12705 (GU14722); (SUERC-12706 (GU14723)).

The largest observable Neolithic windblown sand deposit at Skara Brae accumulated during the early-mid third millennium BC hiatus. Two determinations of 2860–2480 cal. BC (SUERC-12490 (GU14711)) and 2870–2500 cal. BC (SUERC-12696 (GU14712)) were yielded on bone from the uppermost portion of the sand deposits but caution must be exercised given that this material may have been incorporated into the sand during Phase 2 renewed midden deposition at the site. Bayliss *et al.* (2017)'s chronological model offers some further constraint, placing the end of Clarke's Phase 1 to 2870-2815 cal. BC (at 92% probability) (*central_phase_1_end*), and the beginning of Phase 2 to 2840-2685 cal. BC (*central_phase_2_start*) (Bayliss *et al.* 2017 [Supplementary Material, 89]). This suggests that the hiatus sand accumulated over c. two centuries between c. 2870-2685 cal. BC. Sand continued to blow into the inhabited settlement during Phase 2 until cessation of occupation at c. 2530-2455 cal. BC (*central_phase_2_end*; Bayliss *et al.* 2017 [Supplementary Material]. Table S4, 83-96). After cessation of occupation windblown sand continued to periodically accumulate over the settlement over a number of centuries before it was rediscovered in the 19th century.

The Iron Age and later

The data for sand mobilisation in the bay becomes less clear in the successive periods (for example, all that can be stated at Sand Fiold is that sand moved here after c. 800BC) until c. 1000 BC, after which further evidence of extensive sand deposition is identified (Cluett 2007, 274-7). The next datable evidence derives from Snusgar, where sand and soils accumulated in the Late Iron Age-Pictish transition period at cal. AD489-774 cal. BC (GU-17851), before extensive Viking settlement took place. At Skaill cist, windblown sand was deposited at some point between the Early Bronze Age and Late Iron Age (between 765±620 BC <SUTL-621>, and cal. AD550-680 (GU-7245)). Such Late Iron Age determinations are supported by luminescence dates for windblown sand deposition at c. AD310±90 (no lab code) in a coastal exposure 100m west of Skara Brae (Cluett 2007, 274-7). Further sand at Snusgar was then deposited and stabilised with soils at around cal. AD900-1050 (GU-23601–23618), and filled the East Mound settlement at AD1395±125 (lab ID currently unavailable) (Griffiths, D. 2015, 231). At Skaill House sand was mobilised between the 14th-17th centuries cal. AD (GU-7244; GU-7243).

Significant sand deposition is again identified at Snusgar and the Snusgar East Mound to the north of the Bay in the 14th century AD. This is not to say that no extensive sand deposition took place during these chronological gaps; rather, it is indicative of the highly dynamic nature of sand mobilisation, where sand is frequently deposited, reworked, eroded and redeposited. Only more chronological data will allow further precision; at present, with the exception of Skara Brae, it is difficult to identify specific events within this broader context of sand mobilisation although they undoubtedly exist.

A frequent theme, then, is the high geographical variability of windblown sand deposits and their chronologies. At the Bay of Skaill, this is well illustrated by the site at Skara Brae, and the palaeoenvironmental section investigated 100m west of the site (Cluett 2007). Whereas human activity in a densely settled area has allowed for the preservation of multiple lenses and layers of sand securely dated to the later Neolithic period, the earliest deposits OSL dated at the palaeoenvironmental section revealed a Middle Bronze Age (1000±80BC) date followed by Late Iron Age (AD310±190) date (Cluett 2007, 274-7). The deep surface deposits of windblown sand which characterise the Bay of Skaill are undoubtedly obscuring further settlement activity from across the periods, which would help to elucidate some of the apparent chronological gaps. It is impossible to pinpoint precise sources for the sands which accumulated within the prehistoric and historic settlements at the Bay of Skaill, given that the entirety of this landscape has been dominated by deep swathes of windblown sand since at least the Early Neolithic period.

This environmental setting, in which large quantities of sand were frequently mobilised and reworked, would have had a notable impact on the communities settling in the Bay of Skaill - influencing settlement activity and perception of landscape. The longevity of settlement at Skara Brae in the Neolithic, and Snusgar in the Norse period, is a testament to the continued investment in this landscape through the millennia despite the recurrent influx of sand in varying quantities. At present, Skara Brae and Snusgar are the only sites in the Bay of Skaill which offer a fuller view of human interaction with the moving sands. This is notably reflected in the stabilisation of sand accumulations of various depths through the use of midden deposits, as well as the potential of deroofed houses and activity areas functioning as 'sand traps' before being remodelled. The Viking and Norse settlement patterns at the Bay of Skaill and other bays at Birsay and Marwick on West Mainland Orkney are argued by Griffiths to represent a process of retreat from the coast, likely to be linked with increased sand accumulation through the 12^{th}-15^{th} centuries. At the Medieval and post-Medieval periods progressed at the Bay, important farmsteads are found to lie away from the coast edge, with earlier coastal Viking Age settlements at Snusgar and East Mound having been left as sand drift increased (Griffiths 2015, 232).

4.4. Bay of Birsay

The Bay of Birsay lies on the northwest coast of Mainland between two headlands; the Point of Buckquoy (and its tidal island, the Brough of Birsay) to the north, and Marwick Head to the south (Figure 4.20). It is divided by the Point of Snushan promontory, which has technically divided the wide bay into two smaller bays. The bay's narrow beaches are and fronted by boulder beaches topping a rock platform. These supply the extensive fine grained shelly machair of the coast edge, forming dunes which stretch inland for about half a mile (Morris *et al.* 1989, 5) and cover a total area of c. 47ha (Dargie 1998b, 66). The Birsay Links south and west of the Palace Village at Birsay have been particularly affected by windblown sand accumulation (Griffiths 2015, 1). Less sand has accumulated at the Brough of Birsay and the Point of Buckquoy, with any significant modern accumulations mostly lost – although earlier accumulations have been preserved in pockets at the sites. Much of the hinterland has undergone agricultural reclamation, with land use characterised by grazing as well as sand extraction (Mather *et al.* 1974, 23). Five sites are included here, with discussion primarily focused around the results of the Birsay Bay project (below). An additional site (Buckquoy) is described in the appendix due to a relative lack of dating evidence.

Brough Road, Birsay

As part of the Birsay Bay project (lead by Durham University from 1973-1982), a series of sites and deposits (the Birsay "small sites") were investigated on the Brough Road alongside the coastal margin at Birsay Bay (Morris *et al.* 1989) (Figure 4.20). The project comprised excavations and survey, revealing occupation from at least the Neolithic into the Viking and Norse periods. These sites and deposits were primarily investigated through tapestry excavation, whereby eroding sections are cleaned, sampled, and recorded (e.g. Barber 2003). The eroding sites along the Brough Road (Point of Buckquoy and Red Craig), were investigated to characterise their archaeological potential (Figure 4.20). A series of cuttings and small-scale excavations in the eroding coastline were cleaned and recorded, with those containing sand deposits summarised below. The sites are discussed in chronological order, beginning with the Late Neolithic-Early Bronze Age deposits in Area 6, and Cuttings 5 and 6, Point of Buckquoy. Despite their proximity, the sites are discussed separately as there is some ambiguity over their relationship. This is discussed in ‘Excavation methodology’, below. All radiocarbon determinations undertaken for samples from the Birsay Bay sites were calibrated using the curve developed by Klein *et al.* (1982) unless otherwise stated.

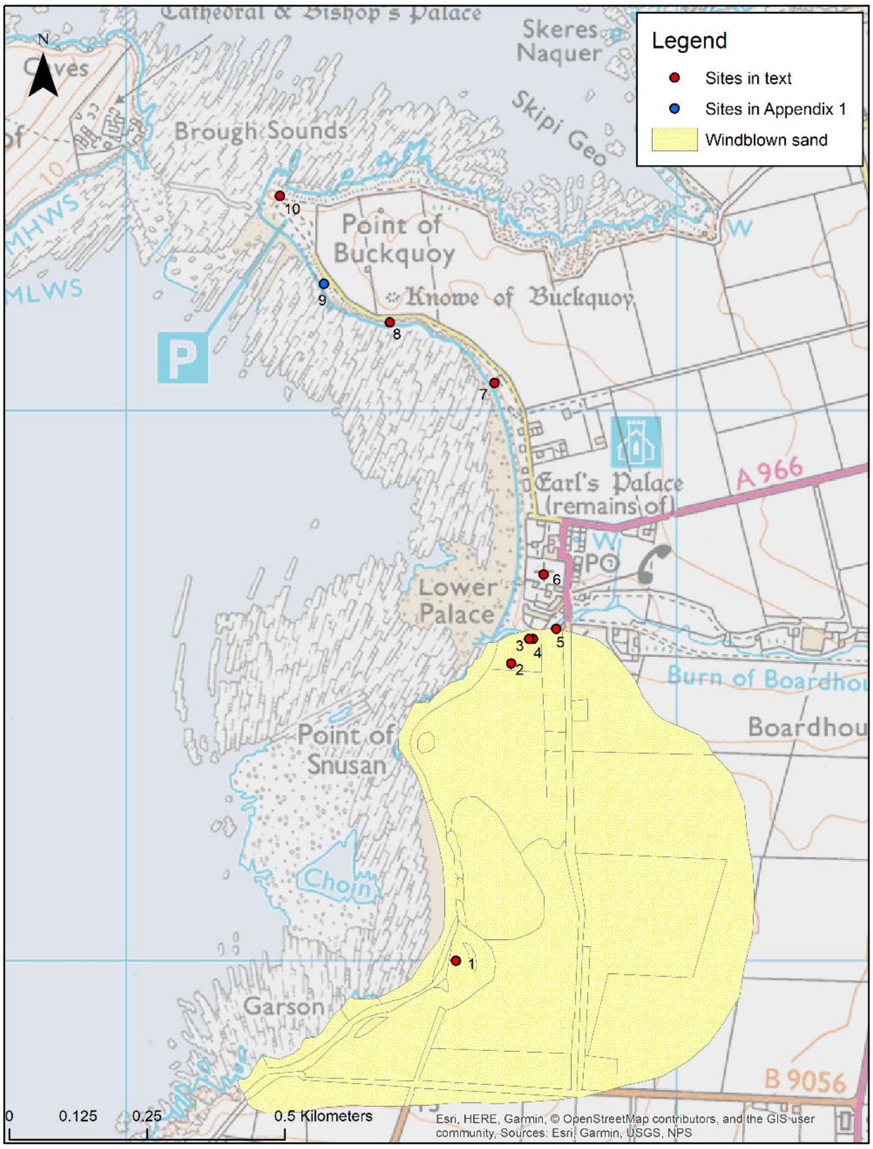

Figure 4.20. Birsay Bay sites. 1. Saevar Howe; 2. Beachview Studio; 3. Beachview Burnside Cutting 1; 4. Beachview Burnside Area 2; 5. Beachview Burnside Area 3; 6; St Magnus’ Kirk; 7. Red Craig Area 1; 8. South of Red Craig; 9. Buckquoy 10. Point of Buckquoy Area 6

4.4.1. Point of Buckquoy

The site lies on the north side of the Point of Buckquoy, north of Birsay Bay (Morris and Pearson in Morris 1989, 80) (Figure 4.21). The area was first investigated in 1960 by F. T. Wainwright, with excavations revealing two conjoined circular structures (Huts 1 and 2) constructed over a midden deposit (Morris and Pearson in Morris et al. 1989, 82-6). The deroofed structures were filled with a c. 0.50m deep deposit of windblown sand (composition unknown) (see Morris *et al.* 1989, Microfiche 2; Illustration M31), with more sand accumulating around exterior (Morris *et al*. 1989, 71-6).

The site (now termed Area 6) was partially reexcavated by the Birsay Bay project in order to clarify the stratigraphy, as were two eroding sections (Cuttings 5 and 6) at the cliff edge to the south of Area 6 (Figure 4.21). Bulk mammal bone (red deer and unidentified fragments) retrieved from the sand interleaved with midden beneath Hut 1's paved floor during Wainwright's excavations was submitted for dating by the Morris *et al*. They yielded a determination of 2630-2180 cal. BC (GU-1557), allowing an early indication that the deposits below the houses probably accumulated during the Late Neolithic, and a *terminus post quem* for their construction (Emery in Morris *et al*. 1989, 80).

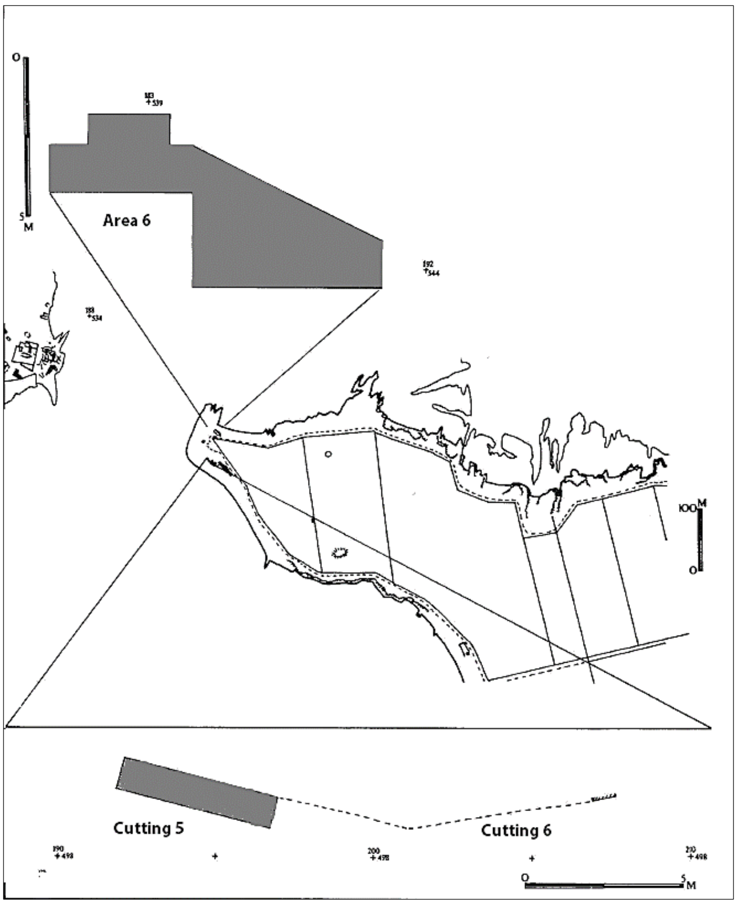

Figure 4.21. Excavation areas at the Point of Buckquoy. Adapted from Morris et al. 1989, 33; Illustration 17.

Area 6

Excavations in 1980

The huts were confirmed as being constructed on an earlier midden-enriched sand which was then used as wall core material. Two phases of structural activity were recorded (Phases B and D), divided by a sand, clay, and midden in Phase C (equivalent to the midden-enriched sand noted beneath the houses during Wainwright's excavations) (Table 9). No diagnostic material culture was recovered by the 1980's excavators to date the structures, but their similarity to Pictish structures (such as those at nearby Buckquoy) was noted (Morris and Pearson in Morris *et al*. 1989, 86). An additional radiocarbon date was commissioned from red deer bone and antler from the Phase C sand and midden, yielding a Late Neolithic-Early Bronze Age range (2285-1690 cal. BC (GU-1640)), slightly later than the date yielded from Wainwright's bulk material (of 2630-2180 cal. BC, GU-1557) (Table 10). Nevertheless this produces a second speculative Late Neolithic date for the accumulation of the Phase C sand dividing Phase B and the houses of Phase D (Pearson in Morris *et al.* 1989, 91). Caution must be exercised with bulk bone samples given the potential for residual material. The later windblown sand deposits from Phases E1 onwards cannot be securely dated but appear to have been deposited following the abandonment of the structures.

Phase	Description
J	Turf and topsoil
H	Material backfilling the 1960 excavation
G	A circular feature filled with loam and lined with stone immediately below the subsoil, interpreted as a kelp burning pit.
F	A thick blackened and reddened sand, possibly the remains of hearth use, overlying the Phase E2 sand.
E2	No evidence of human activity on site. Sandy material filled the ditch excavated in order to construct the earlier bank (Phase D1), and began to seal the collapsed structures.
E1	Disuse and collapse of the structures. Hut 2 was filled with c. 0.50m of clean yellow windblown sand (composition unknown) and boulders
D2	Construction of the huts into the Phase D1 bank, the floor deposits of which comprised dirty compacted sand.
D1	Hut construction activity begins. Phase C deposits were cut into, forming a shallow ditch, and redeposited in order to construct a bank which surrounded and supported the two circular structures constructed in the following phase
C	Phase B stones sealed by a series of sand deposits measuring c. 0.10-0.30m (composition unknown, containing bone and shell), enriched with clay, and midden dumps. Bulk mammal bone, and red deer bone and antler from the midden yielded determinations of 2630-2180 cal. BC (GU-1557) and 2285-1690 cal. BC (GU-1640) respectively.
B	Sandstone flagging and a spread of boulders, perhaps representing the destruction of a nearby structure.
A	A thick brown clay (c. 0.10m) with a large quantity of sandstone chips and some shells, interpreted as the remains of early occupation
Natural	Yellow sandstone bedrock

Table 9. Area 6 stratigraphic sequence, after Morris and Pearson in Morris 1989, 82-6 and Microfiche 2, Illustration M44

Lab ID	Material and context	Date cal. BC (at 95% probability)
GU-1557	Bulk mammal bone (red deer and unidentified fragments from sand and midden underlying Huts 1 and 2	2630-2180
GU-1640	Red deer bone and antler; Phase C sand and midden	2285-1690

Table 10. Radiocarbon determinations from Point of Buckquoy Area 6. After Pearson in Morris et al. 1989, 91.

Cuttings 5 and 6

Cuttings 5 and 6 lie c.40-50m south of Area 6, on the western tip of the Point of Buckquoy (Figure 4.21). A 6 x 1m trench was opened over Cutting 5, while investigation of Cutting 6 was confined to the recording of a c. 7m long eroding section. The deposits here comprised a series of windblown sand accumulations and occupation deposits, varying in thickness from 1m-3m in the cliff section, and deeper still in the Cutting 5 trench (Table 11). The stratigraphic sequences of Cuttings 5 and 6 demonstrate a strong similarity, as can be seen in the tables below and in Figure 4.22.

Point of Buckquoy Cutting 5

Cutting 5 comprised three possible phases of occupation, interleaved with deposits of windblown sand (Table 11). The earliest evidence for occupation is represented by the Phase B midden.

Phase	Description
G	Turf and topsoil
F	Modern structural remains, rubble, and plastic waste.
E5	A midden deposit which developed at the west of the site.
E3 and E4	Windblown sand continued to accumulate to the east of the trench. To the west there was some evidence for structural activity (sandstone blocks) followed by collapse. The sandstones overlay the windblown sand in E2. No artefacts or dated material were recovered
E2	Development of windblown sand accumulations identified across the trench (c. 0.10-0.70m deep), with small layer of occupation deposits to the west. These deposits predate E3 and E4 activity. Thin bands of brown sandy loam between the windblown sand deposits suggests periodic accumulation of this sand punctuated by episodes of stability through the development of soils. The presence of charcoal in one of these loams may be indicative of some form of anthropogenic activity.
E1	Sterile windblown calcareous sand sealing Phase D features, and later cut by Phase E2 and E3 features.
D3	Thin soil horizon (0.05m deep) between two sandblows (with lower sand layer measuring c. 0.10m deep and the upper c. 0.05m deep), all of which overlay the D2 sandstone blocks. No artefacts or dating material recovered
D2	Large sandstone blocks in the east of the trench, perhaps representing a noust-like structure, and some sandy loam soil development
D1	A cut feature identified in the northeast corner of the trench, filled by a thin soil and windblown sand. A further calcareous windblown sand deposit (c. 0.20m deep) was identified in the W of the trench throughout Phase D.
C3	c. 0.65-0.95m layer of windblown calcareous sand overlying the Phase C2 slabs and Phase C1 sand. No artefacts or dated material were recovered
C2	Three sandstone slabs, possibly representing the remains of a structural phase, overlying the Phase C1 windblown sand
C1	A 0.10m layer of sterile windblown calcareous sand which immediately overlies the Phase B midden. No artefacts or dated material were recovered
B	Midden layer (c. 0.10-0.20m deep) including charcoal flecks, shell and bone. This represents the earliest occupation of the site and appears to be contemporary with the Phase B midden in Cutting 6, 5m east of Cutting 5. A bulk sample of red deer bone and other identified fragments yielded a determination of 1770-1370 cal. BC (GU-1556)
A	Dark brown clayey buried soil, the top few centimetres of which contained lenses of calcareous sand.
Natural	Yellow sandstone and thick brown clay with sandstone chips

Table 11. Cutting 5 stratigraphic sequence. After Morris and Alvey in Morris 1989, 92-5 and Microfiche 2, Illustration M46.

Point of Buckquoy Cutting 6

Cutting 6 revealed a similar sequence to that of Cutting 5 (Table 12, Figure 4.22), albeit less extensive in depth. As at Cutting 5, the Phase B midden deposit represents the earliest evidence for anthropogenic activity at the site and is overlain by a deposit of windblown sand (Figure 4.23)

Phase	**Description**
G	Modern boathouse on turf and topsoil. This phase is not labelled 'F' as this is used to denote the intermediary phase observed in Cutting 5, which was not present in Cutting 6.
D and E	Large sandstone slabs set in a possible sandy loam midden deposit with stone, bone and shell.
C	c. 0.20-0.40m of calcareous windblown sand overlying Phase B midden, appearing to represent primary sand dune formation in the area. No artefacts or dated material were recovered but the sand appears to be the same as that observed in Cutting 5 (Phase C).
B	The remains of a collapsed wall representing the earliest occupation of the site. The structural remains were overlain by a large midden deposit which diminished in depth away from the wall. The midden extended for at least 6m to the east, and measured c. 0.10-0.20m depth. It is highly likely to be the same as that identified in Cutting 5 (Phase B). (GU-1222, 1556; SUERC-3572, 3573, 3575, 3588).
A	Primary development of a buried soil with some mixing of calcareous windblown sand in upper layers
Natural	Sandstone bedrock and thick brown clay with sandstone chips

Table 12. Cutting 6 stratigraphic sequence. After Morris and Alvey in Morris 1989, 95-6.

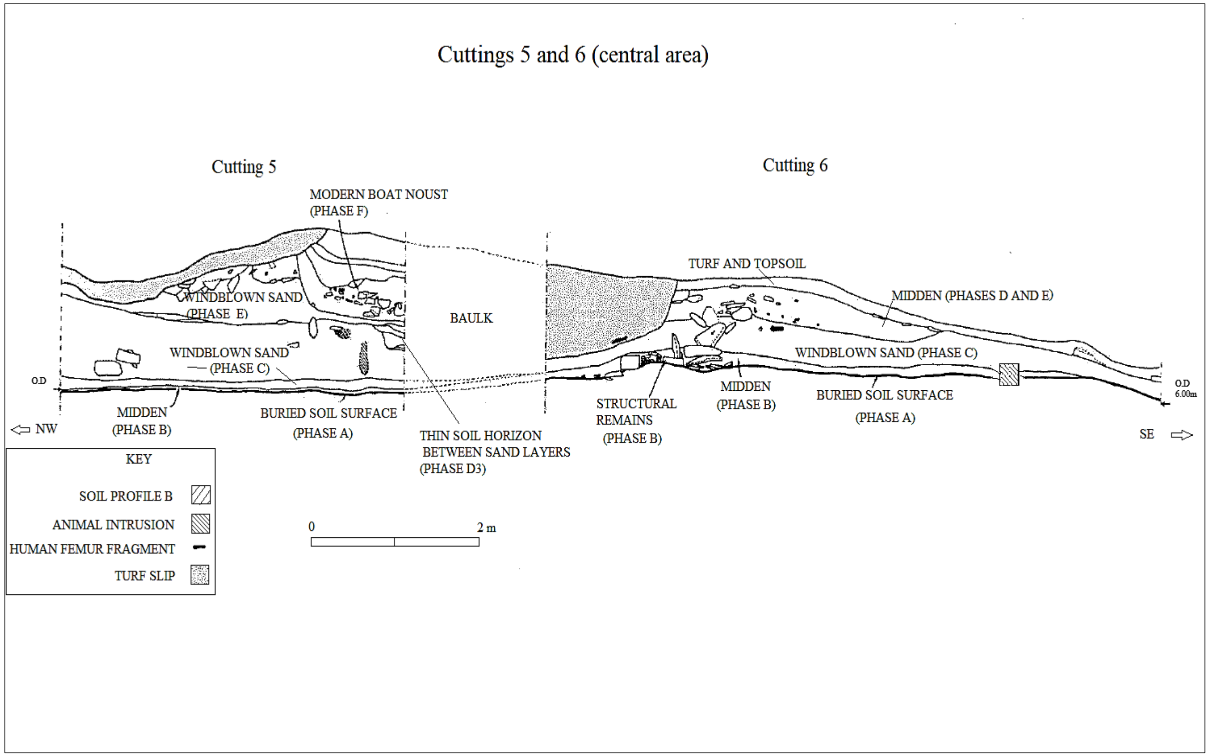

Figure 4.22. Cuttings 5 and 6: section through central area showing deposits and phasing. Adapted from Morris 1989, 98; Illustration 69.

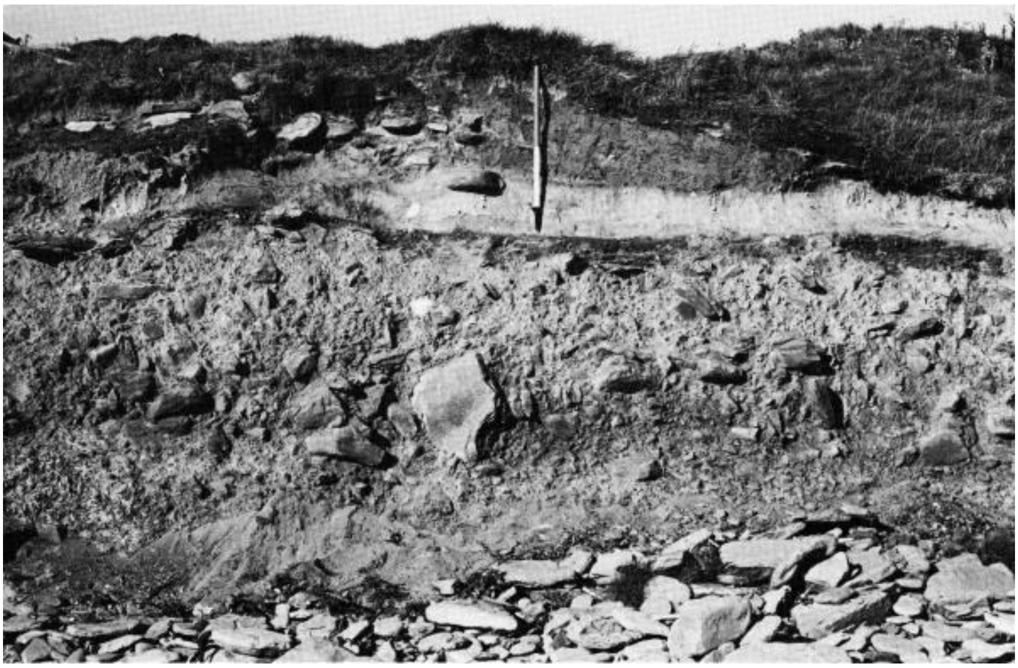

Figure 4.23. Cutting 6 showing buried soil overlain by windblown sand. After Morris 1989, 47.

Windblown sand at Point of Buckquoy

Cuttings 5 and 6

The earliest stratigraphic evidence for windblown sand mobilisation at Cuttings 5 and 6 comes in the form of mixed sand lenses in the uppermost portions of the Phase A palaeosol (Cavanagh in Morris *et al.* 1989, Microfiche sheet 3). These deposits attest to the early onset of sand mobilisation in the locale. Environmental studies provide evidence for the cultivation of soil layers before the Phase B middens were deposited (Morris and Alvey in Morris *et al.* 1989, 104), and may be indicative of the early destabilisation of this coastal landscape. It may be that these small sand deposits represent the beginning of a period of dune formation in the area, which gathered pace in Phase C. Although no direct dates were recovered from Phase A deposits, determinations from the Phase B middens from Cuttings 5 and 6 (below) offer a *terminus ante quem* for the early Phase A sand mobilisation, which must have taken place during or before the Late Neolithic-Early Bronze Age.

The Phase C sand in Cuttings 5 and 6 (measuring c. 0.20-1.00m in depth) was not directly dated, but a series of six radiocarbon determinations (Table 11, Table 12) are available for the formation of the underlying Phase B midden. Two initial determinations were commissioned by the excavators, comprising 1965-1115 cal. BC (GU-1222) on 7g of carbonised barley from the Cutting 6 Phase B midden, and 1770-1370 cal. BC (GU-1556) on a bulk sample of red deer bone and other identified fragments from the Phase B midden deposit in Cuttings 5 and 6 (Morris 1989, 299). While the determination yielded on the grains may represent a 'single event' deposit within the period of midden accumulation, bulk animal bone can only be employed as a *terminus post quem* for the midden as bulk samples can contain material of varying ages (Marshall *et al*. 2016, 14). Nevertheless, these determinations suggested an Early Bronze Age date for accumulation of the midden (Morris 1989, 102).

Further radiocarbon dating on four samples of red deer bone from the Phase B midden deposit from Cutting 6 was undertaken by Ascough *et al.* (2007) (Figure 4.24). These Late Neolithic-Early Bronze Age determinations, along with the two original determinations (GU-1222 and GU-1556, which were recalibrated), were combined into a Bayesian chronological model (Figure 4.25). This indicates a late third to mid second millennium cal. BC for the formation of the midden, from c. 2150-2000 cal. BC (*Boundary start_cutting_6*) to c. 1600-1400 cal. BC (*Boundary end_cutting_6*; Marshall *et al.* 2016, 14). This model offers a *terminus ante quem* for the Phase A sand mobilisation, as well as a *terminus post quem* for the deposition of the Phase C sands in the cuttings. Figure 4.25 demonstrates the tighter chronological precision of the new dates, and as such it is these newer dates which form the author's chronological interpretations of the site. The modelled dates fall more in line with those yielded for the Phase C sand and midden in Area 6, which may be equivalent to the Phase B and C remains observed in Cuttings 5 and 6. Unfortunately, there are no radiocarbon determinations for the deposits overlying the Phase C windblown sand in any area, and as such a more precise date for its deposition cannot be suggested.

Laboratory number	Sample and context description	$\delta^{13}C$ (‰)	Radiocarbon Age (BP)	*Posterior Density Estimate – cal BC (95% probability)*	Reference
GU-1556	Animal bone, mixed collection, mainly red deer + unidentifiable fragments (?red deer) from midden deposits A and B, ZAC in cutting 5 and XF in cutting 6	−20	3260±90	*1885–1795 (6%) or 1780–1405 (88%)*	Morris 1989
GU-1222	Carbonised barley grains (approx. 7g) from midden deposit A, XF in cutting 6	−25	3260±180	*2045–1290*	Morris 1989
SUERC-3588	Animal bone, red deer from midden deposit A, XF in cutting 6	−22.0	3640±35	*2135–2075 (14%) or 2065–1910 (81%)*	Ascough *et al* 2007
SUERC-3572	Animal bone, red deer from midden deposit A, XF in cutting 6	−22.4	3645±40	*2135–1910*	Ascough *et al* 2007
SUERC-3573	Animal bone, red deer from midden deposit A, XF in cutting 6	−22.5	3625±40	*2130–2080 (9%) or 2060–1885 (86%)*	Ascough *et al* 2007
SUERC-3575	Animal bone, red deer from midden deposit A, XF in cutting 6	−22.1	3685±40	*2195–2175 (2%) or 2150–1945 (93%)*	Ascough *et al* 2007

Figure 4.24. Point of Buckquoy Cuttings 5 and 6 radiocarbon dates. Marshall et al. 2016, 32. Calibrated using OxCal 4.2 (Bronk Ramsey 1995; 2009).

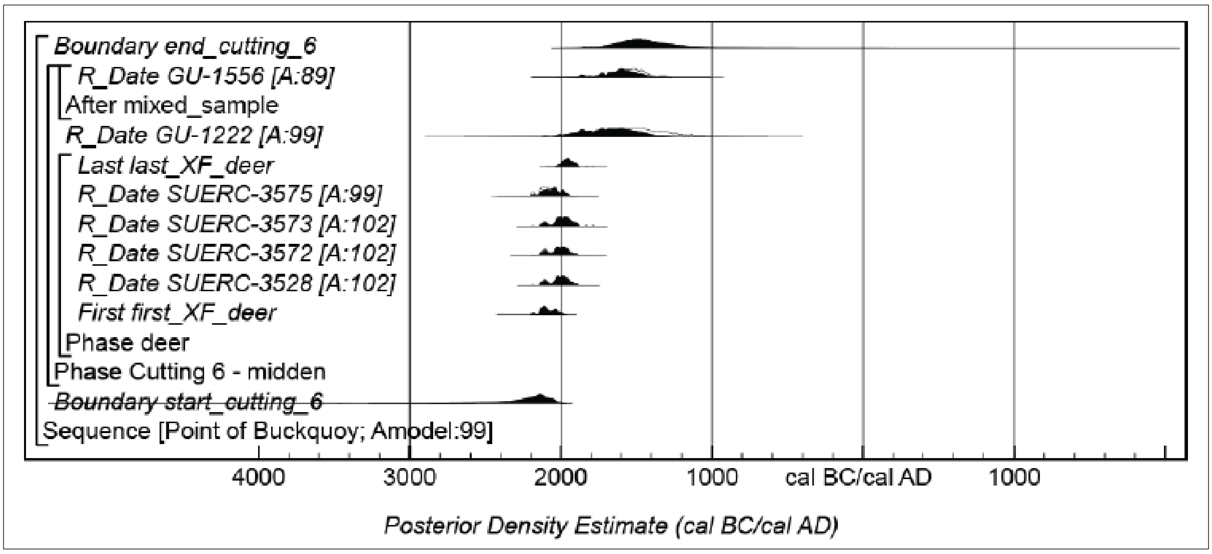

Figure 4.25. Probability distributions for radiocarbon dates from Point of Buckquoy Cutting 6. Marshall et al. 2016, 24

Area 6

The earliest dated evidence for sand mobilisation at Area 6 is from Phase C, from which two determinations of 2630-2180 cal. BC (GU-1557) on bulk mammal bone, and 2285-1690 cal. BC (GU-1640) on red deer bone and antler, were yielded for the sand and midden deposit. The sand in Area 6 was interspersed with midden and clay deposits, perhaps indicative of a longer period of accumulation for the sand punctuated by more concentrated human activity. The fact that the material for GU-1557 was bulk and partially unidentified may account for the earlier range.

A series of later windblown sand deposits accumulated after Phase C in Area 6 and Cutting 5, and to a lesser extent, Cutting 6. In Area 6, c. 1m of windblown calcareous sand filled the remains of Huts 1 and 2 in Phase E. No further radiocarbon determinations are available for the later phases of activity at the Point of Buckquoy as a whole. All that can be stated is that if the structures excavated in Area 6 *are* Pictish in origin, then the sand which filled them after cessation of activity must have taken place in the Pictish period or later. The kelp burning pit excavated at the top of the sequence is undated, but structures of this type typically date to the late 18th- early 19th centuries AD (T. Dawson *pers. comm.*), which provides an unhelpfully wide bracket of time in which the later sand accumulations could have been deposited. In Cutting 5, deep accumulations of calcareous windblown sand covered the underlying deposits in Phases D and E, but again no radiocarbon determinations were recovered from these deposits.

Environmental evidence

Only environmental evidence from Phases A and B at Point of Buckquoy are discussed within the publication. A block of sample was retrieved from the Phase A buried soil and the overlying Phase B midden, c. 3m west of the western limit of Cutting 6. Terrestrial snails from the Phase A soils and Phase B midden, including *discus rotundatus* and *aegopinella pura*, are indicative of a woodland environment, while open grassland species (*Vallonia excentrica* and *Lauria cylindracea*) dominated the Phase C sands suggesting a degree of deforestation and a change to dune pasture "resulting in, or resultant upon, the formation of dunes" (Morris and Alvey 1989, 104; Cavanagh in Morris 1989, Microfiche sheet 2). This uncertainty of the relationship between deforestation and sandblow is typical of the challenges of detangling cause from effect when it comes to such environmental dynamics. The abundance of deer in the midden at the site has been likened and compared to the assemblages at the Links of Noltland, and raises interesting questions concerning wild animal exploitation in this transitional period of earlier prehistory (Morris and Alvey 1989, 104-7; see also Richards *et al.* 2015). Faunal remains were interpreted as representing a mixed economy of hunting and gathering with some animal domestication and cereal agriculture (Morris and Pearson in Morris *et al.* 1989, 95).

Excavation methodology

Interpreting the precise nature of the windblown sand deposits at Point of Buckquoy is challenging for a number of reasons linked to excavation methodology. A lack of scientific dating and chronologically-diagnostic artefacts (ensuring a reliance on a small number of relative dates, some of which were yielded on bulk material), means that a precise chronology for windblown sand deposition is difficult to ascertain. As mentioned above, bulk material can only be used as a *terminus post quem* for the context being dated, given that they can contain material of varying ages (Marshall *et al*. 2016, 14). The problematic nature of the scientific dating which was undertaken is illustrated well by (GU-1556), a date yielded on a bulk sample of partly-unidentified mammal bone which was recovered from midden deposits from both Cuttings 5 and 6. Regardless of the excavators' confidence in the middens being the same, such a practice brings a significant degree of uncertainty to the sample and the event(s) it may be dating.

The small scale of the excavations makes it difficult to ascertain the total extent in area of the windblown sand deposits. Additionally, for the most part the excavators do not state whether these deposits were banded and varying in colour, or whether they resemble a single event. The frequent appearance of bands of occupation deposit and thin soils in some deposits (for example Cutting 5, Phases D and E), would however suggest that these sands accumulated over a longer period of time. Finally, the composition of the sands was not always stated, particularly in the case of the earlier sands, such as those identified in the Phase A buried soils in Cuttings 5 and 6. Overall, however, calcareous sand appears to comprise most if not all of the windblown sediments.

Given their close proximity, it is tempting to draw correlations between the Phase B middens in Cuttings 5 and 6, with the Phase C midden and sands of Area 6. In Area 6's Phase C, GU-1557 presents a notably earlier range than GU-1640, with the latter fitting relatively well with the ranges yielded for the Phase B midden in Cuttings 5 and 6 (see below). It is worth noting, however, that the Phase C deposit in Area 6 contains considerably more windblown sand than the Phase B deposits in Cuttings 5 and 6 and thus may be a different deposit. If the Phase C sand in Cuttings 5 and 6 is the same as the Area 6 sand which covered the houses in Phase E1, then the Phase C sand must be Pictish or later. However, without more comprehensive dating evidence it is not possible to draw any firm conclusions.

4.4.2. Red Craig

Red Craig lies at the neck of the Point of Buckquoy, and can be divided into the areas South of Red Craig (Areas 1 and 2), and Red Craig itself (Areas 3-5) (Figure 4.20), lying c. 200-300m apart, as well as the smaller area at Brough Road Cutting 1. Despite their disparate recording, the areas should be considered as a whole.

South of Red Craig (Brough Road Cutting 1; Areas 1 and 2)

Brough Road Cutting 1, and Red Craig Areas 1 and 2 lie to the north of the bay, mid-way between the Point of Buckquoy and the Earl's Palace. They comprise the remains of a series of long cist inhumations dug into the sand and covered by cairns, with periods of midden and windblown sand accumulation. The deposits were very similar to those first observed in the nearby Brough Road Cutting 1, where Late Iron Age cist burials were interred. Despite having been excavated separately, it is clear that at least Areas 1 and 2 should be considered together given the similarities in their deposits and chronologies, which can for the most part be correlated.

Brough Road Cutting 1

The deposits observed during the recording of Cutting 1 were noted by the excavators to be extremely similar to those in Area 1 (below). Nonetheless, for clarity this cutting has been given its own entry. Materials from both Cutting 1 and Area 1 produced comparative dates, although the two (GU-1550, 1551) from skeletons in Cutting 1 are slightly earlier (Table 13). The sand at Cutting 1 must have accumulated before cal. AD230-570 (GU-1550). It is difficult to ascertain from the excavation report whether the sands in Phases B-D are windblown, or whether they represent deliberate anthropogenic depositions during the construction of the cairns. Resultantly, these deposits are not included as windblown sands.

Phase	Description
D	A series of dark and light sands and stone layers, interpreted as dumped deposits, a soil, more stones, and a modern turf and topsoil
C	A second burial is placed into the cist (GU-1551), covered by more sand and stones, perhaps forming a cairn-like structure
B	Cist burial (GU-1550), cut into deposits of Phase A, and covered by stones and sand
A	Three sand deposits (no dimensions given) containing shell and bone, cut by a cist burial.

Table 13. Brough Road Cutting 1 stratigraphic sequence. After Morris and Emery 1989, 55-6

South of Red Craig Area 1

Following salvage excavation at Cutting 1, Area 1 at Red Craig was excavated through a trial trench measuring c. 17m EW x 7m NS. It lies directly east of Area 2.

Chronology and phasing

Area 1 comprises a series of cist inhumations and midden accumulations founded over layers of windblown sand (Table 14). A total of seven radiocarbon determinations were retrieved from Area 1 and Cutting 1 (Table 15).

Phase	Description
G	Turf and topsoil
F	Accumulation of midden (termed ‘upper midden’) containing bulk mammal bone (GU-1979) and windblown sands (dimensions and composition not stated) above Phase E cist grave.
E	Cist grave cut into, and overlain by, Phase D lower midden, suggesting interment while the midden was still in use (GU-1552, 1553).
D	Development of later Pictish-Viking period midden (termed ‘lower midden’) over the site (dimensions not stated), covering the Phase C windblown sand. Two distinct layers of midden were identified, both of which were dated (Table 15) (GU-1956, 1957)
C	“Thick deposit” of windblown sand (dimensions and composition not stated) which covered the remains of the two cairns.
B	Stone remains representing the collapse/partial destruction of the cairns
A	Late Iron Age-Pictish oval stone cairns (Cairns 1 and 2) with associated long cist inhumations (Skeletons 2 and 3 (GU-1554)), constructed into and over the natural sand. The cist inhumations had been backfilled with the natural sand. A skeleton (Skeleton 1) also overlay Cairn 1 and it appears to have been deposited over the cairn before the deposition of the Phase C sand and Phase D midden, but some time after the construction of Cairn 1.
Natural	Sand interpreted as a ‘natural’ deposit (although shell, bone and stone were recovered) underlying Cairns 1 and 2 (no dimensions or composition stated) =Cutting 1, Phase A

Table 14. Red Craig Area 1 stratigraphic sequence. After Morris, Pearson and Emery in Morris 1989, 119-123.

Lab ID	Material and context	Date cal. AD (at 95% probability)
GU-1550	Cutting 1, Phase B. Skeleton 1 under Cairn 1	230-570
GU-1551	Cutting 1, Phase C. Skeleton 2 under Cairn 1	245-585
GU-1554	Area 1, Skeleton 3, under Cairn 2	55-570
GU-1956	Area 1, lower midden, Phase D. Mixed mammal bone (horse, sheep/goat, cow and pig)	620-890
GU-1957	Area 1, lower midden, Phase D. Mammal bone (horse, sheep/goat, cow and pig)	790-1035
GU-1553	Area 1, Phase E (Episode 10). Skeleton 2, in cist grave	600-915
GU-1552	Area 1, Phase E (Episode 10). Skeleton 1, overlying Cairn 1	880-1140
GU-1979	Area 1, Phase F. Bulk mammal bone from midden	610-1020

Table 15. Radiocarbon determinations from South of Red Craig and Brough Road Cutting 1. Morris, Pearson and Emery in Morris 1989, 123.

South of Red Craig Area 2

Area 2 is located west of Area 1, and comprises seven phases of activity (Table 16). The rich midden deposits of Phase C are likely to represent the waste deriving from late Pictish domestic activity which took place outside the limit of excavation. The stratigraphic deposits correlate well with those recorded in Area 1 and other exploratory cuttings (Table 17) (Morris 1989, 55-66).

Phase	Description
F	Turf and topsoil
E1 and E2	Stones set in a layer of dirty brown loam sand (E1) covered with yellow-brown calcareous sand containing human bone and shell (E2)
D	A single cist grave inhumation covered by stone slabs (GU-1555), cut into the higher levels of the Phase C midden.
C	Midden and occupation debris which extended into Area 1. A series of brown sandy loam layers, shells, pebbles and burnt patches, again interpreted as midden (C1) (GU-1667). These were sealed by a series of sand layers containing bone and shell, followed by further loams and burnt dumps. A thick dark midden layer covered these deposits (C2, GU-1980)
B	Sealing of Phase A deposits with stone spreads and flags mixed with brown sand
A	A series of dirty calcareous sand layers mixed with yellow clay, loams, and burnt material indicative of some form of anthropogenic activity (GU-1955).
Natural	A basal deposit of natural sand above bedrock, into, and above which, a number of deposits were cut and placed.

Table 16. Area 2 stratigraphic sequence after Morris and Emery in Morris 1989, 58-9.

Lab ID	Material and context	Date cal. AD (at 95% probability)
GU-1955	Mammal bone (species not stated), sand layer below midden in Phase A	625-895
GU-1667	Carbonised seed, lower midden (Phase C1) (species not stated)	885-1245
GU-1980	Mammal bone, upper midden in Phase C2 (species not stated)	855-1050
GU-1555	Skeleton 1 in Phase D cist grave	670-1020

Table 17. Radiocarbon determinations from South of Red Craig Area 2. After Emery in Morris et al. 1989, 141.

Red Craig

Having been constructed on natural clay as opposed to sand, the remains excavated at Red Craig (Areas 3-5) provide an interesting comparison with those at South of Red Craig. It is notable that windblown sand layers were not recorded in the deposits at Red Craig. Resultantly, no detailed consideration of the site is included, and only a summary of the remains encountered in Areas 3-5 will be presented below in order to provide some context.

Area 3 at Red Craig lies northeast of Areas 1 and 2 (0.25km), and the remains excavated here represent the majority of archaeological activity recorded across the three areas. The remains comprised a figure of eight stone structure constructed divided into two rooms (A and B), each containing a fire pit with ashy deposits. An ashy deposit from the Room B pit yielded a later Pictish-Early Viking period date range of cal. AD600-915 (GU-1959). Carbonised seed (no species) from clay and rubble deposits infilling the structure yielded a similar determination of cal. AD600-910 (GU-1958) (Emery in Morris *et al*. 1989, 174). Areas 4 and 5 (both of which lay immediately adjacent to Area 3) contained far less archaeologically-significant material. The remains in Area 4 HY24482816 comprised a small section of walling constructed over the clay, and were interpreted as being associated with the Area 3 structure, while Area 5 (HY24482818) was largely devoid of archaeological material (Pearson in Morris 1989, 174-180; 189). No datable material was recovered from either area.

Windblown sand at Red Craig and South of Red Craig

South of Red Craig Area 1

Activity at Area 1 and Brough Road Cutting 1 reveal two phases of burial activity; firstly, the Late Iron Age-Pictish use of long cist burials associated with cairns (Phase A) and secondly, the construction of the Late Pictish-later Norse cist grave in Phase E. These activities are interspersed with the accumulation of middens and deposits of windblown sands (Morris, Pearson and Emery in Morris 1989, 119-23). The Phase A cairns were constructed above a deposit of windblown sand which likely accumulated before AD55-570 (GU-1554). Following their interment and collapse, the Phase A cists and their associated cairns were covered by the thick windblown sand deposit of Phase C. While the Phase C sand is not directly dated, radiocarbon determinations for Phases A and D allow a chronological bracket.

Three determinations were yielded on the pre-Phase C Skeletons 1-3 from Area 1 (Phase B) and Cutting 1 (Table 15), placing their deposition to the late Iron Age and Pictish periods (between c. cal. AD55-570 (GU-1554) and cal. AD245-585 (GU-1551)). The Phase C sand was then covered by a thick midden deposit (Lower Midden) in Phase D, from which two radiocarbon determinations on bulk mammal bone were yielded. The ranges for its accumulation span the later Pictish and Viking periods from c. cal. AD620-1035 (GU-1956, 1957), and resultantly, the Phase C sand accumulated during a period between these Phase B and D date ranges and possibly within a relatively narrow chronological period during the Late Iron Age/Early Pictish period, between c. cal. AD500-600 (GU-1554; GU-1551).

During Phase E, a cist grave cut the Phase D midden (Table 14; Morris, Pearson and Emery in Morris *et al*. 1989, 123). Two further skeletons were sampled for radiocarbon dating, yielding date ranges spanning the later Pictish to later Norse periods from ca. AD600-915 to cal. AD880-1140 (GU-1553, 1552). Phase F is represented by the deposition of more midden material (Upper Midden) over the Phase D midden and Phase E cist after cal. AD880-1140 (GU-1552). The deposition of further calcareous windblown sand is also assigned to this phase, before the development of turf and topsoil cover in Phase G. Bulk mammal bone (red deer, cattle, pig, and sheep) from the Phase F windblown sand yielded a single later Pictish-Norse determination of cal. AD610-1020 (GU-1979) (Morris, Pearson and Emery in Morris *et al*. 1989, 118). This is a younger range than that yielded on the skeletons of Phase E; given that Phase F's GU-1979 was yielded from a bulk bone sample, the dates on the Phase E single skeletons (GU-1553, 1552) may be deemed more reliable providing the context was secure. Resultantly, it can only be suggested that the Phase F sands accumulated after c. cal. AD880-1140 (GU-1552).

South of Red Craig Area 2

The later Pictish and Viking remains at Area 2 are likely to relate to structures and associated activity outside the excavated area, as well as the activity in Area 1 (Emery in Morris 1989, 141). As previously stated, Areas 1 and 2 are best considered as a single entity. This is suggested by the correlations noted between the deposits excavated in the two areas, as summarised in Table 18. Sand incursion can be identified in Phases A, C, and E in Area 2. Four radiocarbon determinations were yielded for Area 2, recovered from Phases A, C1, C2, D (Table 17). Early mixing of the underlying sand occurred in the Late Iron Age-Pictish Phase A, with mammal bone from the mixed sandy layers yielding a determination of cal. AD625-895 (GU-1955). The sands intermixed with midden layers in Phase C accumulated around at least cal. AD855-1050 (mammal bone, GU-1980) to cal. AD885-1245 (carbonised seed, GU-1667).

Area 1	**Area 2**
Phase	**Phase**
F	G
E1 and E2	F
D	E
C	D
B	C
A	B
	A
Natural	Natural

Table 18. Phase correlations between South of Red Craig Areas 1 and 2.

The determination on the Phase D skeleton of cal. AD670-1020 (GU-1555) fits broadly with the dates for the accumulation of the Phase C midden and sands although it displays an earlier date range. The nature of the midden accumulation is not made clear by the excavators, but it is possible that the midden continued to accumulate around the inhumation after its deposition, accounting for the later date ranges. The Phase E deposits are undated, but the sand within these deposits presumably accumulated after cal. AD670-1020 (GU-1555) to cal. AD885-1245 (carbonised seed, GU-1667). More significant palaeoenvironmental data for the Pictish and Viking periods at Birsay Bay is expected in Griffiths *et al*.'s forthcoming monograph. However, some broad conclusions may be drawn. Plant taxa recovered from South of Red Craig (including *plantago* and *potentilla*) are indicative of an open, sand dune habitat during the Pictish and Viking periods, with arable fields growing barley, oats, and possibly flax and (Rackham in Morris *et al*. 1989, 267).

Red Craig

The lack of sand deposits recorded at Red Craig is interesting in itself, and worth considering due to its proximity to the remains at South of Red Craig. Although a sole explanation of the building at Red Craig being constructed upon natural clay as opposed to sand dunes (as is the case at South of Red Craig (Areas 1 and 2)) does not seem to be sufficient, it is certainly likely to have played a role. It is worth considering whether activity at Red Craig Areas 3-5 took place slightly later than at Areas 1 and 2, and that the decision was made to build on more stable ground after witnessing frequent dune sand mobilisation in Areas 1 and 2. A more extensive radiocarbon dating programme would help to better-inform this interpretation to an extent, although there is relatively close correlation between Areas 1-3.

It is conceivable that the dune sand was eroded or scoured from the clay natural in Areas 2 or 3 prior to construction or, depending on the depth and extent of the sand here, removed by the site's early inhabitants. Given the small scale of excavation of Areas 1 and 2, and the lack of structural preservation, it is difficult to ascertain how the windblown sands were building up in this area and resultantly, the direction from which they were mobilised. Such information on the dimensions and depositional source may help to ascertain whether or not any earlier sand which previously-existed in Areas 3-5 (prior to the construction of the structure) was destabilised and deposited in the vicinity of Areas 1 and 2. Any sand which was deposited during the use of the settlement may have been cleared out by the inhabitants, although in this case some small sand deposits would still be expected. It is possible that the sites across Red Craig functioned as a whole, spanning the late Pictish period through to the Viking period with funerary activity taking place in the sand dunes to the south and settlement activity taking place further north. Finally, it must be borne in mind that only comparatively small areas of this coastline were excavated, and further, unexcavated areas of the settlement are almost certain to exist beneath and behind the Brough Road. Excavation of these remains would improve this picture significantly. It is also worth considering whether the lack of identifiable sand at Red Craig itself derives from different levels of occupation activity, with the inhabitants clearing any large deposits of sand which may have blown into the settlement. Any retaining walls at Red Craig may have inhibited large-scale sand mobilisation, with sand instead gathering in more exposed areas with less construction activity – such as the areas of midden accumulations and burials at South of Red Craig.

4.4.3. St Magnus' Kirk

Despite its later date in the context of this thesis, the St Magnus parish church – and the levels upon which it was founded – are worth considering. It is located c. 500m south of Red Craig, in the widest part of the Bay of Birsay (Figure 4.20). Excavation by what was the Central Excavation Unit took place in advance of restoration in 1982, with the opening of seven trenches around the walls of the church (Figure 4.26). The earliest phase (Phase 1) at the site comprised a spread of heat-shattered stones and peat ash, likely to represent burnt mound material. Identified in Trenches 1 and 2 at the north-west corner of the church, this material overlay clean white dune sand (Crone in Morris *et al*. 1996, 14-15). After development of the midden in Phase 2, and its overlying burials, the foundation walls of the church developed incrementally from Phases 2-6 (Table 19). A single radiocarbon determination was recovered from the excavations, with a skeleton from one of two cist inhumations dated to cal. AD800-1030 (GU-1631). This offers a *terminus ante quem* for the accumulation of the underlying midden, and appears to be broadly contemporary with the dated remains from South of Red Craig. Sand (no dimension) accumulated over these burials, into which further burials were then cut.

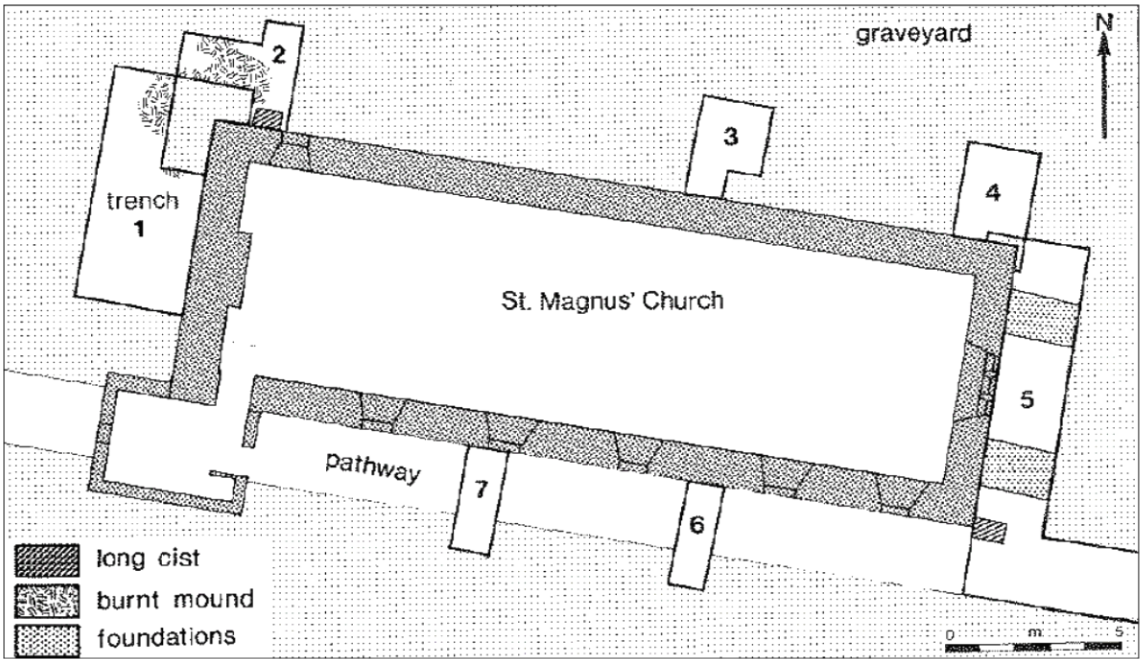

Figure 4.26. Plan of St Magnus' Kirk and excavation trenches. J. Barber in Morris et al. 1996, 11; Illustration 7.

Phase	**Activity**
6	Latest foundations in Trenches 3 and 6, and present church walls in Trenches 3-6.
eme5	Secondary foundations in Trenches 3 and 6, and primary foundations in Trenches 1, 2, 6, 7.
4	Erection of a cut sandstone plinth in Trench 5
3	Secondary walls constructed in Trench 5, and primary foundations in Trenches 3 and 6. Dark grey sand (no dimensions or composition given) overlay the Phase 2 burials, and more undated burials were inserted into this sand deposit
2	Primary walls constructed in Trench 5, and the accumulation of c. 0.30m of midden in the SE corner. A series of c. 7-10 lined inhumations and two cist graves were cut into this midden and therefore postdate it, with the skeleton from Cist 2 yielding a radiocarbon determination of cal. AD800-1030 (GU-1631)
1	Burnt material, comprising probable burnt mound material (heat-shattered stones, and peat ash), in Trenches 1 and 2 overlying clean white calcareous sand free of vegetation.

Table 19. Phasing and activity at St Magnus' Kirk. After Crone in Morris et al. 1996, 20-1.

The sand must have accumulated after cal. AD800-1030 (GU-1631) and before or during the construction of the early church foundations, but a precise date is not possible to ascertain given the lack of direct radiocarbon dates. The early foundations supported a structure dating stylistically to the 10th-11th century AD, which was then remodelled in the Romanesque style in the mid-12th century. It could be suggested, then, that the accumulated within a relatively short time period between the 9th and 11th centuries AD. The church that can be seen today holds its current architectural origins in the 17th-18th centuries, although the early cist burials suggest that a church was located at this site since at least the mid-9th century cal. AD (Crone in Morris *et al*. 1996, 28-31). The foundation trenches for the early church are interesting in that their width increased downwards (from c. 1.3m to almost 1.5m), perhaps serving a stabilising function given the sand subsoil. The foundations had been laid over a cobble layer set in brown sand, and appear to have functioned as an early stabilisation surface (Crone in Morris *et al*. 1996, 15; 17).

4.4.4. Beachview

The sites at Beachview lie c. 120m south of St Magnus' Kirk, within a grassy plain containing three other mounds covered with substantial overburdens of windblown sand; the Point of Snusan, Mount Misery, and Saevar Howe (Emery and Rackham in Morris *et al.* 1996, 35). A number of small-scale investigations were undertaken at three cuttings (Cuttings 1-3) along the Burn of Boardhouse, which runs east-west towards the bay. While Cutting 1 revealed only modern detritus, Cutting 2 contained structural remains and midden overlain by windblown sand. Cutting 3 revealed bone and shell fragments, and was later extended to a larger area (Area 3). These deposits were not dated. Another larger area (Area 2) was also excavated at Beachview Burnside, as well as Area 1 at the Beachview 'Studio' site. It was suggested that the cutting remains could represent either the edge of the Area 2 (see below) mound of Viking/Late Norse midden deposits, or a small part of a much larger mound which also includes the Area 1 structures (Alvey and Pearson in Morris *et al*. 1996, 43). Limited excavation of Area 3 revealed a Late Norse midden deposit covered by windblown sand, followed by turf and topsoil (Alvey in Morris *et al.* 1996, 45-7). It is likely that Cuttings 1 and 2 containing deposits making up the edge of larger multiperiod settlement mound, dating to at least the Norse/Viking period.

Beachview Burnside Area 3

Burnside Area 3 comprised an extension of Cutting 3 along the Burn of Boardhouse, with remains comprising midden deposits (Phase X) overlain by windblown sands in Phase Y (Table 20). Unidentified mammal bone from the midden yielded a radiocarbon determination of cal. AD1020-1320 (GU-2279) (Table 22) (Alvey in Morris *et al*. 1996, 46), indicative of a Norse date for its formation. Most finds were undiagnostic, but the recovery of steatite fragments, and an incised piece of antler may support this determination. No other radiocarbon dates were produced for Area 3, and as such the layers of windblown sand are not directly dated.

Phase	Activity
Z	Turf and topsoil
Y	Three layers of windblown sand, measuring c. 0.68m in depth. The two lower layers were dark and silty at the interface with the midden
X	A later phase of sandy midden, of unknown depth (GU-2279).
W	Stonework and industrial waste

Table 20. Phasing and activity at Beachview Burnside Area 3. After Alvey in Morris et al. 1996, 46.

Beachview Burnside Area 2

Burnside Area 2 again comprised the remains of a substantial Late Norse midden accumulation covered by windblown sand, lying c. 150m southwest of Area 3 (Alvey in Morris *et al.* 1996, 55-6) (Table 21). It is likely that the remains encountered in Area 2 represent the outer peripheries of the Beachview Studio site (below). The midden contained frequent sand inclusions, suggesting sand incursion was occurring regularly throughout the accumulation of the midden – with the highest sand components identified in the peripheries of the midden.

Phase	Activity
Z	Turf and topsoil
Y	Spread of coarse medium sandy loam
X	Development of a series of three midden deposits with frequent sand inclusions. The latest episode of midden deposition was separated from the penultimate episode by a ‘patch’ of windblown sand (dimensions not stated) (GU-2281).
W	A series of mixed sandy clay deposits, sand lenses, and midden overlain by a spread of burnt stones (GU-2280).
V	An area of stonework, likely to represent building collapse and related to structural remains recorded in Cutting 2.

Table 21. Phasing and activity at Beachview Burnside Area 2. After Alvey in Morris et al. 1996, 53-6.

Lab ID	Material and context	Date cal. AD (at 95% probability)
GU-2279	Area 3, Phase X. Unidentified mammal bone from sandy midden	1020-1320
GU-2280	Area 2, Phase W. Unidentified mammal bone from mixed midden and clay	1020-1280
GU-2281	Area 2, Phase X. Unidentified mammal bone from midden uppermost deposit	1030-1280

Table 22. Radiocarbon determinations from Beachview Burnside Areas 2 and 3. Morris et al. 1996, 292-3.

Beachview Studio Site

The Beachview Studio site lies c. 50m south of the excavated areas at Beachview Burnside, with excavations taking place in Area 1, and Sub-Areas D/E (Figure 4.27). Excavation revealed a mound comprised of substantial Viking midden and sand deposits, and structural remains which for the most part can be correlated between the two areas (Table 27). Five structural phases comprised the construction and remodelling of a sub-rectangular building and corn drying kiln – punctuated by periods of use and disuse (Table 25) (Emery in Morris *et al.* 1996, 132). Multiple episodes of windblown sand accumulation took place throughout the life of the site, from at least c. cal. AD900 through to c. AD1200 (Table 26).

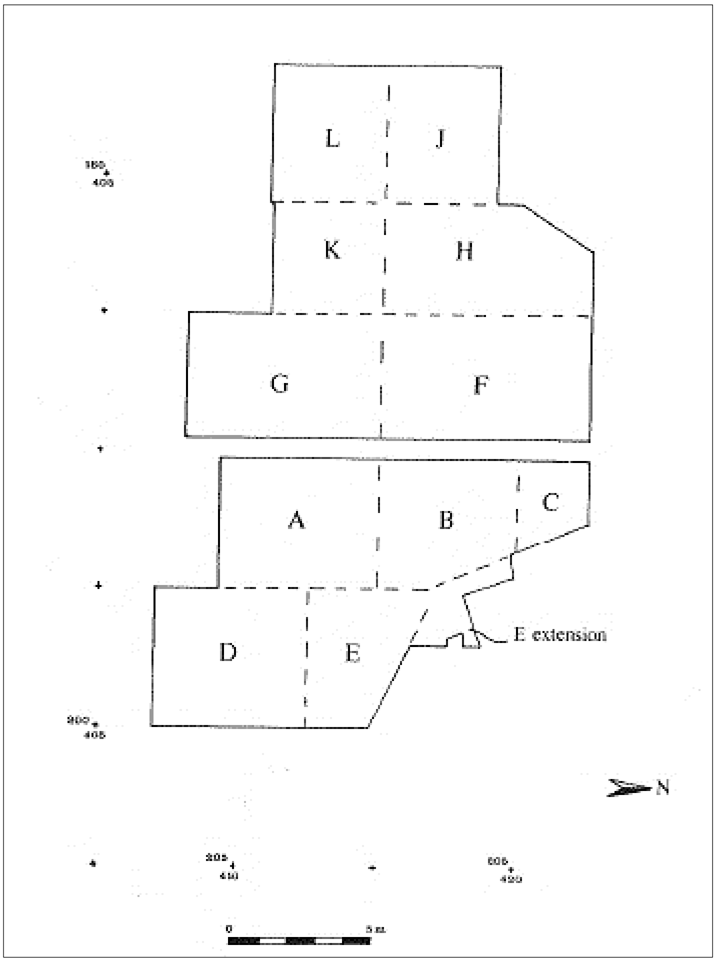

Figure 4.27. Beachview Studio Area 1 with Sub-Areas marked. Morris et al. 1996, 76.

Beachview Studio main Area 1

The main portion of Area 1 comprised Norse-Viking period structural remains infilled with windblown sand and midden deposits (Table 23; Table 24), with Sub-Areas D/E representing the peripheries of the main settlement.

Phase	Activity
Z	Further layers of sand mixed with occupation deposits overlying Phase Y sands, followed by modern rubbish dumping
Y	Accumulation of several layers of windblown sand interspersed with occupation deposits, sandy soils, and rubble (GU-2278, 2275) across the east and west of the site both within and outside the remains of the collapsed subrectangular structure. The divisions and relationships between the various sands was difficult to ascertain. Construction of a length of enclosing wall.
X	Construction of a curved wall, possibly forming part of a bowed structure, over the Phase W sand
W	Construction of a drain into the rubble, which filled with sand.
V	Collapse of the structure walls leaving layers of rubble mixed with sands (GU-2272)
U	Layers of ash and mixed sands accumulate against the Phase N curved structure.
T	Section of walling set onto Phase S midden, butting up against the Phase M wall and narrowing the structure
S	Phase R midden overlain by a further midden deposit containing mixed grey-brown sand and patches of calcareous windblown sand (GU-1191, 2277). This was covered with a spread of greyish sand containing occupation deposits (GU-2274).
R	A circular pit was dug through the underlying deposits into the Phase J sand, and filled with midden material. A layer of clayey midden and rubble overlay the Phase Q clays and the pit (GU-2273)
Q	Phase P occupation deposits overlain by a spread of yellow-brown clayey sand.
P	Accumulation of various occupation deposits including clay, ash, and dirty sand around the second hearth
N	Insertion of a curved wall into the subrectangular building next to the Phase M wall. The wall surrounded a second hearth. This kiln like structure is interpreted as serving a drying function.
M	Construction of stonework features around the south of the structure, including a wall constructed against its north face
L	A series of peat ash layers and clay lumps covering the hearth and part of the sandy floor beneath
K	Construction of an early E-W aligned sub-rectangular structure, containing a hearth set in sand.
J	Layer of calcareous sand (no dimensions given)

Table 23. Phasing and activity at Beachview Studio main Area 1. Morris et al. 1996, 101-128.

Lab ID	Material and context	Date cal. AD (at 95% probability)
GU-2273	Area 1, Phase R. Mammal bone from clayey midden	1134-1280
GU-1191	Area 1, Phase S. Seed from Phase S midden	990-1220
GU-2277	Area 1, Phase S. Mammal bone from Phase S midden	1000-1220
GU-2274	Area 1, Phase S. Mammal bone from Phase S grey sand overlying midden	1190-1379
GU-2272	Mammal bone from Phase V rubble	1163-1300
GU-2278	Area 1, Phase Y. Mammal bone from sand deposits	990-1210
GU-2275	Area 1, Phase Y. Mammal bone from sand deposits	1004-1260

Table 24. Radiocarbon determinations from Beachview Studio main Area 1. Morris et al. 1996, 292-3.

Beachview Studio Sub-Areas D/E

Sub-Areas D/E contain less structural remains (Table 25), and appear to represent the peripheries of the main Area 1 settlement where middens and sands accumulated.

Phase	Activity
Z	Further windblown sand layers covered by subsoil and turf
Y	A series of mixed windblown sand deposits of various colours interspersed with midden accumulations.
X	Construction of a small 'shed' structure with an earth core
W	Frequent dark sands interspersed with light patches of sand, containing frequent mammal and fish bone. Mammal bone from an orange sand yielded a determination of cal. AD1020-1280 (GU-2269)
V	The deposition of an extensive windblown sand deposit over the entire excavated area (dimensions not stated)
U	Yellow windblown sand proceeded to cover the Phase R wall, before being overlain by midden. Mammal bone from the yellow sand yielded determination of cal. AD1001-1410 (GU-2270)
T	A spread of tumble and midden with windblown sand lenses which accumulated to the north of the trench
S	Multiple mixed layers of calcareous windblown sand deposits (GU-2268) (no dimensions stated) were banked against the north side of the Phase R wall.
R	Construction of a roughly coursed wall running NW-SE for c. 6m.
Q	Calcareous sand deposits overlain by a rubble spread. This was covered by further orange windblown calcareous sand (no dimensions stated) (GU-2272).

Table 25. Phasing and activity at Beachview Studio site Area 1, D/E. After Alvey in Morris et al. 1996, 77-88.

Lab ID	Material and context	Date cal. AD (at 95% probability)
GU-2268	Area D/E, Phase S. Mammal bone from sand banked up against Phase R wall	1030-1280
GU-2269	Area D/E, Phase W. Mammal bone from orange sand	1020-1280
GU-2270	Area D/E, Phase U. Mammal bone from yellow sand overlain by midden	1001-1410
GU-2272	Area D/E, Phase Q. Mammal bone from orange sand overlying rubble spread	980-1206

Table 26. Radiocarbon determinations from Beachview Studio site Areas D/E. Morris et al. 1996, 292-3.

Windblown sand at Beachview

The windblown sand accumulations at the Beachview sites are relatively poorly-dated, but nevertheless a few conclusions can be drawn which suggest that considerable sand mobilisation took place in the vicinity from the 9th-13th centuries AD. It is likely that all excavated areas form part of a larger site at Beachview which experienced multiple episodes of such sand mobilisation during its occupation. At Beachview Burnside Area 3, it can only be concluded that the calcareous sands of Phase Y accumulated around, and after, cal. AD1020-1320 (GU-2279) and that it presumably comprised periodic episodes of accumulation given the distinct banding. Sand accumulation was noted in Phases W and X at Burnside Area 2, with the loam of Phase Y also containing windblown sand components. The sand lenses intermixed with midden and sandy clay over the remains of building collapse in Phase W accumulated around cal. AD1020-1280 (GU-2280). The Phase X sands, which punctuated the development of midden deposits in the area, were deposited within a similar time period with the uppermost midden deposit yielding a determination of cal. AD1030-1280 (GU-2281).

Windblown sand deposits were identified in the majority of phases at Beachview Studio (J, Q, S, T-W, Y, and Z) (see Table 27), with most being identified in the peripheries of the site (Areas D/E). The inhabitants of Beachview Studio settled directly over basal sands in Phase J. As the buildings went out of use in Phase S, windblown sands infilled the structures at c. cal. AD900-1220 (GU-1191, 2277), continuing into Phases V, Y, and Z until at least c. cal. AD1163-1300 (GU-2272). Similar dates were yielded for the peripheries. The earliest excavated deposits in Sub-Areas D/E comprised two layers of calcareous sand separated by a rubble spread in Phase Q. Unidentified mammal bone from the upper sand yielded a determination of cal. AD980-1206 (GU-2272). Further accumulations of mixed calcareous sands banked against the north of a NW-SE aligned wall constructed in Phase R, presumably having been mobilised by a southerly prevailing wind. Mammal bone from the lowermost sand yielded a determination of cal. AD1030-1280 (GU-2268) for its deposition. Sand continued to accumulate in the peripheries after cal. AD1020-1280 (GU-2269).

<table>
<tr><th>Activity</th><th>Main Area 1 phase</th><th>Sub-Areas D/E phase</th></tr>
<tr><td>Pre-structure sands</td><td>J</td><td>Q</td></tr>
<tr><td>Enclosure wall</td><td>-</td><td>R</td></tr>
<tr><td>Occupation deposits</td><td>-</td><td>S</td></tr>
<tr><td></td><td>-</td><td>T</td></tr>
<tr><td></td><td>-</td><td>U</td></tr>
<tr><td>Structure and ?enclosure</td><td>K</td><td>V</td></tr>
<tr><td>Occupation within and outside structure</td><td>L</td><td>W</td></tr>
<tr><td>Rebuilding of S wall and construction of ‘shed’ to E</td><td>M</td><td>X</td></tr>
<tr><td>Further occupation and collapse</td><td>-</td><td rowspan="12">Y</td></tr>
<tr><td>Construction and use of kiln; sand and midden to E; wall to S</td><td>N</td></tr>
<tr><td>Infill of rectangular structure</td><td>P</td></tr>
<tr><td></td><td>Q</td></tr>
<tr><td></td><td>R</td></tr>
<tr><td></td><td>S</td></tr>
<tr><td>Narrowing of structure</td><td>T</td></tr>
<tr><td>Collapse of structure</td><td>V</td></tr>
<tr><td>Drain construction</td><td>W</td></tr>
<tr><td></td><td>X</td></tr>
<tr><td>Sand and midden over site</td><td rowspan="3">Y</td></tr>
<tr><td>Enclosing wall</td></tr>
<tr><td>Sands</td><td rowspan="4">Z
Z
Z
Z</td></tr>
<tr><td>Garage track</td><td>-</td></tr>
<tr><td>Sand accumulation</td><td>Z</td></tr>
<tr><td>Modern activity</td><td>Z</td></tr>
</table>

Table 27. Summary of links between Beachview Studio Area 1 and Sub-Areas D/E. After Morris et al. 1996, 160.

4.4.5. Saevar Howe

Saevar Howe lies c. 1.2km south of the Point of Buckquoy and c. 1km southwest of the Beachview sites, within a wider landscape of extensive blown sand. The site was first investigated by James Farrer from 1862-1867, and comprised extensive deposits of blown sand covering, and interleaving with, Pictish and Viking period structural remains, most notably a long-cist cemetery containing c. 14 burials (Farrer 1862; Hedges, J. W. 1983, 74). Excavations took place until “…the enormous quantity of sand rendered it impossible to carry the investigation any further” (Farrer 1862, 104).

Further excavation took place in 1977 (Hedges, J. W. 1983), during which radiocarbon dating and environmental samples were recovered from four exploratory trenches (Figure 4.28). Of these, Trenches A and B were the largest and contained the majority of recorded remains. The excavation confirmed the presence of the Viking long-cist cemetery (although this was not excavated) and associated deposits, and developed chronological phasing for the site. Activity at the site can be divided into two main phases, with subphases separated by deposits of calcareous windblown sand.

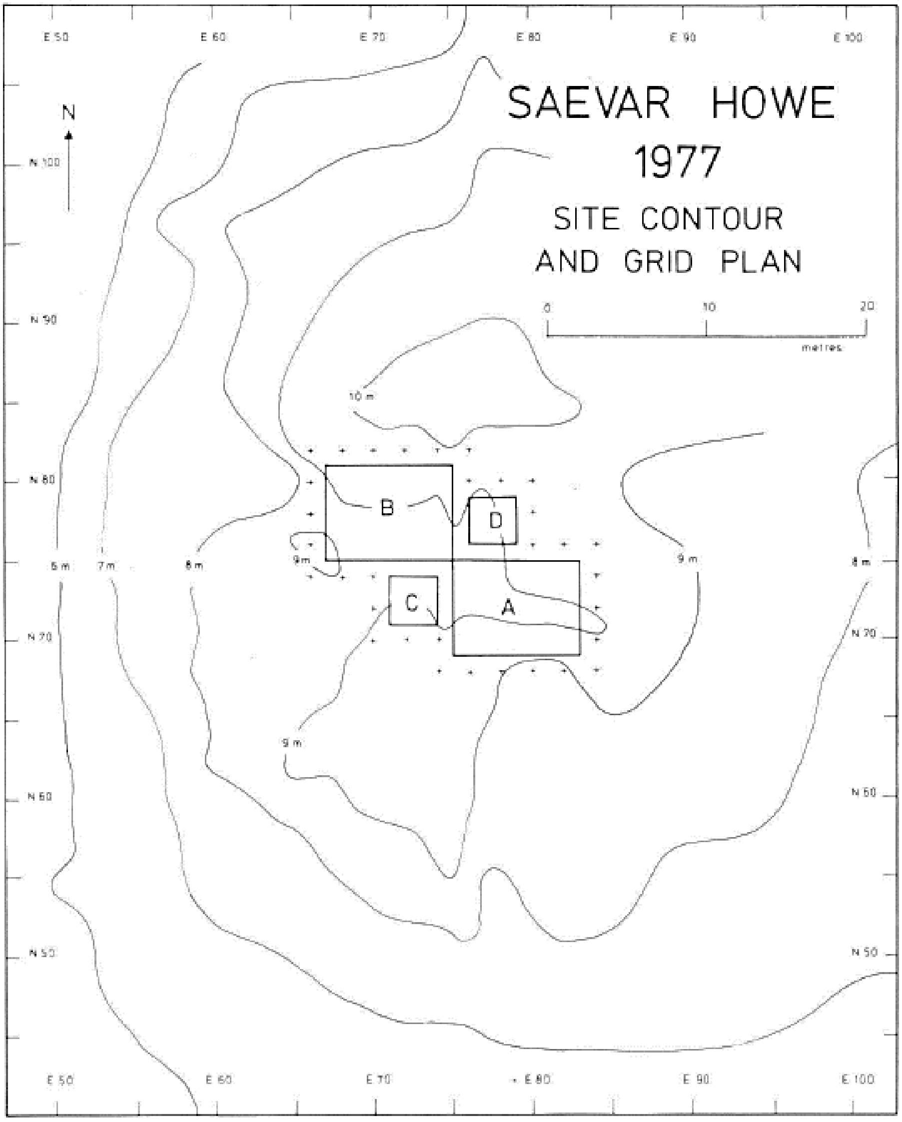

Figure 4.28. Trenches and contours at Saevar Howe. Hedges, J. W. 1983, 75; Figure 2.

Chronology and phasing

Phase I

A series of Pictish structures, with each phase divided by a deposit of windblown calcareous sand which appears to have been predominantly mobilised from the north.

Phase Ia. Structural remains comprising two E-W aligned retaining walls (L76 and L69) were constructed into an earlier windblown sand layer, revealed across the trenches. Earlier structural remains were noted to lie beneath the sand upon which the walls were constructed, but these were not investigated (Hedges, J. W. 1983, 80). No dimensions are given for this sand, which was overlain by a patchy surface of stabilised humic sand and midden. A midden deposit measuring c. 1m squared and 0.10m deep accumulated against wall L76. The structures partially collapsed at the end of their primary use, allowing c. 0.40m of calcareous windblown sand to accumulate across the area (Hedges, J. W. 1983, 80).

Phase Ib. To the east of the Trench B, the blown sand and the earlier midden accumulation were dug away, with one of the Phase Ia retaining walls (L76) being rebuilt, banked into the sand, and extended eastwards for c. 4m (renamed L20). A further stabilised ground surface measuring c. 0.15-020m in depth then developed over Phase Ia's 0.40m of windblown sand, butting up against wall L20. A further 0.30-0.40m of windblown sand then accumulated against this wall and across the excavated area (Hedges, J. W. 1983, 80; Figure 6).

Phase Ic. Three groups of walls were constructed on top of the previous sand deposit. More drifted sand butted against the walls constructed to the east of the site. All the structures were found to have collapsed prior to the start of Phase IIa and covered with windblown sand (no dimensions given), indicative of an abandonment of the site prior to the construction of the Viking houses (Hedges, J. W. 1983, 81).

Phase II

Three superimposed Viking 'hall house' structures measuring c. 12m long with associated features, occupied over a significant period of time in Trenches A and D.

Phase IIa. A 0.10-0.20m ground surface had formed over the Phase I remains, over which the first of three 'halls' was constructed. The remains were poorly-preserved, but appear to represent an E-W aligned hall structure. A retaining wall was also constructed to the west of the house, perhaps functioning as a means of keeping the area to the west of the house free from drifting sand, where c. 0.40m of midden accumulated (GU-1402). Phase IIa ended with the cessation of occupation inside the house, structural collapse, and the covering of the floor and the south of the house with c. 0.23-0.70m of windblown sand layers interleaved with humic sand (Hedges, J. W. 1983, 82).

Phase IIb. In this phase, a new hall-house was constructed over the sand and collapsed remains, on the same alignment as the Phase IIa structure with a southern entrance and a central path through the structure (GU-1400). Sand continued to be mobilised and periodically consolidated, to a depth of c. 0.70m outside the house (Hedges 1983, 83). On the abandonment of this house, a c. 0.20m deep layer of sand was able to blow into the building and its immediate surroundings, possibly driven by a collapse of the north wall. A ground surface the developed over the collapsed wall (no dimensions given) (Hedges, J. W. 1983, 83).

Phase IIc. On the reoccupation of the site, the sand was mostly cleared out to a depth of c. 0.10m and the Phase IIb hall-house was reoccupied and rebuilt with a wall core of sand and stone. The remains of the Phase Ic house were the best-preserved, and included a rebuilt north wall and a reconstructed southern entrance with a flagged drain running beneath it. Late in the occupation of the house, the southern entrance was blocked by a double-faced wall, and the drain filled with sand (GU-1401). After occupation, midden deposits (no dimensions given) accumulated inside the house (Hedges, J. W. 1983, 85).

The dating evidence for settlement at Saevar Howe is generally poor; recovery of bone combs, pins, and steatite fragments typologically consistent with Pictish and Norse activity provide some dating evidence, and are supported by a small suite of three radiocarbon determinations, although these were only recovered from Phase II contexts (Table 28). The determinations for activity at Saevar Howe are of variable quality, but appear to demonstrate that occupation took place from at least the 7th century cal. AD, and perhaps into the early 10th (Hedges. J. W. 1983, 116).

Lab ID	**Material and context**	**Date cal. AD (at 95% probability)**
GU-1400	Willow (*salix*) charcoal, from central path of Phase IIb house	660-990
GU-1401	Mixed faunal remains (fish, mammal, and shell) from fill of Phase IIc drain	540-720
GU-1402	Spruce (*picea*) charcoal, from midden-enriched ground surface contemporary with the first of the three Phase II houses (Phase IIa)	660-890

Table 28. Radiocarbon determinations from Saevar Howe. After Hedges, J. W. 1983, 108.

Windblown sand at Saevar Howe

The drifting of windblown sand, and accumulation over the site, (as opposed to the larger sandblows which appear to separate the main phases of occupation) appears to have occurred on a regular basis in the excavated areas. It was noted by the excavators that the greatest and deepest accumulations of sand occurred to the north of the site (Hedges, J. W. 1983), indicative of a southerly prevailing wind. No dates were yielded on Phase I material, and the dates which were yielded from Phase II contexts provide only a relative chronology for the accumulation of windblown sand.

Mixed faunal remains from the sand-filled drain of the Phase IIc house may offer a direct date range for sand deposition at cal. AD540-720 (GU-1401). Caution must be exercised, however, given that the bulk dating sample comprises a mixture of faunal remains (including marine shell) thus compromising the reliability of the determination. Given its relatively early date range (lying within the Late Iron Age-Pictish period) it is possible that this material was redeposited from an earlier context, or that the phasing of the drain structure has been misinterpreted. The basic radiocarbon chronology allows a tentative suggestion of Pictish (from at least c. cal. AD660-890 (GU-1402) in Phase II) and Norse sand accumulations having taken place throughout the life of the settlement. It was acknowledged by the 1977 excavators that it was difficult to interpret the partially-excavated remains at Saevar Howe (Hedges, J. W. 1983, 77) and resultantly, there are many aspects of the chronological sequences which would require further investigation before firm conclusions on the nature of sand accumulation at the site could be developed.

4.4.6. Discussion: windblown sand at the Bay of Birsay

A broad chronological pattern can be observed in the Bay of Birsay, with the earliest settlements of the Late Neolithic and Early Bronze Age recorded thus far identified at the north of the Bay, clustered around the Point of Buckquoy, with later activity recorded southwards in the sandiest area of Birsay Bay. Unsurprisingly, the most substantial recorded episodes of sand mobilisation took place here. The earliest dated sand deposits at Birsay Bay accumulated from at least 2630-2180 cal. BC (GU-1557)) at Point of Buckquoy Area 6. There is a lack of chronological evidence for Late Bronze Age-Early Iron Age activity at Birsay Bay, either resulting from a shift in settlement activity during this period, or a lack of identification.

From the Late Iron Age, settlement appears to have migrated southwards with a clustering of Norse activity – and increased sand mobilisation – at Red Craig and Beachview. Late Iron Age sand mobilisation was recorded at South of Red Craig Area 1 (from c. cal. AD55-585 (GU-1554, 1551), with further movement spanning the native-Norse interface at around cal. AD620-1035 (GU-1956, 1957). The latest dated sand deposits were identified at Beachview Studio site, with mobilisation and deposition identified from around cal. AD980-1206 (GU-2272) and into the Early Medieval period (from cal. AD1020-1280 (GU-2269) (Morris et al. 1996, 292-3).

As is the case in other locales, the increased incidences of later sand movement could be partly attributed to an increased investment in the landscape both in terms of settlement and agriculture. In most cases, sand mobilisation was manifested in layers which had accumulated in areas which had gone out of use. A long tradition of the use of sand and sandy subsoils for construction and burials can be identified at Birsay Bay, from the Late Iron Age (around the 2nd century cal. AD) into the Norse and Early Medieval periods, with radiocarbon determinations for the Beachview sites broadly clustering around cal. AD1000-1300. Birsay Bay remained as a persistent place into the Medieval period, with the construction of St Magnus' Kirk illustrating an acknowledgement and understanding of sand stabilisation strategies, and a desire to continue occupation here.

The environmental sampling at Buckquoy (Appendix 1, not to be confused with Point of Buckquoy) offers some supplementary detail on the nature of the later landscape at Skaill. A nearby eroding coastal section c. 200m north of the site was sampled for molluscan analysis (Evans, J. in Ritchie 1977), revealing an interesting environmental sequence which unfortunately not dated. A buried soil above natural was overlain by c. 0.18m of calcareous windblown sand containing grassland snail species indicative of a period of deforestation of the previously wooded-soils (Evans, J. in Ritchie 1977, 217). Midden then accumulated over this sand. Although it is tempting to associate this midden with the scant remains at Buckquoy, or indeed those further north at Point of Buckquoy, the lack of any radiocarbon dating renders this impossible. It can, however, be used to further confirm that sand movement took place during periods of human occupation across the Point of Buckquoy.

Excavation strategy

Most archaeological investigations in the Bay of Birsay took place through the medium of 'tapestry' excavations. Such approaches were a new methodology in this region, and although they were successful and informative to an extent, it becomes clear that such eroding sections, even when cleaned, sampled and recorded, are not reliable or representative indicators of the nature of these sites in part due to the stratigraphic complexity and deflation of deposits. Many key deposits at the sites lack the scientific dating required to draw firm conclusions about windblown sand chronologies, and as such only very broad ranges based on relative dates can be offered in the majority of cases. It is unfortunate that in the case of the important site at Beachview, no published stratigraphic sections or measurements for deposits are available ensuring that it is not possible to give dimensions for the sand deposits. Resultantly, it is difficult to estimate the nature and extent of the frequent windblown sand accumulations here. The current lack of chronologically-constrained palaeoenvironmental data for the bay ensures that a contextual environmental narrative like that developed for the Bay of Skaill cannot be attempted here.

4.5. Deerness

Deerness comprises a peninsula at the east of Mainland Orkney, to which it is joined by a dune-covered isthmus. The west coast is low-lying, while the north, south and east coasts are dominated by high cliffs. Two particularly distinctive sandy bays are located on the south and east coasts, namely Newark Bay and Sandside Bay respectively. Significant blown sand deposits forming dunes and links are located at these bays, as well as at Mirkady Point and St Peter's Pool at the east (Buteux *et al.* 1997, 7). Sandside Bay stands as an area of geological significance in that it contains aeolianite (lithified sand) beneath the dunes (Mather *et al.* 1974, 31).

4.5.1. Skaill, Deerness

Unlike the other sites dealt with for Mainland Orkney, the site at Skaill (Deerness) lies on the east coast of the island on the south-central beach of the shallow Sandside Bay (Mather *et al.* 1974, 31) (Figure 4.29). The bay is exposed to long fetches from the east and northeast, and the sands are characterised by their high carbonate content. The windblown sand covers a total of c. 35ha (Dargie 1998b, 67; Table 1c). The site at Skaill lies at the coast edge within extensive sand dunes, behind which have developed interbedded peats and sand.

Excavations were carried out by Peter Gelling (1963-81) and later published by Simon Buteux (Buteux *et al.* 1997). The publication of Gelling's work is based on excavation records which were frequently incomplete, and as such many aspects of the report have been somewhat pieced together. Much of the dating evidence is based only on diagnostic artefacts, and there are few published section drawings to estimate any deposit depths not given in the text. Six locations (each treated as a specific site) were investigated within a radius of c. 100m, comprising a settlement sequence encompassing the Late Bronze Age to the post-Medieval period (Figure 4.30). Sites 1-4 lay within the main coastal blown sand deposits, while Sites 5 and 6 lay within cultivated fields (Buteux *et al.* 1997, 2). The sites and their broad periods are summarised below, firstly simply by site number and then chronologically. All radiocarbon determinations are calibrated using curves developed by Pearson and Stuiver (1986).

Site 1: Norse, Medieval

Site 2: Norse

Site 4: Norse, post-Medieval

Site 5: Late Bronze Age

Site 6: Iron Age, Pictish

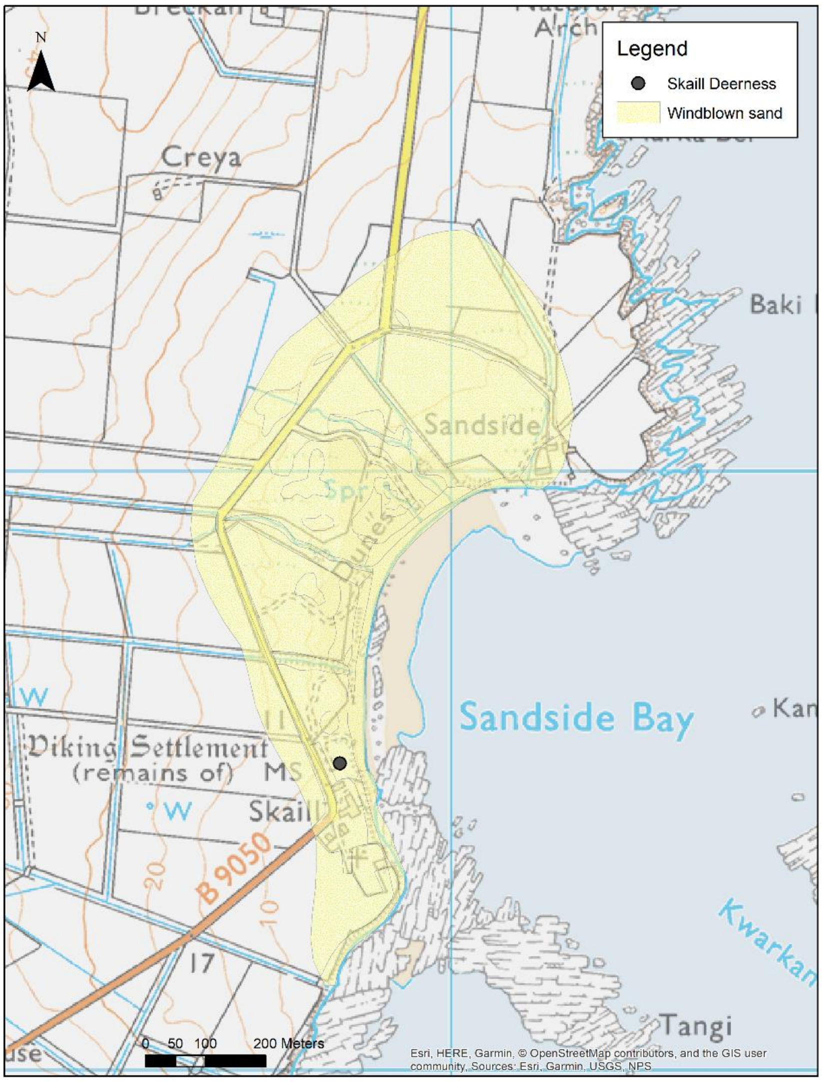

Figure 4.29. Location of Skaill Deerness

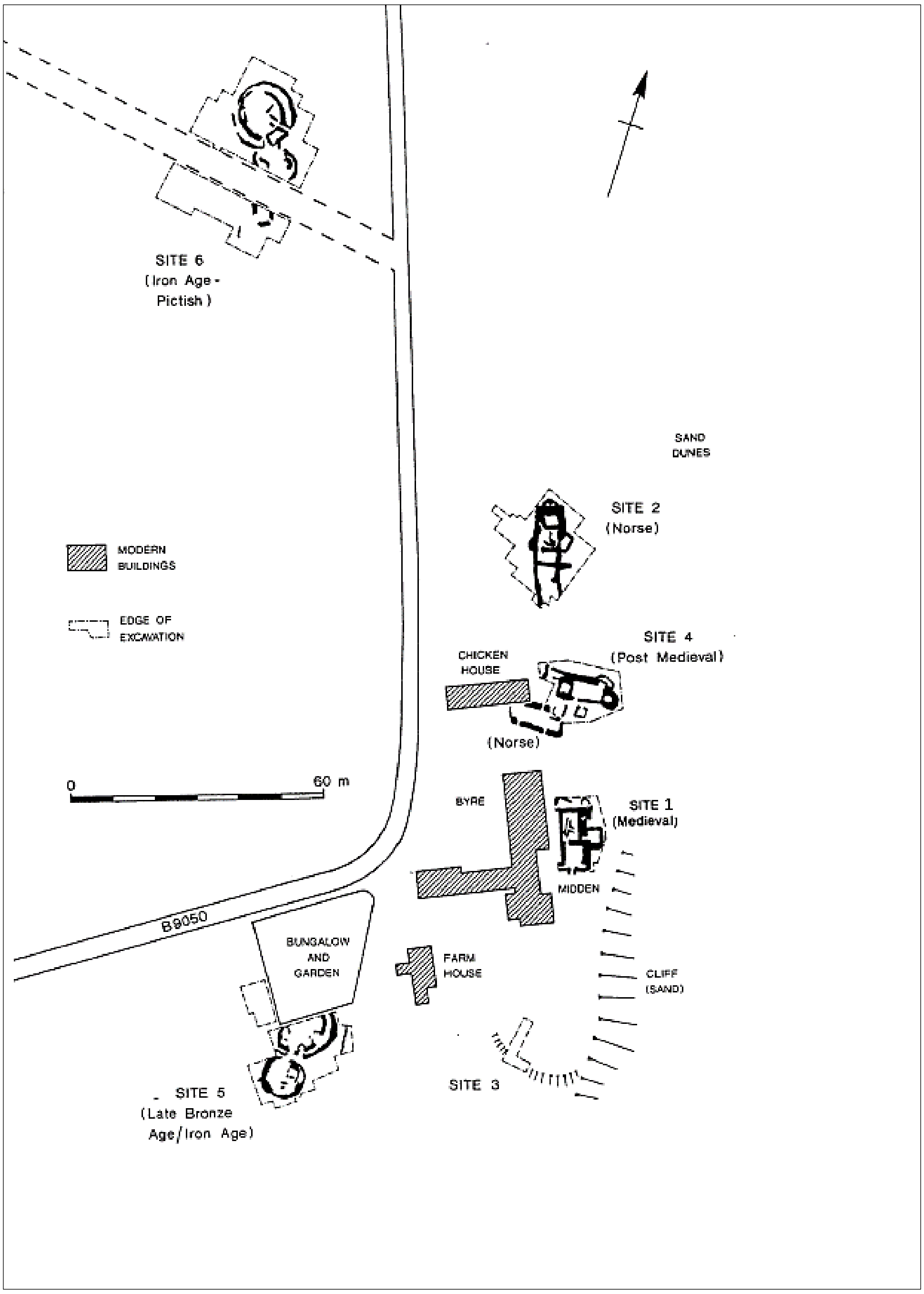

Figure 4.30. Location map of Skaill sites discussed in text. Buteux *et al*. 1997, 5.

Site 5: Late Bronze Age-Pictish settlement

Site 5 is located south of the modern bungalow at Skaill (Figure 4.30). Excavation here produced no known record of windblown sand deposits. The site was excavated in a series of distinct areas year by year (1969-1973), with each backfilled after its respective season. Resultantly, the whole extent of the excavated area was never visible at the same time. It is likely that this excavation area represents only a small portion of the total settlement (Buteux *et al.* 1997, 24). Little written record exists for Site 5, and the context labelling and numbering system appears to have disorganised and patchy. Three stratigraphic 'levels' of occupation were identified by Gelling, with six phases of occupation attributed to them. These labels are often confusing to follow, and as well as being described here, they are summarised in Table 29. Level 3 (Phase 2) comprises the activity immediately preceding, or perhaps contemporary with, Level 2. Level 2 comprises the occupation of two Late Bronze Age stone buildings (Structures 1 and 2) which represent the most extensive occupation sequence at the site (Phases 3-6). Level 1 comprises the Iron Age or Pictish reoccupation of the site (Phases 7 and 8) (Buteux *et al.* 1997, 24).

Level	Phase	Period	Activity
1	7 and 8	Middle-Late Iron Age/Pictish	Reoccupation activity
2	3-6	Late Bronze Age	Construction and occupation of Structures 1 and 2
3	2	Middle-Late Bronze Age	Activity immediately preceding or contemporary with Level 2
-	1	Early Bronze Age	Ard cultivation of soils and windblown sand

Table 29. Summary of phasing and activities at Site 5, and their respective stratigraphic 'levels'. After Buteux et al. 1997, 28-9.

An ard-cultivated buried ploughsoil of up to 0.25m in depth (which overlay a sandy clay merging into boulder clay (Buteux *et al.* 1997, 17) (Figure 4.31) predated any structural occupation of the site, and has been attributed to Phase 1. Burnt bone (no species given) from the base of the soil dated its development to 1949-1752 cal. BC (OxA-1716) (Buteux *et al* 1997, 18; 253), in the Early-Middle Bronze Age. This ploughsoil was also identified beneath the Site 6 structural remains, and probably represents an earlier, 'missing' phase of settlement at the same locale (Buteux *et al.* 1997, 255).

Figure 4.31. Ard marks at Site 6. Buteux et al. 1997, 23.

In Phase 2 (Level 3) a series of features including pits, postholes and gullies were cut into the ardmarked soil, while Phases 3 and 4 (Level 2) comprised the construction of the sub-oval Structures 1 and 2 respectively. It is possible that the Phase 2 (Level 3) features do not represent a standalone phase, and are rather associated with Structures 1 and 2 (Buteux *et al.* 1997, 28).

Phase 5 (also Level 2) saw modifications to the structures which concluded in the joining of the two buildings to create a paired structure, a feature also noted at Skaill Site 6, Tofts Ness, and Links of Noltland. Use of Structure 1 ceased in Phase 6, when it was infilled with rubble and midden material. The ceramic assemblages from Phases 2-6 were dominated by bucket-shaped vessels, indicative of a Middle-Bronze Age occupation date (Buteux *et al.* 1997, 28-9). Phases 7 and 8 are described as reoccupation phases, and are contained within Level 1. Structure 1 was infilled with rubble and midden containing Early Iron Age flat-rimmed ware and Middle Iron Age everted rim ware in Phase 7. Phase 8 is recognised by an assemblage of Late Iron Age/Pictish artefacts as opposed to any distinctive structural remains. This assemblage was used to date Phase 8 to the 7^{th}-9^{th} centuries AD (Buteux *et al.* 1997, 29).

Only two radiocarbon determinations are available for the site; 354-305/240 cal. BC (Birm-397), and 370-1 cal. BC (Birm-413) which is a repeat of Birm-397. The Early-Middle Iron Age dates would fit within the site's Phase 7 reoccupation. It is unclear as to which of the six samples produced the determinations, and their stratigraphic location and composition (which is termed only as 'hearth material') is also unknown (Buteux *et al.* 1997, 252). Given the additional uncertainty surrounding the precise stratigraphy of the site it would be unwise to put too much emphasis on an effectively single date (Buteux *et al.* 1997, 29). Instead, only a broad period-based range can be assigned, with occupation tentatively dated to the Middle Bronze Age-Middle Iron Age.

Site 6: Early Iron Age-Pictish settlement

An Early Iron Age-Pictish settlement – Site 6 – was identified to the far northwest of the site, c. 200m north from Site 5 (Figure 4.30). A road divided the site into 6 North (excavated 1975-1978) and 6 South (excavated 1979-1981) (Figure 4.32). Evidence for windblown sand deposition was noted at this site. As at Site 5, the remains were divided into a number of stratigraphic levels (1-6), as summarised in Table 30 and Table 31. Levels 4-6 at Site 6 South broadly equate to Site 6 North's Level 2 (occupation of the roundhouse), while Levels 1-3 at Site 6 South equate to Site 6 North's Level 1 (post-roundhouse activity) (Buteux *et al.* 1997, 45). Numbers for specific phases of occupation within the stratigraphic levels were not used consistently by Gelling, who only referred to stratigraphic levels in the majority of his notes (Buteux *et al.* 1997, 38). Eight radiocarbon determinations were recovered from Site 6, all of which were from 6 North (Table 32). Furthermore, all of the dated materials were sampled from two trenches within Site 6 North: the 1974 trench, which was opened over the roundhouse entrance directly opposite the dividing road, and the 1975 trench, immediately east of the 1974 trench. As at Site 5, one trench was opened per year, and then backfilled.

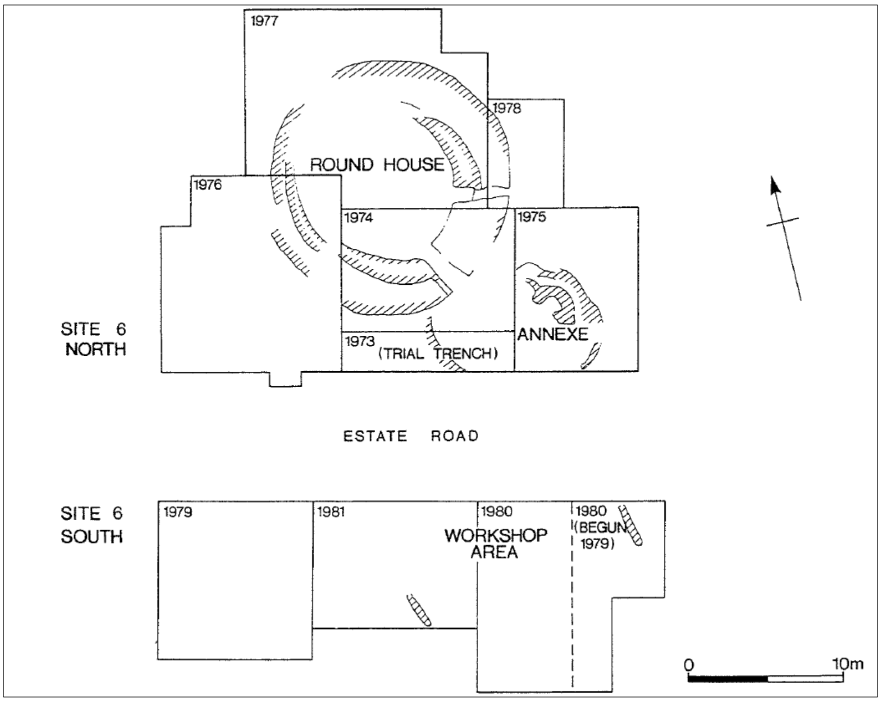

Figure 4.32. Excavated trenches at Skaill Site 6. After Buteux et al. 1997, 56.

Level	Period	Activity
1	Late Iron Age/Pictish	Post-roundhouse activity: paving and levelling
2	Early Iron Age	Construction and main occupation of roundhouse and associated features
3	Early Iron Age	Pre-roundhouse activity and roundhouse construction
-	Early Bronze Age	'Ardmark horizon'-

Table 30. Summary of stratigraphic levels and corresponding activities at Site 6 North. After Buteux et al. 1997, 38-55.

<table>
<tr><th>Level</th><th>Period</th><th>Activity</th></tr>
<tr><td>1</td><td rowspan="3">Late Iron Age/Pictish</td><td rowspan="3">Post-roundhouse activity: paving and levelling</td></tr>
<tr><td>2</td></tr>
<tr><td>3</td></tr>
<tr><td>4</td><td rowspan="3">Early Iron Age</td><td rowspan="3">Construction and main occupation of roundhouse and associated features</td></tr>
<tr><td>5</td></tr>
<tr><td>6</td></tr>
</table>

Table 31. Summary of stratigraphic levels and corresponding activities at Site 6 South. After Buteux et al. 1997, 38-55.

The earliest activity at Site 6 comprised the same ardmarked soil as that at Site 5. This was then cut by two pits and a hearth, the functions of which are unclear (Buteux *et al.* 1997, 51). These remains were assigned Level 3. Phase 2 of occupation (with associated deposits termed Level 2) saw the construction of a radially-divided roundhouse at Site 6 North, which was not assigned a structure number. Dating evidence is sparse (Table 32) but judging by the numerous modifications and remodelling (including the construction of a series of drains) which took place, it is likely that the structure was occupied over a long period of time, likely from the 1st-4th centuries AD. An annexe was also constructed to the southwest of the roundhouse in Site 6 North (Buteux *et al.* 1997, 52).

Features likely to be contemporary with the roundhouse and annexe were identified at Site 6 South, including a line of postholes and paved areas which developed into a small-scale industrial area containing a hearth and smithing slag later in the occupation of the roundhouse (Buteux *et al.* 1997, 52). The development of the early roundhouse has been dated by diagnostic artefacts and two radiocarbon determinations. The presence of stone ard points and flat-rimmed ware can only broadly place the construction and early occupation of the roundhouse and annexe to the Early Iron Age (c. 700-200BC). Similar ceramic forms and fabrics were recovered from the later phases of Site 5, suggesting that some form of continuity between the two sites is likely (Buteux *et al.* 1997, 255). A bulk charcoal sample (predominantly willow) from a pit belonging to the earliest part of the annexe was dated to 170 cal. BC–cal. AD 80 (Birm-764), in the Middle Iron Age. It is plausible that the annexe was a later addition to the roundhouse, thus accounting for the later date, but in the absence of a larger suite of radiocarbon dates it is difficult to come to any firm conclusions.

A second determination of cal. AD125-405 (Birm-593) was yielded on birch from a hearth underlying the deposits which later levelled the roundhouse. Ceramic assemblages characterised by flat-based wares with everted rims also appear to confirm a 1st-4th century AD occupation range (Buteux *et al.* 1997, 53; 252). A determination of cal. AD405-610 (Birm-766) was retrieved on willow from a 'furnace' in the annexe, and although this is cited as relating to the developed stage of roundhouse and annexe occupation (Buteux *et al.* 1997, 53), it is a comparatively late date and fits better within the determinations for the end of roundhouse occupation (see below).

Between c. AD400-600, the roundhouse, its annexe, and the remains in Site 6 South were levelled and paved over (Level 1) in what has been described as a radical change in the nature of the settlement (Buteux *et al.* 1997, 258). A mixed layer of sand and sterile soils sealed the remains of the roundhouse and this was then paved over, providing a level upon which a series of sub-rectangular structures could be constructed (see below). The dimensions of this deposit are not clearly stated, and no drawn sections are included in the monograph. They are described as covering "much of the area of the roundhouse and its associated structures", containing little in the way of occupation deposit (Buteux *et al.* 1997, 49).

Approximately three rectangular and subrectangular rooms or buildings reminiscent of Pictish style were constructed on this paved surface in Site 6 North and South. Midden spreads were also identified but due to their proximity to the modern ground surface the remains of the structures demonstrated considerable plough damage, and their precise form is unclear (Buteux et al. 1997, 52). They are likely to represent the remains of a group of roofed domestic structures and open yard areas. The paving and structures in both areas were later covered with soil and rubble spreads which appeared to form a surface, associated with occupation deposits. Windblown sand (no dimensions given) was observed both above and below these spreads in Site 6 North (Buteux *et al.* 1997, 48) but interestingly, not in Site 6 South.

The date range for the cessation of roundhouse activity and construction of the later rectangular structures is slightly better-informed, although none of the samples are numbered, or their precise stratigraphic position marked. A determination of cal. AD420-650 (Birm-592) was yielded on birch "hearth material" from an occupation layer between the Level 1 paving and topsoil. A determination of cal. AD550-670 (Birm-763) was yielded on willow charcoal "low in Level 1". A determination of cal. AD600-770 (Birm-762) was yielded on willow charcoal from an unknown deposit described by Gelling as "earlier than the end of Period 1 and earlier still than the fragmentary period 1 remains". A final determination of cal. AD600-770 (Birm-765) was yielded on willow and other material taken from immediately beneath the Level 1 paving. From these dates, a range of cal. AD420-775 can be presented for the late occupation of the roundhouse and the paving and structures which sealed the roundhouse and annexe (Buteux *et al.* 1997, 53; 252). No scientific dating information is available for the later rectangular structures, but diagnostic material dating to the 4th-6th centuries (a copper alloy brooch and pins) appears to confirm this age range. Settlement at Site 6 appears to have come to an end in the late 8th century AD (Buteux *et al.* 1997, 53). Approximately 100m to the southwest, the Site 2 Pictish/Norse settlement (below) was constructed around AD800.

Lab ID	Site	Material and context	Date (cal. BC/AD) at 95% probability
Birm-592	6 North, 1974 trench	Described as "hearth material (birch)" from 0.33m below modern ground surface. Occupation layer between Level 1 paving and topsoil, relating to final 'Pictish' occupation of site	cal. AD420-650
Birm-593	6 North, 1974 trench	Birch from a hearth under the sterile layer immediately below the Layer 1 paving. Relates to a late stage of Level 2 roundhouse occupation	cal. AD125-405
Birm-594	6 North, 1974 trench	Sample described as "hearth material…mostly soil and a very fine black organic deposit" which overlay leached sand natural in southeast corner of 1974 trench. Buteux suggests that while it should be disregarded for settlement dating evidence, it harmonises slightly with the determination (OxA-1437) on the ploughsoil from the North Cliff section (1513-1392 cal. BC). What is 1974 trench	1430-1010 cal. BC
Birm-762	6 North, 1975 trench	Willow, from Level 1 material. Dates Period 1 activity	cal. AD610-775

Birm-765	6 North, 1975 trench	Willow and other material from immediately beneath Level 1 paving and relating to occupation immediately prior to of contemporary with its laying	cal. AD600-770
Birm-766	6 North, 1975 trench	Mainly willow, “from furnace in Level 2”. Positive identification of the furnace in question was not possible, but it is possible that it refers to a feature in the annexe of Site 6 North	cal. AD405-610
Birm-763	6 North, 1975 trench	Mainly willow, from low in Level 1 occupation material	cal. AD550-670
Birm-764	6 North, 1975 trench	Mainly willow from a pit cut into the natural clay during Level 3 occupation in Site 6 North, and one of the earliest features at the site	170cal. BC-cal. AD80

Table 32. Radiocarbon determinations yielded from Site 6 North. After Buteux et al. 1997, 252-3.

Site 2. Pictish - Norse settlement.

Site 2 was located in the sand dunes 100m southwest of Site 6 (Figure 4.33), and comprised a sequence of houses (1-5), with 1 being the earliest structure, and 5 the latest. Chronologically-diagnostic material suggests that occupation began in the 8th/9th centuries AD and lasted into the 11th century. The earliest noted occupation of the area was represented by a series of small pits – possibly representing post pits for a timber structure - dug into the underlying dune sand. A rectangular structure, termed ‘House 1’ was then built above these remains, and also directly onto the sand (Edwards in Buteux *et al.* 1997, 71). It was orientated northwest-southeast, with its east and west walls lying on either side of a shallow depression in the sand. The occupation of House 1 was associated with the accumulation of a midden (‘Midden 3’) on the dune sand to the west of the structure’s door, from which chronologically-diagnostic material including a hipped pin and ‘Pictish’ combs were recovered. These roughly place the occupation of House 1 to the 8th-9th centuries AD (Edwards in Buteux *et al.* 1997, 72; 76).

House 1 was later remodelled into a longer north-south aligned rectangular building more reminiscent of a Norse structure, termed House 2. Ceramics of Norse manufacture appears to confirm this, and place its occupation to the 9th-10th centuries (Edwards in Buteux *et al.* 1997, 73). House 2 underwent a period of abandonment before House 3 was constructed above it. During this period, the east wall of House 2 collapsed inwards and the house was covered by c. 0.30m of windblown sand (Edwards in Buteux *et al.* 1997, 73). The observation of coloured banding within the sand deposit indicates of a gradual accumulation as opposed to a singular event.

House 3 – a Norse hall-house - was constructed above House 2 on the same alignment, and its occupation is associated with the accumulation of Middens 1 and 2. Norse fabric D pottery, pins, and single-sided composite bone combs place the occupation of House 2 and the accumulation of the middens to the 9th-11th centuries (Edwards in Buteux *et al.* 1997, 75). No further windblown sand deposits were noted in Houses 4 and 5, the use of which extended into the 12th century AD. These houses expanded the site northwards, with House 4 being constructed into the northern part of House 3, and House 5 being built into the northern part of House 4 (Edwards in Buteux *et al.* 1997, 75). The true extent of Norse settlement at Site 2 is unclear, but it is likely that Houses 1-3 largely acted as ancillary buildings with the rest of the settlement likely to have been eroded or buried in the sand dunes (Buteux *et al.* 1997, 254).

Figure 4.33. Site 2 at Skaill, Deerness. RCAHMS Online Digital Images SC 450812

Site 4. Norse and Medieval settlement

Midway between Sites 1 and 2, a Norse and Medieval settlement with evidence for windblown sand deposition was termed Site 4. The remains comprised an east-west aligned Norse domestic structure which was built directly upon the dune sand, and the remains of a post-Medieval barn and kiln. After its use, the Norse structure was covered by 1.25-1.50m of windblown sand which provided a stratigraphic separation between the Norse and post Medieval remains (Edwards in Buteux *et al.* 1997, 78). The barn was orientated east-west, with the kiln lying at its eastern extent, and was constructed into and against dune sand. A paved path leading to the barn's south-facing door was framed by two small square structures. The east wall of the structure to the east of the path had been constructed against the dune sand (Gelling *et al.* in Buteux *et al.* 1997, 211). There is little dating evidence available for the structures at this site; at best the barn and kiln (which are tentatively dated to the 16th century by their architectural features) provide a broad *terminus ante quem* for the construction and occupation of the Norse building. The Norse building is dated only by its association with Norse-style pins and a corroded iron spearhead, as well as its turf wall core (Edwards in Buteux *et al.* 1997, 79). Gelling (1984, 32) refers to an 'occupation deposit' within the sand, suggesting that this sand accumulated over time as opposed to during a single event.

Sites 1 and 3. Norse and Medieval remains

The remains recovered from Sites 1 and 3 (both of which lie to the south of Site 4) have been grouped together for the purpose of this summary, given the scant nature of the evidence for Site 3. Site 1 comprised a series of fragmentary walls constructed upon a thin layer of sand (no dimensions given) overlying boulder clay. A single-sided composite Norse comb was recovered from an occupation deposit associated with the walling, and offers a possible Late Norse date for these fragmentary remains (Gelling *et al.* in Buteux *et al.* 1997, 80). After the Norse building became derelict, a north-south orientated Medieval building divided into two rooms (1 and 2) was constructed above it. Approximately 0.40m of clean windblown sand had accumulated on the east side of Room 1, opposite the entrance - presumably during a period of dilapidation where sand was able to blow through the entrance (Gelling *et al.* in Buteux *et al.* 1997, 210-11). A layer of clean clay was then deposited over the top of this sand, presumably in an attempt to level the floor for a later period of use (Gelling *et al.* in Buteux *et al.* 1997, 220; Figure 4.34).

Site 3 lies south of Site 1, and comprised two phases of activity revealed in a 10m long L-shaped trench. A section of drain running north-south represented the earlier phase, covered by an area of paving. A paved path was then laid across it in the later phase. These remains were all sealed by a deep midden deposit. No datable material was recovered for either phase, but Gelling suspected that they belonged to the Norse period (Edwards in Buteux *et al.* 1997, 81).

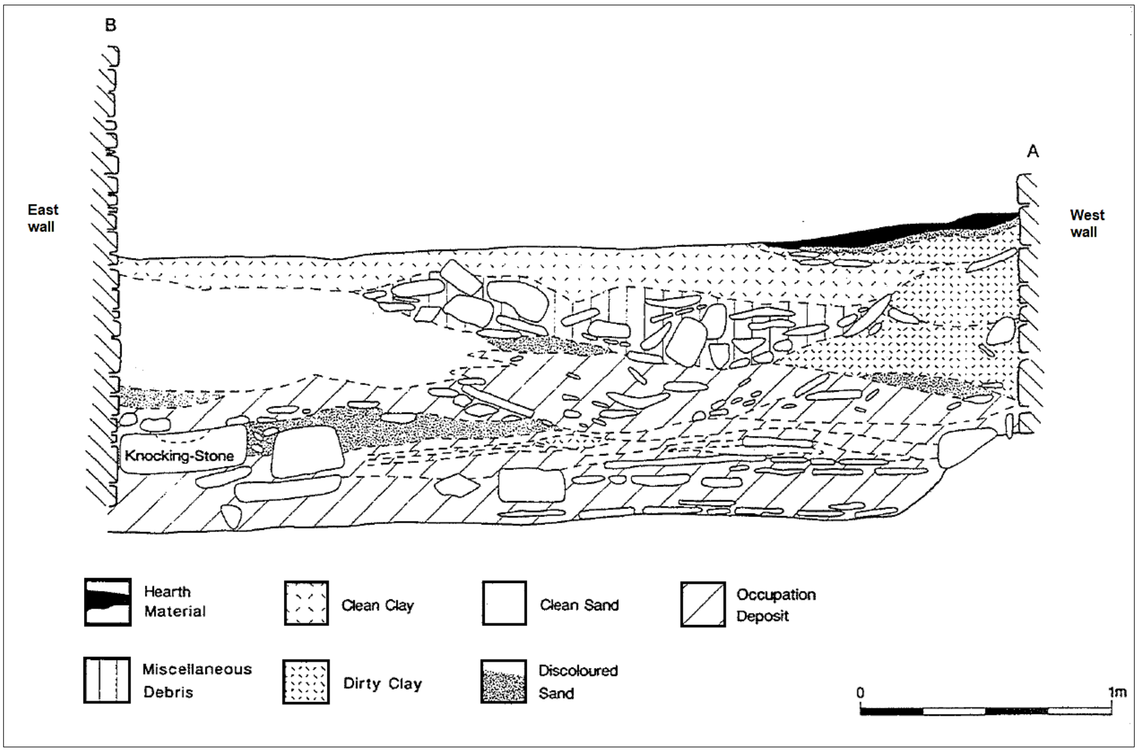

Figure 4.34. Section through Site 3's Room 1. After Buteux et al. 1997, 220.

4.5.2. Discussion: windblown sand at Skaill, Deerness

Five windblown sand deposits were visually identified across five sites at Skaill, and are summarised chronologically here. The first two deposits were identified at Site 6, where sands accumulated firstly after cessation of Iron Age activity, and secondly after Pictish activity at the site. At Site 2, the east wall of Norse House 2 collapsed and c. 0.30m of windblown sand accumulated over the structure. At Site 4, a Norse structure was covered with 1.25-1.50m of windblown sand prior to the construction of the post-Medieval remains. At Site 1, the easterly room of a Medieval structure overlying Norse remains was filled with 0.40m of windblown sand, which accumulated against the east wall. An additional extensive sand deposit covered much of the coastal cordon and cultivated soils at some point after the Middle Bronze Age. The precise date for this sand accumulation is unclear, as discussed in 'Living with Sand at Skaill' (below).

Chronology

The chronological resolution for the structures and windblown sand deposits at Skaill is poor, stemming from the lack of scientific dates available. Only 12 determinations were recovered from Skaill, and the majority were yielded on bulk wood charcoal although the dates generally seem to confirm the chronologically diagnostic artefactual material. Clear species identifications were not provided for all samples, which were often comprised of mixed charcoal materials. Additionally, no radiocarbon determinations were yielded for the Norse, Medieval, and Post Medieval phases of occupation (Sites 1-4). This is particularly problematic as it is these sites, which are located within the sand dunes nearest the coast edge, which display the most extensive windblown sand deposits.

Two radiocarbon determinations were yielded for Site 5, and eight for Site 6. Two additional determinations were yielded on material recovered from the nearby cliff sections (Buteux *et al.* 1997, 18; 252). The dearth of radiocarbon data was in part due to the non-traditional methods of recording employed by Gelling, where few context numbers were assigned. Descriptive labels were often assigned to the contexts, for example 'above shell midden' and 'reoccupation layer' (Buteux *et al.* 1997, 24), and broad phases of activity were often referred to as belonging to 'layers' with little spatial reference made. Sites 1-4 were dated only by their architectural styles and diagnostic artefactual remains. The precise significance and nature of many of the sites is therefore difficult to disentangle, and caution should be taken with any interpretation of the evidence.

Later prehistoric windblown sand (Sites 5 and 6): between 1513-1392 cal. BC (OxA-1437) and 8th-10th centuries AD)

At Sites 5 and 6, 0.25m of sandy soil overlay a sandy clay merging into boulder clay (Buteux *et al.* 1997, 17) (Figure 4.31) and provides the earliest recorded evidence for anthropogenic activity at Skaill. It was observed inland below the structures at Sites 5 and 6, and within two coastal sections (see below). Ard marks attest to the cultivation – and improvement through manuring – of the sandy soils. In the cliff sections, this soil was overlain by a thick capping deposit (no dimension) of windblown calcareous dune sand which was in turn covered by modern turf.

It is difficult to determine a precise date for the accumulation of this windblown sand, which was to become an extensive landscape deposit. A Middle Bronze Age radiocarbon determination of 1513-1392 cal. BC (OxA-1437) on charcoal fragments (no species given) from the top of the buried soil which underlay the sand provides a *terminus post quem* for its deposition (Buteux *et al.* 1997, 18; 253). The Norse and later period settlements nearer the coastline were constructed directly over this sand and resultantly, it can only be suggested that it may have been deposited between the Middle Bronze Age and the 8th-10th centuries AD. Its absence at Sites 5 and 6 may be due to their position further inland away from the extensive dunes occupied in the Norse and Medieval periods.

Late Iron Age-Pictish windblown sand (Site 6). c. cal. AD420-775 (Birm-592, 763, 765)

At Site 6 South, the Iron Age roundhouse and annexe were paved over during the 4th-6th centuries AD. Their structural state prior to this is unclear, and they are described only as being 'levelled', presumably after a period of deterioration. Prior to the laying of the paving, a layer of sand and soils (dimensions not stated) sealed the remains at Site 6 North and South. No detail as to the nature of this deposit was offered in the monograph, and as such it is unclear whether it represents a natural episode of sand deposition and soil formation, or a levelling deposit. A series of rectangular and sub-rectangular Pictish structures were built over the surface, and these were later covered by rubble spreads intermingled with windblown sand. Again, no dimensions were given for these deposits (Buteux *et al.* 1997, 48).

A series of radiocarbon determinations (Table 32) ensure that some chronological constraint can be suggested for the accumulation of these two sand deposits. A determination of cal. AD600-770 (Birm-765) on mixed charcoal from immediately beneath the paving offers the closet related date for earlier sand deposition (the sand and soil which underlay the paving). No further information is offered on whether this sample was retrieved from the sand and soil deposit itself, or from material relating to late roundhouse occupation. A range of cal. AD420-775 has been offered for the late occupation of the roundhouse and paving sealing the roundhouse (Buteux *et al.* 1997, 53; 252), based on determinations from Birm-592, Birm-763, and Birm-765. This provides a broad chronological range for the deposition of the sand and soils. The deposition of the second sand deposit (which was intermingled with rubble over the Pictish surfaces) must also be placed within this date range as no determinations were yielded for the later Pictish structures. Diagnostic material dating to the 4^{th}-6^{th} centuries supports this age range (Buteux *et al.* 1997, 53).

Norse windblown sand (Site 2). c. AD800-900

At Site 2, the Norse remains (comprising five structures) were constructed directly into the underlying dune sand. No radiocarbon determinations were recovered from the remains, although chronologically-diagnostic material indicates that occupation ran from the 8^{th}/9^{th} centuries AD with the construction of House 1, into the 11^{th} century AD (Edwards in Buteux *et al.* 1997, 71). House 1, which was more reminiscent of Pictish styles, was remodelled into a longer north-south aligned structure (House 2). This house, which was more reminiscent of a Norse style, collapsed and became dilapidated after its use. Its east wall collapsed inward, and the house became covered with c. 0.30m of windblown sand (Edwards in Buteux *et al.* 1997, 73) which presumably entered at the east either across the collapsed wall of through the remains of the eastern entrance to the house. Coloured banding within this sand is indicative of its formation through periodic accumulation as opposed to formation through a singular event.

House 3 was then constructed over the top of the remains of House 2 and the sand deposit. No chronologically-diagnostic material from a secure context was recovered from House 2. Based on the presence of double-sided combs of Curle's Type B, an 8^{th}-9^{th} century AD date has been suggested for the occupation of House 1. A late 9^{th}-early 10^{th} century AD date based on the presence of Fabric D pottery, single sided composite bone combs, and pins amongst other diagnostically Norse material, has been suggested for House 3 (Buteux *et al.* 1997, 73-74). This allows a rough bracketing of the occupation of House 2 – and its windblown sand deposit – to the 9th-10th centuries AD. A second, more extensive (c. 1.25-1.50m) sand deposit was identified at Site 4, which accumulated over the Norse remains. Given the broad possible date range for the deposition of this sand, this deposit is discussed in the section below.

Medieval and post Medieval windblown sand (Sites 1 and 4). c. AD1100-1200 (Site 1); c. AD900-1600 (Site 4).

At Site 1, c. 0.40m of sand blew into the east end of Room 1 of the Medieval structure which overlay fragmentary Norse remains. The building was interpreted as an early 12th century first-floor hall which underwent a series of modification, dilapidation, and recommissioning beyond the 12th century (Buteux 1997, 268). A late 12th century date can be posited for this windblown sand accumulation, but it is clear that this was not the final event in the occupation sequence of the structure, as the floor was then levelled with c. 0.25m of clay for a later period of use (Gelling *et al.* in Buteux *et al.* 1997, 220; Figure 16.3).

Based on their architectural styles, the construction of the post-Medieval barn and kiln at Site 4 has been dated to the 16th/17th century (Buteux *et al*. 1997, 268). This broad date offers a *terminus ante quem* for the deposition of the extensive c. 1.25-1.50m sand they were constructed on, which had accumulated over a stylistically Norse structure which could not be securely dated (see above, 'Norse windblown sand'. Resultantly, only a broad date range of AD900-AD1600 can be posited for the deposition of this sand (Buteux *et al.* 1997, 79-80). The sand appears to have accumulated over time, with Gelling (1984, 32) referring to an 'occupation deposit' within the sand.

Living with sand at Skaill

The evidence for windblown sand deposition at Skaill is piecemeal and not well-recorded, and it is difficult to interpret its exact role in the formation of the six sites. It is hard to estimate the dimensions and extent of the sand deposits as only small areas of the sites were opened – and then backfilled – each season (Buteux *et al.* 1997, 24). Additionally, few pro forma sheets were completed for deposits encountered. The excavator (Gelling) chose to divide the remains encountered at Skaill into a series of sites, and this is a format which has continued through to publication by the author (Buteux) and in this thesis for ease of interpretation. It is worth reflecting, however, on whether this approach in fact restricts and hinders the interpretation of the site given that they are in such close proximity in distance (within 100 metres of each other) with chronological overlaps. The exposed soil profiles along the coastline and extensive dune systems attest to the significant coastal changes which have taken place at Skaill. With this in mind, it is possible that some additional settlement areas in the coastal zone have been washed away, or remain buried in the dunes (Buteux *et al.* 1997, 254). The material composition of the sands is rarely referred to in the report. The sites are located within extensive areas of machair, with much of the later construction activity (e.g. at Site 2) taking place directly upon the calcareous dune sand at the south of Sandside Bay. It seems reasonable to assume that the sands which were deposited during the occupation of Skaill derived from these calcareous sands.

It is difficult to ascertain precise extents and dimensions of windblown sand at the Skaill sites, but where possible, this has been stated in the site-specific discussions above. All identified deposits again appear to have accumulated in disused areas of the site, over collapsed and/or dilapidated structures and occupation areas which acted as sand traps. This suggests that any sand which might have blown in during occupation periods was removed by the occupants if it blew into the settlement from the surrounding dunes, or incorporated into occupation material.

The direction in which the deposits were mobilised is also unclear, although a consideration of the recorded activity at Sites 2 and 4 does highlight some interesting points. It is worth noting that at Site 1, the 0.40m of windblown sand blew into the eastern end of Room 1in the north-south Medieval structure. It can be posited that the sand was moved by a westerly prevailing wind – towards the east. In the early phases of activity in this structure, the building was accessed by doors from the south and west. In the later phases, these doors were blocked, and an entrance to the structure was instead placed at the north end of the building. Although there is no way of knowing whether these structural changes to the entranceways were undertaken as a result of windblown sand incursion, it is an interesting point that is worth considering given the high level of refurbishment which took place in Site 1's later phases. At Site 2, the opposite occurred in that the east wall of the Norse period House 2 collapsed, and 0.30m of windblown sand then accumulated inside the north-south aligned structure. This may indicate that the sand accumulation was mobilised from the east, and was able to enter the structure over the collapsed wall.

Environmental context

No in-depth scientific study or sampling of the midden deposits was undertaken at Skaill. This is problematic as more recent studies at sites including Skara Brae (Clarke and Shepherd *forthcoming*), Tofts Ness (Dockrill and Bond 2009), and Snusgar (D. Griffiths *pers. comm.*) reveal that windblown sands comprised a significant component of occupation deposits associated with the settlements. This indicates that windblown sand incursion was a regular occurrence that did not halt occupation activity, and this may well be the case at Skaill given its location directly within dune sands.

The nearest palaeoenvironmental study to provide some context to the changing landscape at Deerness is that undertaken on a peat deposit near the Brough of Deerness (Donaldson 1981), at HY581078. No radiocarbon samples were taken, and so the pollen is of limited use in the creation of a precise vegetational history. Nevertheless, the broad trend of birch woodland decline and the increase in grassland vegetation in the pollen diagrams would appear to demonstrate broad agreement with palaeoenvironmental studies undertaken in the Bay of Skaill on the West Mainland (Keatinge and Dickson 1979 and see Skara Brae') and Point of Buckquoy, Birsay (Evans J. G. 1979), which identify this change from c. 3700 cal. BC (Keatinge and Dickson 1979) and prior to large-scale settlement and anthropogenic activity.

Two exposed cliff sections adjacent to the coastline at Skaill were investigated to develop a greater understanding of soil formation and cultivation at the site. The first (South Cliff Section) lay beneath the wall of the modern churchyard, while the second (North Cliff Section) lay north of this. Both were buried by the thick covering of windblown sand discussed above, the dimensions of which were not given as recording only took place from the base of the dune sand (Limbrey in Buteux *et al.* 1997, 19). Beneath the windblown sand, c. 0.45m of deposits were recorded in the South Cliff Section, while in the North Cliff Section c. 0.73m of deposits were revealed. Both sets of deposits overlay boulder clay, visible in the sections.

As at Sites 5 and 6 the ardmarked buried ploughsoil was identified in the sections, measuring between 0.10-0.20m in depth. In contrast to the sites, however, the ploughsoil in the sections was found to be overlain by a darker grey soil (c. 0.05-0.20m deep) which formed before the deposition of the windblown sand which covered them. Presumably this dark soil was eroded by anthropogenic activity further inland where the earlier prehistoric sites (5 and 6) were established. At both sections, the ploughsoil and grey soil overlay pale sandy clay merging into boulder clay (Limbrey in Buteux *et al.* 1997, 19). Both sets of ploughsoils contained fine-medium windblown sand components, indicative of the increasing incorporation of sand into these soils as sand began to blow inland (Limbrey in Buteux *et al.* 1997, 19). The recovery of charcoal, bone, tooth, flint, and pottery fragments from the ploughsoil may suggest the incorporation of midden materials into the soil, perhaps in an attempt to improve its quality. It was noted that while bone and shell were poorly preserved in the lower portions of the soil, the upper layers produced shell which had perhaps been preserved under the increasingly calcareous soil conditions (Limbrey in Buteux *et al.* 1997, 20). It is notable that this ploughsoil was already a podzol (an indicator of anthropogenic input through grazing, clearance and burning) prior to its cultivation, suggesting that this soil development was not indicative of an initial phase of deforestation and cultivation (Limbrey in Buteux *et al.* 1997, 20).

The Middle Bronze Age remains at Site 5 overlay the soil, ensuring that its development had to date to the Middle Bronze Age or earlier. This was confirmed by two radiocarbon determinations yielded on burnt materials from the soil in the North Cliff Section.

Charcoal (no material identified) from the lower soil layer produced a determination of 1949-1752 cal. BC (OxA-1716), while burnt bone (no species identified) from the upper soil level yielded a determination of 1513-1392 cal. BC (OxA-1437) (Buteux *et al.* 1997, 253). These place the formation of the soil to within the Early-Middle Bronze Age.

An additional date on 'hearth material' directly overlying leached sand natural in the southeast corner of Site 6's 1974 trench was dated to 1430-1010 cal. BC (Birm-594), fitting relatively well with the date from the upper layer of soil in the North Cliff Section. These three determinations produce a calibrated date range of 1949-1038 cal. BC for the soil and its development (Buteux *et al.* 1997, 253). This offers a *terminus post quem* for the deposition of the overlying windblown sand deposits, into which the majority of later sites were constructed. The dark soil identified between the windblown sand and ploughsoil discussed above may represent a period of stasis before the main episode of extensive windblown sand incursion in the landscape.

A consideration of the location of the settlements through time may shed light on the nature of windblown sand deposition at Skaill. The prehistoric sites (5 and 6) lie inland of the most extensive dunes at Skaill; Site 6 contained two deposits of windblown sand, while Site 5 contained no identifiable sand. The deposit one of the windblown sands, which accumulated after the Pictish occupation, was identified in Site 6 North but not Site 6 South. The Norse and Medieval sites of 1-4 lie nearer to the coast and were constructed directly onto the sand dunes which were to become problematic as occupation developed. All but Site 3 (the remains of which were notably sparse) displayed distinctive windblown sand deposits. The deepest windblown sand deposit, which measured c. 1.25-1.50m, was observed over the Norse remains at Site 4. Only a broad date of c. AD800-AD1500/1600 can be posited for its deposition. It is plausible that extensive activity in the dunes in the Viking period led to deflation and in turn extended periods of windblown sand movement.

The longevity of occupation at Skaill suggests windblown sand incursion was not perceived as a considerable problem. The visibility and availability of valuable construction materials in the sand following destruction of previous buildings no doubt proved attractive to those who went on to reoccupy the settlement areas over time. Sand mobilisation appears to have increased during the Viking and Medieval periods, perhaps due to an increase in construction and agricultural activity in the dunes. Further excavation and survey would allow a fuller picture of the extent of settlement activity in the dunes, which was likely to have also included extensive midden deposits and agricultural soils interleaved with blown sands.

4.6. Papa Westray

Lying to the northeast of Westray, the small island of Papa Westray measures c. 7km in length, and c. 2km in width (Lowe 1998, 1). The exposed north and north east of the island contain high cliffs, while the south is more fertile and low-lying. The highest point on the island is North Hill at 48m OD. Middle Old Red Sandstone groups make up the bedrock geology, while extensive areas of windblown sand characterise drift deposits on the east of the island, as well as pockets on the south and west coast where the Knap of Howar and St Boniface are located (Figure 4.35). Erosion is particularly prominent to the south and east of the island (Moore and Wilson 1999, 63-4). The quality of data for windblown sand deposition on archaeological sites on the island is varied (Table 33). Two sites with prehistoric sand deposition are recorded (Knap of Howar and St Boniface), but dates for the sands recorded at the remaining four sites cannot be posited. As such, only the Knap of Howar and St Boniface are discussed here.

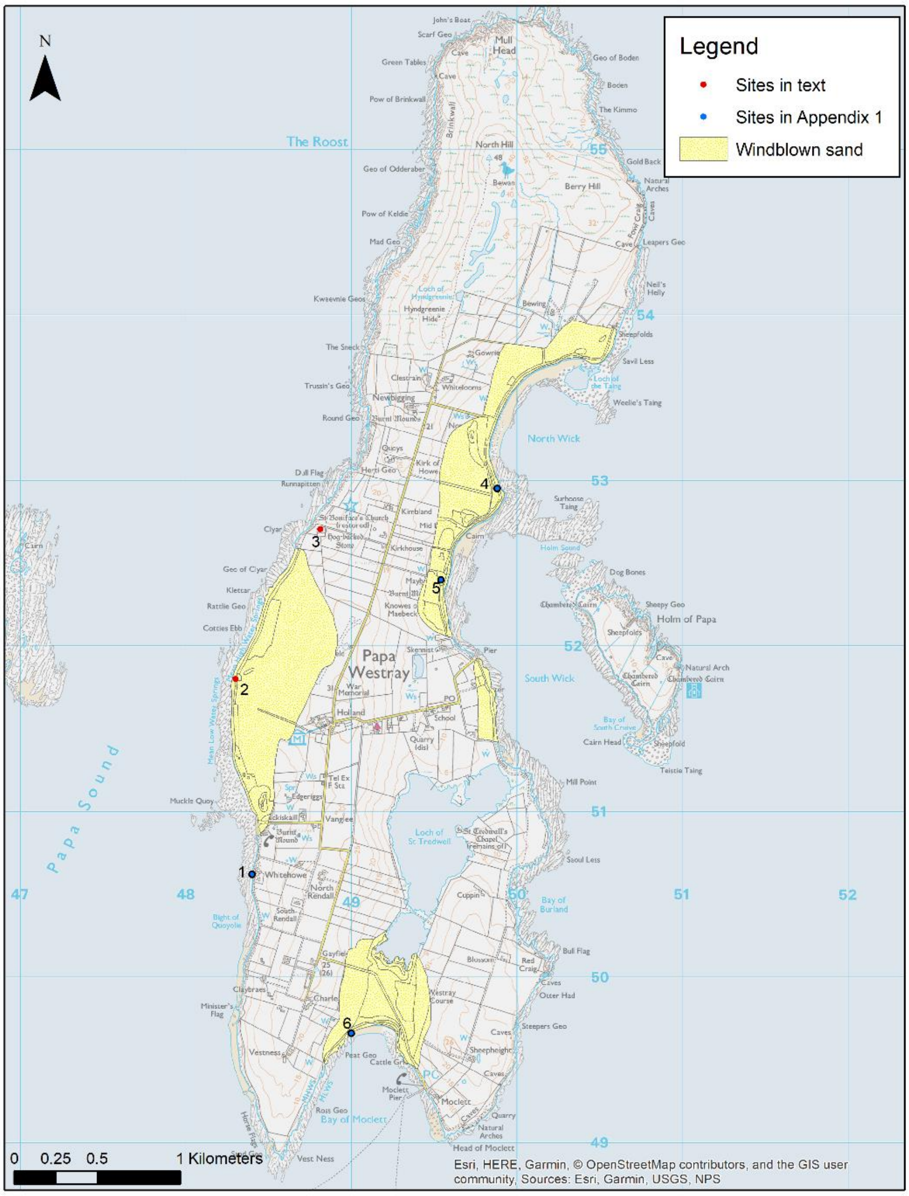

Figure 4.35. Papa Westray sites. 1. King's Craig; 2. Knap of Howar; 3. St Boniface; 4. Cott; 5. Mayback; 6. Moclett.

Site	Site type	Period of human activity	Sandblow period	Reference
Knap of Howar	Settlement	Early Neolithic (from c. 3635-3370 cal. BC (*start_knap_of_howar*) to c. 3305-2835 cal. BC (*end_knap_of_howar*).	Early Neolithic (Between c. 3635-3370 cal. BC (*start_knap_of_howar*) and 3345-3020 cal. BC (OxA-16476) (Bayliss et al. 2017 [Supplementary Material], 14; 19); after c. 3500-2850 cal. BC.	Ritchie 1983; Bayliss *et al*. 2017
St Boniface	Settlement	Middle Neolithic (c. 3020-2700 cal. BC(AA-9561) to Norse/Medieval (c. cal. AD1010-1280 (GU-3069c)	Early-Middle Neolithic (3020-2700 cal. BC(AA-9561); Early Bronze Age (between 1610-1320 cal. BC (AA-9560) and 1535–1115 cal. BC (AA-9562)) Early-Middle Iron Age (625-190 cal. BC (GU-3268c)) Middle Iron Age (c. 340 cal. BC-cal. AD115 (GU-3275c; GU-3061c))	Lowe 1998
King's Craig	Settlement, midden	Multiperiod. Prehistoric, Norse	Unknown prehistoric	Moore and Wilson 1998
Bay of Moclett	Cultivation soil	Unknown	Unknown	Moore and Wilson 1998
Cott	Settlement, midden	Prehistoric, Norse	Unknown prehistoric	Moore and Wilson 1998
Mayback	Midden, farm mound	Medieval, post-Medieval (14^{th}-18^{th} centuries AD)	Unknown Prehistoric or Norse-Early Medieval.	Moore and Wilson 1998

Table 33. Papa Westray sites showing occupation and sandblow periods

4.6.1. Knap of Howar

The Early Neolithic site at Knap of Howar lies on the west coast of Papa Westray in what are now the low-lying pasturelands of Holland farm (Figure 4.36), comprising c. 55ha of windblown sand land cover (Dargie 1998b, 205). Apart from a few instances, windblown sand mobilisation does not appear to have been a significant feature at this site or its landscape during its occupation. Rather, it was later that the landscape was covered by extensive machair deposits punctuated with periods of soil development. After occupation ceased in c. 3305–2835 cal. BC (*end_knap_of_howar*; Bayliss *et al*. 2017 [Supplementary material], 96), the site was covered by the c. 2.5m of windblown sand which continues to cover this area of Papa Westray's west coast (Ritchie 1983, 40).

The site was first excavated in 1929 and the 1930's by William Traill and William Kirkness (1937), who emptied the structures of overlying windblown sands (Figure 4.37). It was re-excavated in 1973 and 1975 (Ritchie 1983) to recover dating evidence and consolidate structural remains. The remains comprised two drystone sub-rectangular domestic structures (Houses 1 and 2) deroofed and filled with windblown sand, and surrounded by midden accumulations (Figure 4.38). The structure walls survive to heights of 1.6m and like Skara Brae, were found to contain hearths, pits, benches, 'beds' and cupboards. The primary mode of subsistence was pastoral, along with evidence for marine resource exploitation and cereal cultivation, despite poor pollen preservation conditions (Ritchie 1983, 56-7).

Figure 4.36. Oblique view of Knap of Howar in its landscape context, taken facing SSE. RCAHMS Aerial Photography Digital Collection: DP 060176.

Figure 4.37. Workmen removing the overburden of blown sand from House 2 during Traill and Kirkness' excavations (1937). CANMORE Digital Images SC 1258382.

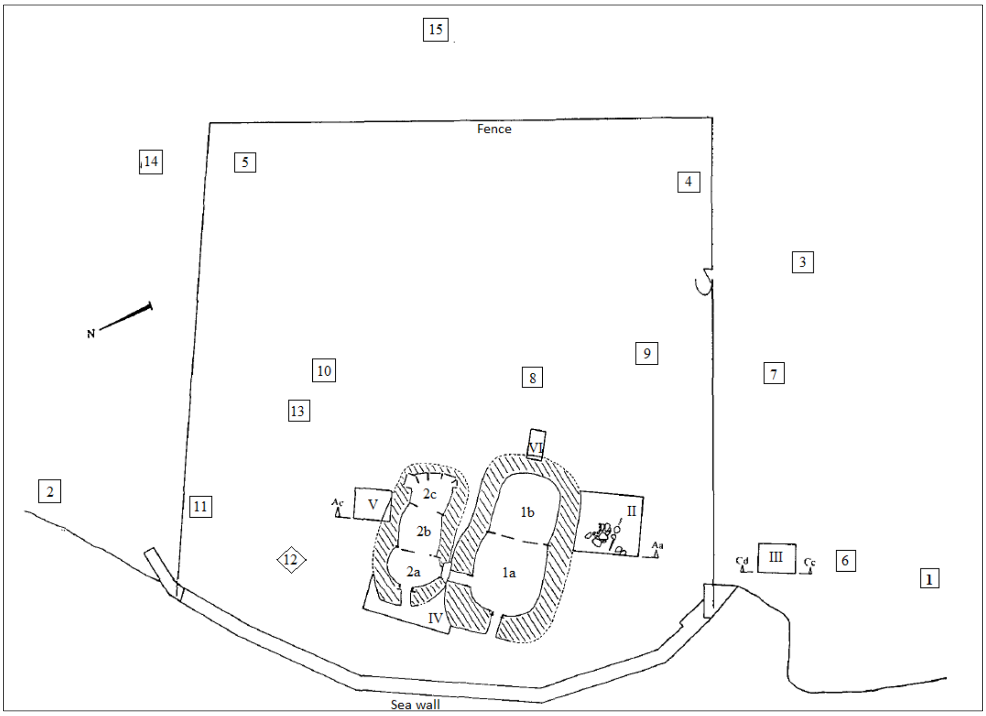

Figure 4.38. Map showing location of test pits and trenches excavated by Ritchie at Knap of Howar. Adapted from Ritchie 1983, 46, Fig. 2. 1:400m scale.

Chronology and phasing

Five trenches (II-VI) and 16 test pits (1-16) (Figure 4.38) were excavated by Ritchie, encompassing the house interiors and exteriors, the settlement's immediate environs, and c. 36 square metres of eroding midden. A stratigraphic sequence comprising two main phases of activity was devised: Period I, consisting of a substantial midden deposit, and Period II, representing the construction and occupation of Houses 1 and 2.

Period I (lower midden)

The primary phase of activity is represented by a c. 0.40m deep midden deposit (termed the 'lower midden'). Exposed in Trenches II-VI and in the house wall cores (Ritchie 1983, 44), the midden deposits became shallower to the east of the houses. With the exception of a small area of stone paving and some upright stones observed in Trench II, there was no evidence for any contemporary structures in the excavated area; it is plausible that any earlier structures were lost to marine erosion, or their materials reused for Phase II construction (Ritchie 1983, 46). In Trench III, the lower midden was distinguishable from the upper Phase II midden in that it was lighter, finer and contained less shell – but this difference was not as visible elsewhere, for example in Trench II, which lay directly outside the southwest wall of House 1 (Ritchie 1983, 45). The surfaces of the Phase I and II middens were notably level, perhaps for ease of construction. It is plausible that as at other comparable sites (for example Skara Brae), the middens within the settlement were enhanced to support small-scale cultivation (Ritchie 1983, 45-6).

Period II (Houses 1 and 2)

Phase II comprised the construction of rectilinear Houses 1 and 2 (c. 7-10m in diameter) upon the Period I 'lower midden', and the accumulation of an upper layer of midden (c. 0.20-1.00m thick) contemporary with Period II activity. Small quantities of undisturbed floor deposits were discovered during Ritchie's excavation. It is likely that the construction of the houses was roughly contemporary (Ritchie 1983, 52). Both were contained a midden wall core (redeposited from Period I), and displayed entrances facing northwest toward the coastline.

House 1

Lying to the south of House 2, House 1 proved to be the larger and better-preserved of the two structures. A small passageway (Passage B) joined the two houses through the north wall of House 1, where the walls of the two houses abutted each other (Figure 4.38). House 1 was divided into two rooms (1a and 1b); what remained of the floor deposits in Ia consisted of 0.33m dirty brown sand, charcoal trample, and midden patches (Ritchie 1983, 46). The south and north wall cores contained patches of sand which lay between the Phase I 'lower midden' upon which the house was constructed, and the midden which filled the walls (Ritchie 1983, 48).

House 2

House 2 was divided into three compartments (2a, b, and c), and contained similar furnishings and recesses to House 1. It was noted that no artefacts were recovered from any of the storage facilities in House 2, compartment C during the original or later excavations, perhaps also indicating an unhurried and planned cessation of activity (Ritchie 1983, 51). Like House 1, House 2 was found to be in a state of collapse, with the north wall having fallen before the house filled with sand (Ritchie 1983, 50). House 2 was found to have had its doorways blocked up, perhaps during the occupation of House 1 (Ritchie 1983, 44).

Test Pits 1-16

The primary aim of the test pit excavations was to identify the extent of the midden deposits, with an additional test pit (16) excavated c. 0.5km east of the site (HY485 523) to investigate environmental sequences in the landscape (Ritchie 1983, 53). Based on these test pits, the extent of the midden is was estimated as lying c. 4m north of House 2, coeval with the east of House 1, and c. 20m to the south of House 1, comprising c. 500m²

(Ritchie 1983, 53). The midden depths varied from c. 0.45m in Test Pit 12 (c. 5m north of House 2), to 1.8m in Test Pit 9 (c. 10m south of House 1). Only the stratigraphic logs for Test Pits 4 and 16 were presented in the report (see below, 'Windblown sand at Knap of Howar') and resultantly it is impossible to gauge the exact composition of the deposits excavated in the other pits.

Radiocarbon dating

Eleven initial samples were submitted for radiocarbon analyses (Table 34) which comprised ten samples of bulk mixed animal bone (species not stated), and one from organic soil in Test Pit 16 east of the settlement area (Ritchie 1983, 57-8; Renfrew and Buteux 1985, 264; Bayliss *et al.* 2017 [Supplementary Material], 18) and were calibrated using a curve devised by R. M. Clark (1975).

Lab ID	**Context and material**	**Uncalibrated radiocarbon Age (bc)**	**Calibrated date range (cal. BC), at 95% probability**
SRR-345	Animal bone, mixed. Floor deposit, House 1, Period II	2398±75	3400-2600
SRR-346	Animal bone, mixed. Secondary floor deposit in passage, House 1a, Period II	2582±70	3650-2900
Birm-814	Animal bone, mixed. Secondary floor deposit, House 2, Period II	2740±130	3900-2900
Birm-815	Animal bone, mixed. Primary midden, Trench IV, Period I	2300±130	3400-2300
SRR-344	Animal bone, mixed. Secondary midden, Trench III, Period II	2501±70	3500-2850
SRR-348	Animal bone, mixed. Secondary midden, Trench II, Period II	2815±70	3900-3100
SRR-349	Animal bone, mixed. Primary midden, Trench II, Period I	2472±70	3500-2700
Birm-816	Animal bone, mixed. Primary midden, Trench V, Period I	2820±180	4300-2800

Birm-813	Animal bone, mixed. Primary midden in wall core, House 2, Period I	2320±100	3350-2450
SRR-347, SRR-452	Animal bone, mixed. Primary midden in south wall core, House 1, Period I (both dates determined from same sample)	3756±85, 2131±65	4840-4330, 2900-2300
Birm-817	Organic buried soil at base of Test Pit 16	2880±100	3800-3400

Table 34. Knap of Howar initial radiocarbon determinations. Ritchie 1983, 118.

An additional eight determinations were later yielded on samples of single unburnt bones (Bronk Ramsey *et al.* 2002) before being withdrawn as a result of a technical issue at the Oxford laboratory. These samples have been redated (Sheridan and Higham 2006, 202-3; 2007) and calibrated using OxCal 3.10. (Table 35). None of the dated bone was articulated, and resultantly it must be noted that these dates could be residual (Ashmore 1999; Bayliss *et al.* 2017 [Supplementary Material], 18).

Lab ID	**Context**	**Uncalibrated radiocarbon Age (bp)**	**Calibrated date range cal. BC (at 95% probability)**
OXA-16475	Sheep bone. House 1, layer 9. Primary midden within House 1 wall core	4603±39	3500-3340
OxA-16476	Sheep/goat bone. House 1, layer 16. Primary midden sealed below the wall of House 1	4458±39	3330-3020 or 3345-3020 (Bayliss *et al.* 2017; see below)
OxA-16477	Sheep/goat bone. House 2, Passage B, layer 4. Secondary floor deposit in House 2 at the entrance to passage linking the two houses. Sealed by blocking material, providing *a terminus post quem* for the latter	4420±39	3270-2930

OxA-16478	Cattle bone. House 2, layer 7. Secondary floor deposit of House 2	4510±39	3350-3100
OxA-16479	Sheep/goat bone. House 2, layer 12. Primary floor deposit of House 2	4552±39	3370-3110
OxA-16480	Sheep bone. Trench III, layer 3. Secondary midden c. 20m south of House 1	4633±39	3500-3360
OxA-17778	Pig bone. Trench III, layer 4. Primary midden c. 20m south of House 1	4673±31	3630-3360
OxA-16481	Sheep/goat bone. Trench V, layer 2. Secondary midden outside House 2	4443±39	3330-3010

Table 35. Redated Knap of Howar radiocarbon determinations. Sheridan and Higham 2006, 202-3; 2007, 225. Additional context descriptions from Bayliss *et al*. 2017 [Supplementary material], Table S1; 74-77.

Bayesian modelling places occupation in the second half of the fourth millennium cal. BC (Bayliss *et al.* (2017) (Figure 4.39), based upon the initial determinations on animal bone from Ritchie's excavations (1983) (Table 34), and the eight redated determinations (Bronk Ramsey *et al.* 2002; Sheridan and Higham 2006; 3007) (Table 35). This total excludes the measurement from Test Pit 16 (Birm-817) which contained no archaeology, and two measurements (SRR-347 and SRR-352) which were respectively earlier and later than a date from the same context, OxA-16475 (Bayliss *et al.* 2017 [Supplementary Material], 18). The model was developed using OxCal 4.2. It estimates the beginning of activity at 3635–3370 cal. BC (*Boundary start_knap_of_howar*). A *terminus post quem* of 3345-3020 cal. BC (OxA-16476) has been offered for the construction of House 1 (Bayliss *et al.* 2017 [Supplementary Material], 19). Cessation of activity at the settlement is estimated at c. 3305-2835 cal. BC (*Boundary end_knap of howar*).

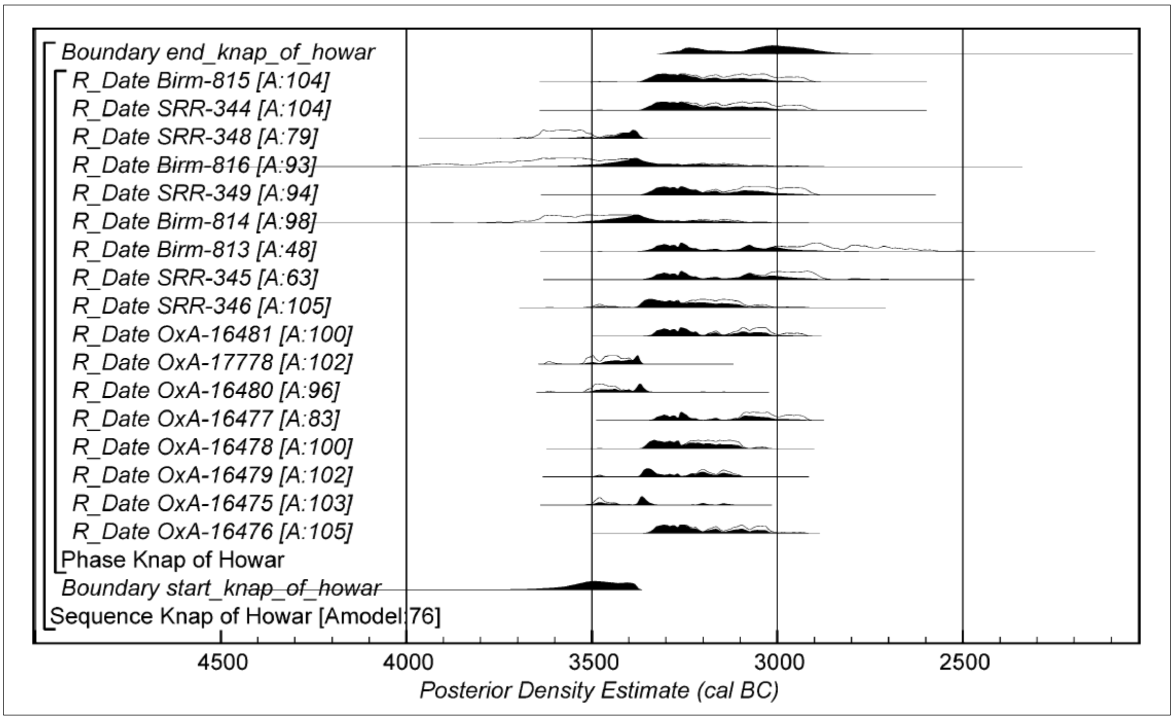

Figure 4.39. Probability distributions of radiocarbon dates from Knap of Howar. As with other models produced by Bayliss et al. (2017, 28), each distribution illustrates the relative probability that a dated event occurred at a particular time. The blank outline distribution for each date represents the simple radiocarbon calibration data, while the shaded (black) distribution is based on the chronological model used by the authors. Bayliss *et al.* 2017 [Supplementary Material] 39, Figure S17).

Windblown sand at Knap of Howar

The nature of archaeological investigation at Knap of Howar presents some difficulty when interpreting the extent and chronology of windblown sand accumulation. The deposits filling the house interiors were largely cleared during the original excavations (Traill and Kirkness 1937), who were largely interested in the superstructure of the houses. This makes it difficult to pinpoint any sand deposits which may have accumulated during occupation, and whether these were deposited naturally or by human activity (as flooring material, for example).

The only significant evidence for large-scale accumulation of windblown sand at the site is the 2.5m of sand which infilled the structures after occupation ceased, which was "very quickly disposed of by throwing it over the cliff" during Traill and Kirkness' excavations (1937, 309). Any dating evidence for this deposit, which is likely to have accumulated over a long period of time, is therefore missing. The material composition of any sand deposits encountered at the site is also not stated in either excavation report. This is somewhat remedied by the analysis of the windblown sand deposits exposed in neighbouring cliff sections, all of which were calcareous in composition (Evans, J. G. and Vaughan in Ritchie 1983, 106). The available evidence for sand movement at the site is summarised below.

Period I: Primary midden

The lower midden was identified in Trenches II-VI, and also used in the House 1 and 2 wall cores (Ritchie 1983, 44). Little detail was offered regarding the composition of the Period I midden, but it was noted that both the Period I and II middens displayed a low sand content, and did not contain any sand lenses or accumulations (Whittington in Ritchie 1983, 117). A small amount of windblown sand was deposited between the cessation of Period I midden accumulation, and Period II activity. In the north and south walls of House 1, patches of sand (no dimensions) were observed between the midden wall core, and the underlying Period I midden onto which the houses were constructed (Ritchie 1983, 48). Given that the Period II wall core appears to be comprised of redeposited Period I midden, any radiocarbon determinations from this deposit cannot be used as a *terminus ante quem* for the deposition of this sand. A "thin layer" of sand between the lower (Phase I) and Upper (Phase II) middens was also observed in Trench V, comprising no more than a few mm in the drawn section (Ritchie 1983, 49; Figure 4). Resultantly, it appears that either a small amount of sand (or a larger deposit which was mostly cleared) accumulated in late Period I.

Mixed animal bone from the Period I midden in Trench V yielded a determination of 4300-2800 cal. BC (Birm-816), while a sheep/goat bone from the Period II midden in Trench V yielded a determination of 3330-3010 cal. BC (OxA-16481). These ranges are not particularly informative in terms of providing a chronological bracket for the deposition of the sand between the two periods. Using the chronological estimates offered by Bayliss *et al.* (2017), sand accumulation would have occurred at some point between 3635-3370 cal. BC (when Bayliss *et al.* estimate the beginning of Period I activity at Knap of Howar), and 3345-3020 cal. BC (OxA-16476) – the terminus post quem for construction of House 1 (Bayliss *et al.* 2017 [Supplementary Material], 19) – a span of approximately three centuries.

Period II

Sand deposits within the houses themselves (excluding those accumulations which took place after their abandonment) are limited to a few recorded incidences. Many of the internal deposits were cleared out during the 1930's excavations, and their level of survival varies from almost all deposits being cleared from the west compartment of House 1, to only superficial clearance of deposits in the middle and west compartments of House 2 (Ritchie 1983, 46). When the sands do occur, they are usually stratified between occupation deposits, and it is difficult to ascertain whether these were blown into the houses from the west during their use, or deliberately laid by the inhabitants.

House 1

In the west compartment of House 1 and the passageway joining the two houses, dark brown sand mixed with charcoal trample and brown midden was described as a primary component of the c. 0.33m of surviving floor material which overlay a paved surface (Ritchie 1983, 46). Its dark brown colour and mixed nature would suggest an anthropogenic origin as opposed to a clean windblown sand layer.

House 2

House 2 contained the remains of two hearths in its middle compartment (2b). The primary hearth (11) lay near the centre, while the less substantial secondary scoop hearth (10) lay to the west of the primary hearth (Ritchie 1983, 47; Figure 3). The primary hearth (11) was infilled by c. 0.20m of sand and underlay c. 0.30m of ashy hearth deposits (Ritchie 1983, 50; Figure 5). Approximately 0.20m of surviving ashy and greasy floor deposits were separated by a thin lense of sand of no more than a few millimetres (Richie 1983, 49; Figure 4). These floor deposits appeared to correspond with the two different hearths (Ritchie 1983, 51), and comprise rakeout deposits.

Given its discrete, scattered nature (see Ritchie 1983, 49; Figure 4), it seems possible that this sand was deliberately laid down – perhaps as a levelling deposit or to halt to initial buildup of hearth rakeouts. In the front compartment of House 2 (2a) and its passage adjoining House 1, the floor deposits comprised a dark greyish-brown humic sand (Ritchie 1983, 51). Sheep/goat bone from this layer was dated to 3270-2930 cal. BC (OxA-16477). Again, the dimensions of this deposit were not stated, it is unclear whether this deposit was blown in through the front door of the structure, or laid as a floor deposit.

Late Phase II

During later occupation of the settlement, the entrances to House 2 were blocked after wall or roofing collapse in the vicinity of the passage B. It was suggested by Ritchie that this passage, and House 2 itself, were perhaps decommissioned due to its instability while House 1 occupation continued (Ritchie 1983, 44). This may represent the slow decommissioning of the settlement prior to its final abandonment. The precise nature of the end of settlement at Knap of Howar – and the possible role played by increased windblown sand mobilisation – is unclear. The covering of the site by large windblown sand accumulations took place after cessation of activity at the settlement, presumably after the roofing of the structures had decayed or been robbed. During their excavations, Traill and Kirkness noted a c. 0.10m-0.11m thick turf line which had developed at the top of the deroofed house walls, overlain by the c. 2.5m of windblown sand accumulations (Traill and Kirkness 1937, 314). Its extent was not stated by the excavators, but the turf was also noted in Ritchie's Trenches II and III, and may also correlate with that observed in Test Pit 4 to the far south of the site (see below, 'Environmental context').

In three aforementioned areas investigated by Ritchie, however, the c. 0.10-0.15m of turf was sealed between two layers of windblown sand. The drawn section of Trench III best represents this sequence (Figure 4.40, Section Cd-Cd; Ritchie 1983, 44). Here, the upper sand layer measured c. 0.20m, while the lower sand measured c. 0.02-0.15m and overlay the top of the Phase 2 midden (layer 3). No further stratigraphic information was offered by Traill and Kirkness with regards to the turf identified during their excavations and resultantly, it is not clear whether this turf did originally overlie an additional, earlier sand layer (as was the case in Trenches II, III, and Test Pit 4) which was then removed during the original excavations.

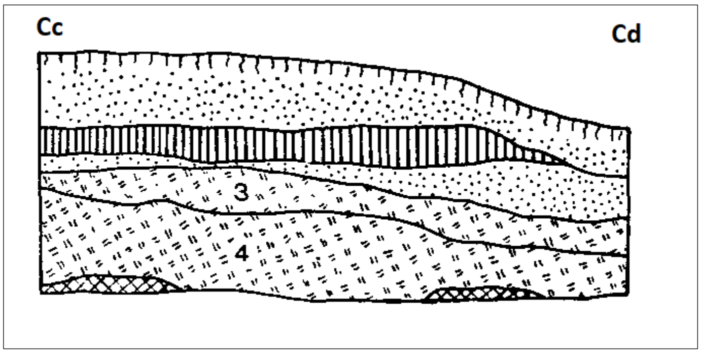

Figure 4.40. Trench III west section Cc-Cd. After Ritchie 1983, 49; Figure 4.

Two radiocarbon determinations are available for the Phase 2 midden overlain by the sands and turf in Trench III. A determination of 3500-2850 cal. BC (SRR-344) was yielded on mixed animal bone, while a sheep bone yielded a determination of 3500-3360 cal. BC (OxA-16480). SRR-344 was yielded on bulk mixed bone and should thus be treated with caution, but these determinations do offer a broad *terminus post quem* for the deposition of the overlying windblown sands and turf, in the absence of any directly dated material. The turf line may represent a period of relative stability during which a small amount of vegetation was able to colonise, in what was becoming an increasingly sand-dominated landscape following the end of occupation at Howar.

Environmental context

The environmental record at the Knap of Howar indicates that sand mobilisation only became a significant feature of this landscape after the occupation of Knap of Howar had ceased. The sequence from Trench II shows the accumulation of the primary and secondary middens over glacial till, followed by the development of buried soils interleaved between c. 0.10-0.25m deep windblown sand deposits (Figure 4.41). This sequence is typical of the sediment sequences sampled at the site itself and in its vicinity for pollen analysis. Pollen preservation at the site was found to be poor, owing to the high shell content of the machair and the soils which overlay it. No grains were retrieved from the sampled deposits in Trenches II, V, and VI, and only 10 were identified from the buried soils in Test Pits 4, 14, 15, and 16 (Whittington in Ritchie 1983, 117). Resultantly, it reveals little about the environmental context at the site.

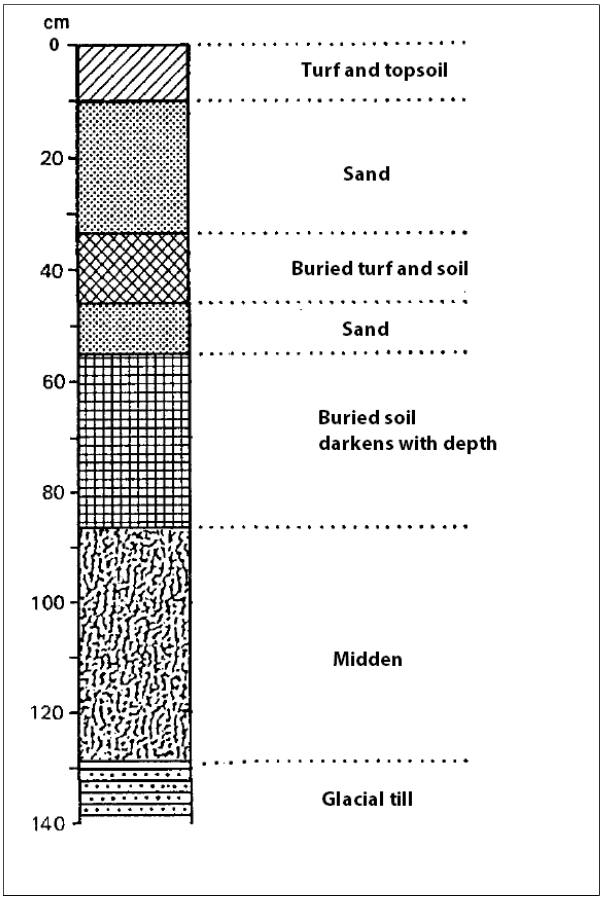

Figure 4.41. Trench II soil profile displaying typical sequences encountered across the Knap of Howar and its immediate landscape. After Whittington in Ritchie 1983, 116; Figure 27.

A similar sequence was noted in Test Pit 4, located c. 0.17m SSW of the houses. The depth (0.17m) of the soil deposit in Test Pit 4 (Table 36) may be indicative of its use for arable agriculture, as is the recovery of *triticum* (wheat) pollen (Ritchie 1983, 53). Additional environmental samples were taken from Test Pit 16, located c. 0.45km north of the site within a pocket of blown sand. Beneath a "substantial" sand deposit (the dimensions for which were not stated) a 0.06m thick basal buried soil was encountered (Ritchie 1983, 53). This soil returned a radiocarbon determination of 3800-3400 cal. BC (Birm-817), offering only a *terminus post quem* for the deposition of the windblown sand overlying it. It may be that this more substantial sand deposit represents the large-scale formation of the dune pasture system which continues to characterise the modern landscape.

Depth below surface (m)	Description
0-0.6	Modern turf
0.06-0.47	Windblown sand
0.47-1.00	Buried soil
1.00-1.26	Windblown sand
1.26-1.37	Buried soil
1.37-1.60	Boulder clay

Table 36. Stratigraphic units observed in Test Pit 4. After Ritchie 1983, 53.

Molluscan evidence

In order to further develop the palaeoenvironmental context for the site, two eroding coastal sections (PW IV and PW II) were sampled for molluscan assemblages (Evans and Vaughan in Ritchie 1983). The sequences comprised buried soils and foreshore-derived calcareous windblown sands. Evans and Vaughan state that the lower sedimentary sequence (PW IV) precedes that of PW II, with the archaeological site lying at the interface of the two sections, and continuing into the upper sedimentary sequence of PWII (Evans, J. G. and Vaughan in Ritchie 1983, 106-8). The justification for this assertion is unclear however, as no chronology was established for these sections. The sequences are summarised below.

PW IV

PW IV lay c. 55m north of the site. The section comprised a basal orange boulder clay, overlain by a buried soil and 2.30m of calcareous windblown sand (Table 37).

Depth below surface (m)	Description
0-0.10	Modern turf
0.10-0.40	Brown humic sand becoming paler with depth
0.40-2.70	Pale orange-stained silvery sand
2.70-2.82	Buried soil with marine shell fragments. Dark-brown stony loam with hairline calcareous sand lenses and sand particles throughout
2.82+	Orange boulder clay. (B)-horizon of buried soil.

Table 37. Stratigraphic units recorded in section PWIV (after Evans, J. G. and Vaughan in Ritchie 1983, 108).

PW II

Lying c.100m northeast of the site, this extensive section contained a number of interstratified windblown sand and soil horizons (Table 38).

Depth below surface (m)	Description
0-0.10	Modern turf. Dark brown sandy loam
0.10-0.30	Yellowish brown sand with faint humic bands
0.30-0.57	Clean light yellowish brown sand, lacking humic bands
0.57-0.59	Brown clay with intercalated sand lenses
0.59-1.04	Clean pale-yellow sand
1.04-1.07	Very pale brown clay with hair-line organic bands
1.07-1.11	Light grey sand
1.11-1.16	Very dark reddish-brown organic clay
1.16-1.22	Dark yellowish brown humic sand
1.22-1.62	Very pale brown sand
1.62-1.72	Buried soil. Dark brown non-calcareous loam
1.72+	Bedrock

Table 38. Stratigraphic units recorded in section PWII (after Evans, J. G. and Vaughan in Ritchie 1983, 108).

PWIV

Hairline sand layers and particles in the buried soil suggests that sand accumulated slowly throughout the development of the soil, prior to the deposition of the 2.30m of windblown calcareous sand overlying it. The sand grains were incorporated into the soil matrix by faunal and human activity. Various species of land snail (including *Carychium* and *Vertigo pusilla*) are indicative of a scrub and woodland vegetation during the development of the buried soil (Evans, J. G. and Vaughan in Ritchie 1983, 108).

The buried soil in PW IV differed from that observed in PW II in that it contained sand layers and marine shell. The presence of sand in the buried soil is indicative of increasing sand mobilisation prior to the more significant sand incursion which overlay this soil. The land snail taxa observed from this soil were devoid of open-ground species, and more representative of a scrub or woodland habitat (Evans, J. G. and Vaughan 1983, 108). A buried soil immediately below the division between Houses 1 and 2 was similarly indicative of a scrub or woodland environment (Evans, J. G. and Vaughan in Ritchie 1983, 108).

PWII

The molluscan sequence and stratigraphic record from this section are indicative of a series of stable land surfaces which sometimes flooded, alternated with episodes of sand deposition. The lack of shells in the basal buried soil above the bedrock suggests a rapid initial deposition of the sand overlying it (Evans, J. G. and Vaughan 1983, 108-9).

Environmental context: discussion

In terms of the provenance of the sand in the sections, trenches, and test pits, the clean, loose nature of the deposit, along with the lack of observed shell, indicate a source likely to originate from the uppermost layers of sand from the nearby foreshore. The organic soil horizons may reflect longer periods of accumulation in a relatively stable, damp environment with some damp grasslands forming and perhaps small, freshwater ponds. The molluscan remains are indicative of a former woodland environment where windblown calcareous sand was already slowly beginning to be accumulated, and incorporated into the developing buried soil. There then appears to be a change towards a more open landscape with less wooded areas, with surface instability and significant movements of sand (Whittington in Ritchie 1983, 117).

This instability may have been driven in part by human activity such as vegetation clearance and cultivation. The environmental sequences at the Knap of Howar are further supported by palaeobotanical and environmental investigations undertaken by Spencer (1975), Evans, J. G. and Spencer in Ritchie (1977); Evans, J. G. (1979), and Keatinge and Dickson (1979), which all came to similar conclusions regarding environmental change in the earlier-middle Neolithic in Orkney. In contrast, early settlement at the site appears to have taken place when the landscape was more stable in terms of sand mobilisation, upon an organic soil surface (Whittington in Ritchie 1983, 117).

Excavation strategy

The evidence recorded in the eroding sections reveals some information about the Knap of Howar's environment, although there is no directly-associated chronological data available to directly link these deposits with those at the site. The main sand and marl horizons were broadly assumed to be contemporary with, or later than, the archaeological site (Evans, J. G. and Vaughan 1983, 106). A lack of chronological evidence means that this assumption is problematic, and must be treated with caution. The initial radiocarbon dates from the archaeological sequences are also worth approaching with caution in that all were yielded on bulk bone samples, as opposed to those redated by the Oxford radiocarbon laboratory which were all yielded on single, disarticulated bones. When combined into the model produced by Bayliss et al. (2017), however, there is a better understanding of the chronological sequences at the site.

While the archaeological sequences at the Knap of Howar are not particularly enlightening with regards to windblown sand movement during its occupation in the earlier Neolithic, the site is nevertheless important as its environmental sequences suggest that settlement began prior to any large-scale sand mobilisation driving machair development. This is in contrast to the Late Neolithic settlement of the Bay of Skaill, where the occupants of Skara Brae elected to colonise what had already become a machair landscape.

4.6.2. St Boniface

St Boniface lies on the northwest coast of Papa Westray, to the north of an extensive source of windblown sand and c. 2km north of the Knap of Howar. The multiperiod site was excavated in 1990 in response to the threat of coastal erosion (Figure 4.42). The upstanding archaeological remains comprise a Medieval parish church (St Boniface) and graveyard. Beneath and to the west of the church lies an extensive Iron Age settlement, Munkerhoose (CANMORE ID 2867). A large 'farm mound' is located to the north of the church (Lowe 1998, 1-2; (Davidson *et al.* 1986 and see Figure 4.43).

The exposed cliff section comprised extensive remains of structures, midden and windblown sand deposits. During the tapestry excavation, the eroding section was divided into three Areas (1-3, from north to south), with corresponding stratigraphic excavation blocks. These areas contained two mounds; one comprised mostly of stone (Areas 2 and 3), and the other of sediments (Area 1) (Lowe 1998, 2). Area 1 contained the Medieval farm mound, with the Iron Age and earlier prehistoric settlement comprising Areas 2 and 3 (Lowe 1998, 15; and see Figure 4.43 and Figure 4.44). A period of near-continuous occupation from 1250BC-AD1250 was posited, although activity began earlier than this (see Table 39). The site underwent several changes in function and social use, from funerary to domestic in its earliest phases, to the monumentalisation of the settlement with the construction of a substantial roundhouse, followed by the accumulation of the farm mound and the establishment of an ecclesiastical base.

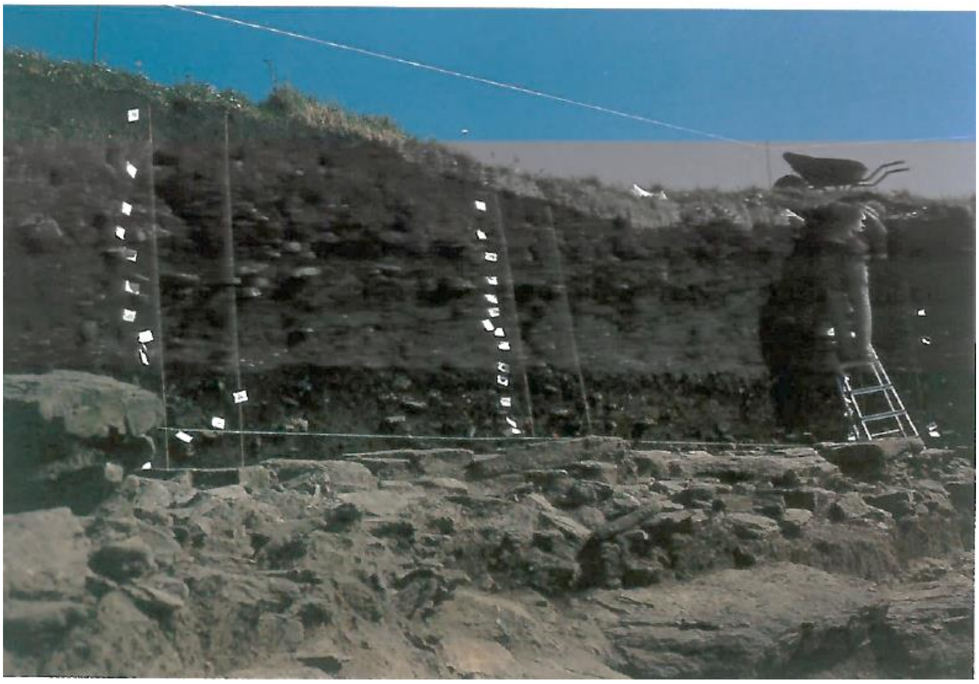

Figure 4.42. Sampling and recording from the cliff face at St Boniface. Owen and Dalland 1999, 13.

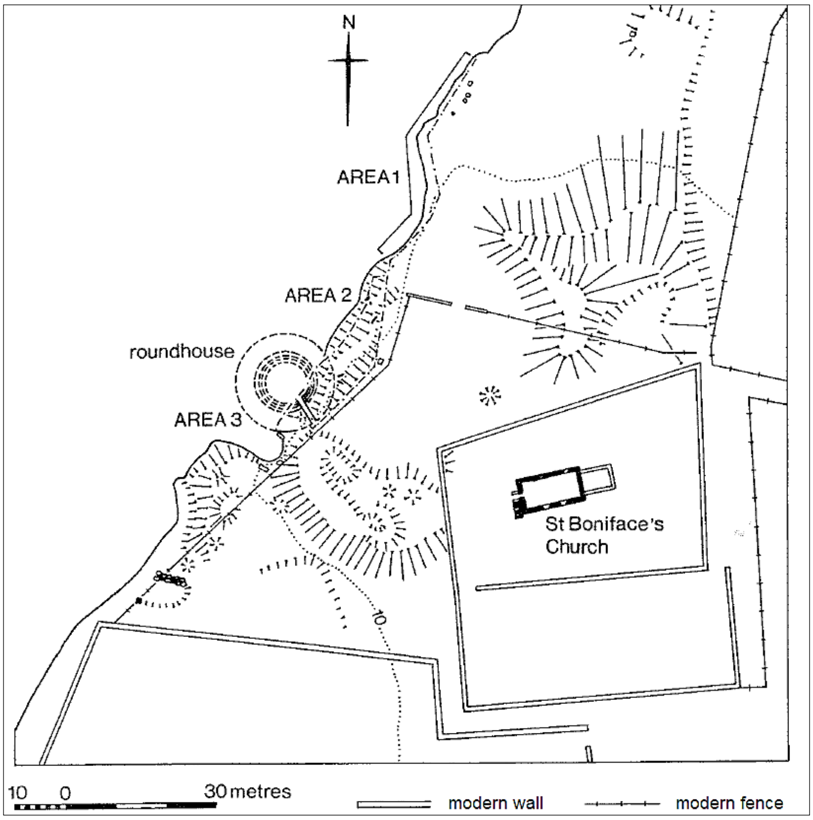

Figure 4.43. Map of St Boniface showing location of Areas 1-3. After Lowe 1998, 3; Illustration 2.

Chronology and phasing

Nine radiocarbon and typologically-dated phases of activity were identified at the site (Table 39), two of which represented episodes of windblown sand incursion; one in the Early Neolithic, into which Phase 1 funerary features were cut, and one in the earlier Bronze Age (Phase 3) separating two phases of occupation. Sand continued to accumulate in smaller quantities across the site. Unless otherwise stated, all radiocarbon determinations are calibrated using curves from Pearson *et al*. (1986).

Phase	Activity	Date	Period
1	Funerary features cut into windblown sand.	c. 3020-2700 cal. BC (AA-9561) and 1610-1320 cal. BC (AA-9560)	Neolithic-Bronze Age
2	Earliest settlement. Two structures (1a and 1b).	Also lies within the 3020-2700 cal. BC (AA-9561) - 1610-1320 cal. BC (AA-9560) date range.	Neolithic-Bronze Age
3	Windblown sand accumulation and rubble deposits.	Between 1610-1320 cal. BC (AA-9560) and 1535 – 1115 cal. BC (AA-9562).	Bronze Age
4	Late 2nd century BC settlement.	c. 1535-1115 cal. BC (AA-9562).	Bronze Age
5	Unenclosed roundhouse settlement.	c. 750 BC–250 BC 800-390 cal. BC (GU-3059c; GU-3271c) 625-190 cal. BC (GU-3268c) 620-190 cal. BC (GU-3060c and GU-3268c)	Early-Middle Iron Age
6.1	Enclosed roundhouse settlement.	c. 250BC–AD75	Middle Iron Age
6.2	Enclosed roundhouse settlement and secondary enclosure.	c. AD80-AD250.	Late Iron Age
6.3	Abandonment of enclosure.	c. AD250-AD300. 190 cal. BC-cal. AD120 (GU-3280c) 85 cal. BC-cal. AD210 (GU-3277c). cal. AD80-365 (AA-9564)	Late Iron Age
7	Late Iron Age deposits.	AD250-AD750. cal. AD285-670 (GU-3063) - cal. AD620-880 (GU-3064c)	Late Iron Age
8	‘Farm mound’ and final structures in Area 2.	c. AD1100-1250 (cal. AD990-1255 (GU-3066c)-cal. AD 1010-1280 (GU-3069c)	Early Medieval
9	Turf and topsoil	-	Modern

Table 39. Phases of occupation at St Boniface. After Lowe 1998, 97-124.

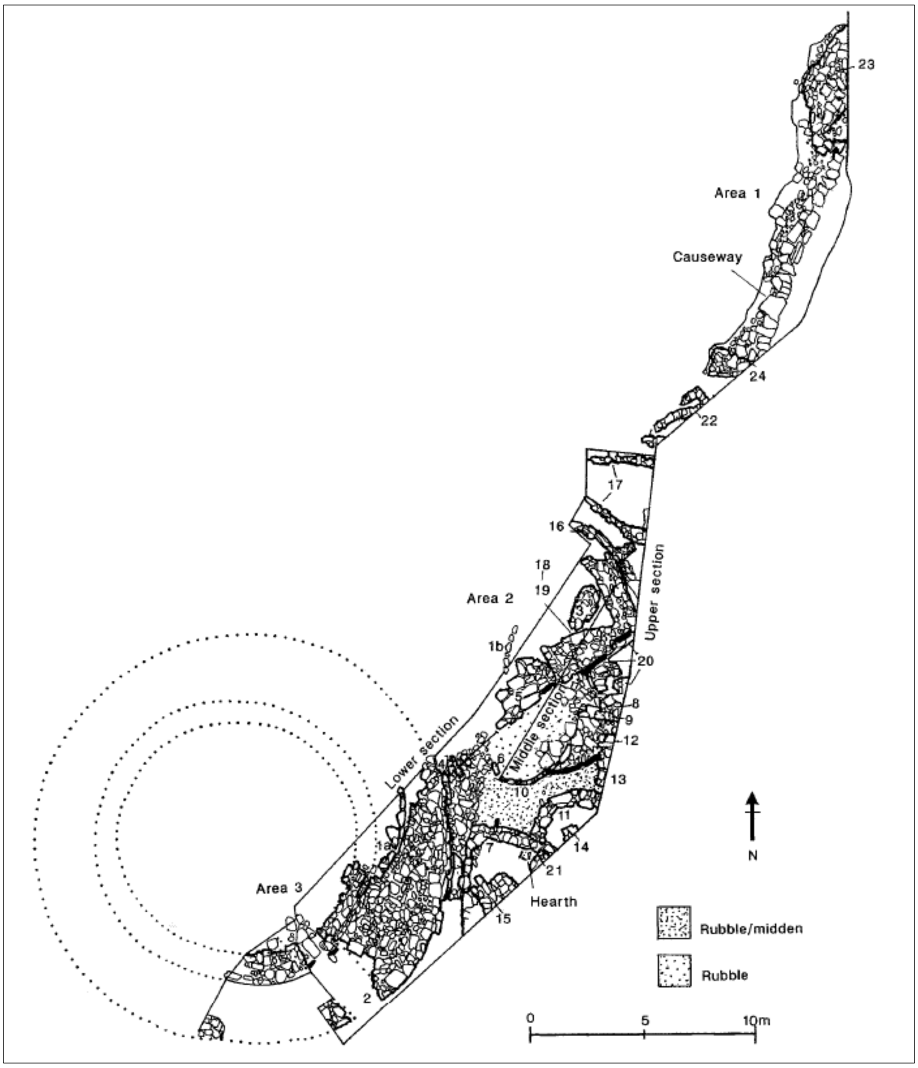

Figure 4.44. Non-phased plan of excavated structures at St Boniface. Lowe 1998, 22. Illustration 11.

Phase 1 (c. 3020-2700 cal. BC (AA-9561) - 1610-1320 cal. BC(AA-9560).

Windblown sand accumulation during the earliest phases of activity at the site was identified in Area 3, south of the site (Figure 4.44). The earliest-recorded deposits comprised a series of calcareous windblown sand deposits (surviving only where they were sealed beneath later structures) and sandy loam soils (Lowe 1988, 23). The basal deposit comprised a sterile sandy loam soil over till and bedrock. This was overlain by, and partly admixed with, c. 0.50m of calcareous windblown sand (Lowe 1998, 23). This sand also directly overlay till in areas where the underlying soil appears to have eroded away. Cattle bone from the windblown sand yielded a radiocarbon date of 3020-2700 cal. BC (AA-9561) (Lowe 1998, 23; 115), although it is possible that this was a later intrusion. This sand was later buried in the Iron Age, having been eroded and mixed into the underlying soil in the millennia prior to this (Lowe 1998, 23). Given the existence of similar activities elsewhere, it is also worth bearing in mind the possibility that some sand was purposely integrated into the soil.

The earliest structural activity at the site is marked by the Phase 1 funerary activity in Area 3, predating Phase 2 settlement and Phase 3 windblown sand accumulations (see below). Three cist-like structures were cut into the c. 0.50m of sand described above, as well as a small cairn later covered by windblown sand. Radiocarbon samples from below and above the features yielded dates of 3020-2700 cal. BC from cattle bone (AA-9561) (Phase 1) and 1610-1320 cal. BC on cattle and pig bone at 96.1% probability (AA-9560) (Phase 3) respectively. These ranges place the construction of the funerary features within the second or late third millennium (between 3020-2700 cal. BC and 1610-1320 cal. BC) (Lowe 1998, 23; 115). The excavators do not state whether the dated animal bone samples derived from a single entity or a mixture of bone. It is worth bearing in mind the possibility of contamination via deflation in the samples retrieved from the windblown sand deposit, which may have been eroded and reworked.

Phase 2 (c. 3020-2700 cal. BC (AA-9561) to 1610-1320 cal. BC (AA-9560)).

The earliest structural settlement activity comprised the remains of two buildings in Area 3, 1a and 1b. 1b comprised a line of angular stones, perhaps the remains of a wall line or kerb (Lowe 1998, 27). No artefactual remains or associated surfaces were recovered from 1b. Structure 1a comprised the remains of a cellular building running beneath the walls of a later roundhouse (Structure 2). One sherd of heavily tempered pottery was recovered from a burnt clay deposit (interpreted as a hearth base) from the interior of 1a. This pottery was of a Late Bronze Age/Early Iron Age form, with a similar type also being recorded from the wall core of the Structure 2 roundhouse. Resultantly, this pottery may be a contaminant from these later deposits (Lowe 1998, 27).

The stratigraphic and chronological evidence for this phase is confusing owing to the nature of excavation. Both structures were built over the Phase 1 windblown sand, but their upper stratigraphies differ. Whereas structure 1b is sealed by the Phase 3 sand (see below), 1a can only be said to predate the Phase 5 roundhouse construction. As such, it is possible that the structures are contemporary with the Phase 1 cists, but 1a may be contemporary with Phase 4. All that can be concluded is that as with the Phase 1 deposits, the structures lie within the chronological range of 3020-2700 cal. BC (AA-9561) to 1610-1320 cal. BC (AA-9560), from the radiocarbon determinations yielded by Phase 1 and 3 deposits (Lowe 1998, 27-30).

Phase 3 (from 1610-1320 cal. BC (AA-9560) to 1535-1115 cal. BC (AA-9562))

In Phase 3, over 1m of calcareous windblown sand and rubble deposits accumulated over the collapsed Phase 2 (Structures 1a and 1b) remains in Area 3 (Lowe 1998, Illustration 31). The sand and rubble deposits were in turn sealed by the later prehistoric structures of Phase 4 and 5 (Structures 2, 3, and 4). No developed soil horizons were identified in the sand, perhaps indicative of an unstable surface subject to erosive action from natural or human activity, or of rapid accumulation. The rubble deposits may be indicative of some demolition debris from Phase 2 structures, but no upstanding structures were identified. A stone-lined posthole cutting the Phase 3 windblown sand, and overlain by more rubble and sand, may also attest to some form of construction activity (Lowe 1998, 30).

Charred naked barley grains, a cetacean bone tool and Late Bronze Age or Early Iron Age pottery were recovered from the sands, comparable to those from the Tofts Ness, Sanday ceramic assemblages. The level of anthropogenic content varied across the Phase 3 deposits and the blocks into which they were divided, indicative of the differential deflation of an unstable sand horizon. The Phase 3 windblown sand deposit also partially overlay the Phase 1 windblown sand, and Structure 1b of Phase 2 (Lowe 1998, 30-1). Cattle and pig bone from the sand and rubble deposit (AA-9560), and cattle and deer bone from an occupation deposit (AA-9562) in the overlying Structure 4 (assigned to Phase 5) suggest the deposits accumulated in the earlier Bronze Age, between 1610-1320 cal. BC (AA-9560) and 1535–1115 cal. BC (AA-9562) (Lowe 1998, 30; 124).

Phase 4 (c. 1535-1115 cal. BC)

From Phase 4-6.2, settlement appears to have continued at the site unbroken, broadly encompassing c. 1500BC-AD250. During this period, later prehistoric buildings were constructed, repaired, robbed, levelled, rebuilt, reused and then eventually abandoned. Three Late Bronze Age buildings (Structures 3-5) were constructed in Phase 4 in Areas 2-3 over the preceding Phases 1 and 3 sands and rubble. Structures 3 and 4 appear to have been contemporaneous, with both containing a series of windblown sands and sediments which accumulated following their abandonment. Structure 5 was constructed over these structures after their deterioration (Lowe 1998, 36). The three structures lay to the north of the Phase 5 roundhouse. All three structures contained rubble and anthropogenic material comprising construction, occupation and post-abandonment demolition and collapse deposits. The 0.5m 'raft' of rubble covering Structures 4 and 5 was employed as a level upon which a series of Phase 6 structures were built (including Structures 6 and 10) (Lowe 1998, 30-1).

Structure 5 comprised the remains of the north wall of a c. 5m long, NE-SW aligned rectilinear building which was constructed over the remains of Structures 3 and 4. The majority of the structure was eroded by the sea to the west, and demolished to the east (Lowe 1998, 35). The fragmentary remains of Structure 3 comprised an area of paving at the north of Area 2, laid over the Phase 3 sand accumulations. Frequent charcoal, burnt peat, and charred barley grains may indicate that this structure served a grain storage and drying function. After cessation of use and demolition, approximately 0.30m of sediment and windblown sand deposits overlay the structure, and abutted the internal partition wall of Structure 4 to the south (Lowe 1998, 35-6). These deposits contained charcoal, peat ash, and rubble indicative of post-deposition disturbance and deflation, with the sand being deposited over a period of time and punctuated by dumping of anthropogenic material (Lowe 1998, 36).

Structure 4 lay to the immediate north of the Phase 6 roundhouse, and was also constructed over the Phase 3 sand. It comprised the remains of a faced cellular structure with only the south wall and part of a north partition wall surviving (Lowe 1998, 36). Approximately 0.05-0.10m of well-stratified surfaces comprising mixed occupation and windblown sand deposits accumulated inside the structure (Lowe 1998, Illus. 31). A charcoal-rich silty floor layer recorded as third in this sequence of deposits contained cattle and red deer bone from which a radiocarbon determination of 1535-1115 cal. BC (AA-9562) was yielded. Occupation of both Structures 3 and 4 have been broadly attributed to this period given that they are stratigraphically linked (Lowe 1998, 36).

Phase 5 (c. 750 BC-250 BC).

Phase 5 marked the construction and occupation of an unenclosed roundhouse settlement in Areas 2 and 3, comprising a roundhouse or broch (Structure 2), cell (Structure 22), low mound, buried ground surface, and shell midden which all spanned the Late Bronze Age and Early Iron Age (Lowe 1998, 37). Structure 2 was constructed over the Phase 3 sands to the west, and rubble to the east, as well as Structure 1a (Lowe 1998, 118). This differential positioning over deposits of varying stability may have led to subsidence of the structure over time. Structure 2 comprised a SE-facing entrance, with two phases of construction apparent; the second phase comprised the addition of a series of wall-skins, perhaps in an aid to increase stability or as weather-proofing. Given that it was constructed over the Phase 3 sand deposits, Structure 2 must have been constructed after 1610-1320 cal. BC (AA-9560). A shell midden which accumulated against Structure 2's exterior east wall offers a broad *terminus ante quem* of c. 800-390 cal. BC (GU-3059c and GU-3271c, both from limpet shells) for its construction (Lowe 1998, 43).

Structure 22 is also posited as belonging to the Phase 5 settlement, and comprises the remains of a small cellular building in Area 1 (Lowe 1998, 118). Limpets from the fill of the linear feature interpreted as a rubbish pit, and the low mound described below (both of which underlie Structure 22) provide a terminus post quem of 620-190 cal. BC (GU-3060c and GU-3268c) for its construction (Lowe 1998, 39). After its disuse, Structure 22 was infilled by a sequence of post-abandonment deposits in Phase 6.1 (see below). The low mound (c. 1m high and 1.5m wide) comprised demolition deposits, midden and windblown sands, with tip lines indicating its formation as a product of activities to the south or east of the mound. Limpet shell from the sandy loam deposit at the base of the mound yielded a broad date range of 625-190 cal. BC (GU-3268c) for its construction and accumulation (Lowe 1998, 40).

Phase 6.1

Phase 6.1 spanned the last quarter of the first millennium BC (c. 250BC-AD75), and saw the cutting of an enclosure ditch (Structure 16) and construction of post-roundhouse structures (Structures 6-8, 11, 18, 23, and 24). Phase 5's Structure 22 was infilled by a sequence of post-abandonment deposits. These comprised a basal deposit of c. 0.10m of yellow windblown sand, followed by a rapid backfilling with stones and soil with tip lines from the southeast. This was followed with a midden deposit containing less stone. The final backfilling deposit comprised a shell midden intermixed with sand in loam, c. 3m across and 0.45m high. Radiocarbon determinations from winkles (340 cal. BC-cal. AD75 (GU-3275c)) and limpets (235 cal. BC-cal. AD115 (GU-3061c)) in the midden provide a *terminus ante quem* for the occupation and cessation of use of Structure 22, and a broad date for the accumulation of the sand (Lowe 1998, 54).

A series of other structural remains which did not contain identifiable windblown sediments also belong to this phase. These include Structure 24, which comprised the remains of a free-standing EW-aligned wall which may have acted as a retaining wall for the midden and rubble deposits which accumulated over and around Structure 22 (see below), and abutted the wall (Lowe 1998, 51). A possible building or paved area (Structure 23) was constructed before cal. AD285-670 (GU-3063), with the remains of another structure (18) comprising a series of floor deposits and two wall segments which formed after 770-375 cal. BC (GU-3273c) (Lowe 1998, 55). The enclosure ditch (Structure 16) cut through the Phase 3 sand deposits and till, and was constructed after 405-100 cal. BC (GU-3058c: winkles). Deposits which appear to have rapidly backfilled the ditch returned radiocarbon determinations of 400-50 cal. BC (GU-3274c: limpets). Two small subrectangular structures (Structures 11 and 7) were constructed after 800-390 cal. BC and before cal. AD25-330 (GU-3282c), while the infill from the remains of a walled structure (Structure 6) offer a *terminus ante quem* of 50 cal. BC-cal. AD235 (GU-3278c) for its construction (Lowe 1998, 81).

Phase 6.2.

Broadly spanning the first quarter of the first millennium AD, Phase 6.2 is characterised by the cutting of the secondary enclosure ditch (Structure 17), and the construction and subsequent abandonment and demolition of associated structures (see below) and a secondary enclosure wall and entrance façade (Structure 19) (Lowe 1998, 66). The secondary enclosure ditch lay c. 1.5m north of the earlier ditch (Structure 16), and cut through the backfilled Phase 6.1 ditch. The ditch was not directly dated, but the date of 235 cal. BC-cal. AD115 (GU-3061c) from the Phase 6.1 shell midden offers a *terminus post quem* for its construction (Lowe 1998, 73). The basal fills of the secondary enclosure ditch comprised silt-wash, enriched with sand and midden material (Lowe 1998, 82).

This phase also marks the construction of post-roundhouse Structures 9, 10, 12, and 13 which surrounded the entrance façade and secondary ditch. These structures comprised fragmentary walls and paving, with all displaying post-abandonment deposits including rubble and loamy soil. Structure 9 comprised an undated fragmentary wall and floor, containing post-abandonment deposits comprising brown loam and stones. It lay inside the secondary entrance façade of Phase 6.2 (Structure 20) (Lowe 1998, 80). Structure 10 overlay Phase 6.1's Structure 6, and constituted an undated internal wall face and occupation surfaces, followed by dump deposits (soil and rubble) which accumulated after its abandonment (Lowe 1998, 78). Structure 10 was constructed after 50 cal. BC-cal. AD235 (GU-3278c).

Structure 12 lay inside the secondary enclosure ditch and overlay Structure 10 and its infill deposits (Phase 6.2), and was constructed after 50 cal. BC-cal. AD235 (GU-3278c). The structure was filled with soil, rubble and midden later in the phase (Lowe 1998, 75). One of the latest buildings on the site, Structure 13 comprised a wall fragment and area of paving (Lowe 1998, 74). A blocking wall which formalised the abandonment of the Structure 2 roundhouse (Phase 5) and the post-roundhouse Structure 7 (Phase 6.1) (Lowe 1998, 74) was also constructed. The phase also marks the infilling of Phase 6.1's Structure 6, with shells from the rubble debris and midden yielding a determination of c. 50 cal. BC-cal. AD235 (GU-3278c) (Lowe 1998, 81). In contrast to previous phases, no notable windblown sand deposits were reported from this phase, nor from the Phase 6.3 abandonment deposits. This may indicate a period of stabilisation of sand sources in the vicinity of the site.

Phase 6.3.

6.3 is characterised by an apparent cessation of activity at the site, with the abandonment and infilling of the enclosure, entrance façade, and Structures 7 and 11. 0.90m of rubble and midden material filled the façade (Structure 19), with the basal deposits from the primary fill yielding dates on mammal bone and shell of cal. AD80-365 (AA-9564) and 190 cal. BC-cal. AD120 (GU-3280c). These dates provide a *terminus post quem* for the rest of the infilling of the façade (Lowe 1998, 83). The lowermost fills of the secondary enclosure ditch comprised stone robbing debris, rubble from dismantled structures, and redeposited midden. Shells from these deposits yielded a radiocarbon determination of 85 cal. BC-cal. AD210 (GU-3277c). This date also provides a terminus post quem for the undated upper infill deposits, which comprised silty soils and animal bone (Lowe 1998, 82-3).

Phase 7

In Phase 7 activity shifted to the north of the site, and spanned c. AD250-750. This period is characterised by a large accumulation of dumped ash residues dated to the Late Iron Age, which were then levelled - potentially in advance of, or during, cultivation (Lowe 1998, 86). The formation of extensive and deep plaggen soils took place from cal. AD285-670 to cal. AD 520-870. At the end of Phase 7, this northern area was also abandoned from AD750-1100, and a ground surface developed, before reuse of the area from AD1100-1250, by the rapid accumulation of the Phase 8 'farm mound'.

The 0.50-0.90m of Late Iron Age ash deposits overlay the shell midden, causeway and Structure 23 of Phase 6.1, and were sealed by the sandy loam ground surface. The matrix was one of sandy silty loam, with additions of charcoal, shell and fuel ash representing dumps of specialised midden interleaved with periods of soil formation (Lowe 1998, 88). Mammal bone from the basal deposit yielded a radiocarbon determination of cal. AD285-670 (GU-3063), while shell and mammal bone yielded two dates from the top of the deposit; cal. AD620-880 (GU-3064c) and cal. AD520-870 (GU-3065).

A sandy loam ground surface containing anthropogenic material developed over these dumped deposits, and was in turn overlain by the Phase 8 farm mound accumulations. Cattle and sheep bone from these overlying sediments yielded a radiocarbon determination of cal. AD990-1240 (GU-3067), while bulk animal bone from the ash deposits underlying the ground surface yielded a determination of cal. AD520-870 (GU-3065). These bracketing dates indicate the formation period for the ground surface, with probability distributions in the chronological data suggesting that it existed for between 310-525 years (Lowe 1998, 86; 106).

Phase 8

Phase 8 comprised a series of undated deposits and structures in Area 2, and the development of a 'farm mound' in Area 1 (Lowe 1998, 88). The Area 2 structures comprised a drystone wall and paved floor of a structure (21) built over Phase 8 rubble deposits, as well as a series of rubble and collapse deposits. They are tentatively assigned a broad age range of AD1100-1500. The farm mound deposits are assigned to the period AD1100-1250 (Lowe 1998, 89). The farm mound comprised sandy silty loam deposits, ash, midden, fish and animal bone, burnt turves and other organic sediments which accumulated rapidly over the Phase 7 Late Iron Age buried ground surface (Lowe 1998, 89). Radiocarbon dating of a bulk deposit of shells and cattle, sheep and goat bone places the foundation of the farm mound to cal. AD990-1255 (GU-3066c), with shells from the upper portion of the mound yielding a date of cal. AD1010-1280 (GU-3069c) (Dalland in Lowe 1998, 106-7). Unlike other, 'farm mounds' across the island, no distinct windblown sand accumulations or horizons were noted in the St Boniface mound. The frequent sandy loams which characterise the matrix of the mound do however suggest that sand may have still moving in the area to some extent, and was a notable component in the soils surrounding the settlement.

Discussion: windblown sand at St Boniface

In total, five windblown deposits of varying dimensions and composition were visually identified during the St Boniface excavations, all of which can be roughly assigned a prehistoric age range. The first occurred, in the Neolithic period prior to extensive occupation activity (Phase 1), the second in the earlier Bronze Age (Phase 3), the third in the later Bronze Age (Phase 4) and the final two in the Early-Middle Iron Age (Phases 5 and 6).

Chronology

Episodes of Neolithic windblown sand accumulation during the earliest phases of activity were identified in Areas 1-3 (Figure 4.43). This comprised a series of calcareous windblown sand deposits (which survived only where they were sealed beneath later structures) and sandy loam soils overlying the basal till (Lowe 1988, 23). A contrast can be noted between the deposits overlying the till in Areas 1, and Areas 2 and 3. While Area 1's deposit was characterised by c. 0.40m of non-calcareous sandy loam, the till in Areas 2 and 3 was overlain by the c. 0.50m of calcareous windblown sand (Carter in Lowe 1998, 184-5). It is likely that the sandy loam was formed by the admixture of sand with the till-derived soil profile, and that the 0.50m of calcareous sand which covered the till in Areas 2 and 3 originally stretched into Area 1 as well. It is conceivable that the sand in Areas 2 and 3 was originally much more extensive in terms of its depth and width, with human activity removing more extensive deep sand cover here an in Area 1 (Carter in Lowe 1998, 185).

This windblown sand also directly overlay till in areas where the underlying soil appears to have eroded away. Cattle bone from the windblown sand yielded a radiocarbon date of 3020-2700 cal. BC at 95.6% probability (AA-9561) which provide a *terminus ante quem* for the deposition of the basal windblown sand (Lowe 1998, 23; 115). It must be noted, however, that the dated bone from this layer may have originated from a later deposit which became eroded and deflated. This sand was later buried in the Iron Age, having been eroded and mixed into the underlying soil in the millennia prior to this (Lowe 1998, 23). Given the existence of similar activities elsewhere, it is also worth bearing in mind the possibility that some sand was purposely integrated into the soil.

The next recorded incidence of windblown sand accumulation appears in Phase 3. Here c. 1m of windblown well-sorted calcareous sand and rubble deposits accumulated over the piecemeal remains of the Phase 2 structures in Area 3 after their abandonment in the earlier Bronze Age. Cattle and pig bone from this deposit yielded a determination of 1610-1320 cal. BC (AA-9560), while cattle and deer bone from a sealed occupation deposit in Structure 4 (which was constructed directly over the windblown sand) was dated to c. 1535–1115 cal. BC (AA-9562) (Lowe 1998, 30; 124). The varying colour and inclusions within the sand – as well as the appearance of rubble deposits - indicate that this deposit accumulated over a longer period of time, as opposed to representing a single event. Lowe interpreted the period of sand accumulation as marking the "abandonment of the early site" (Lowe 1998, 30; 124).

In Phase 4 (1535-1115 cal. BC), Late Bronze Age Structures 3 and 4 were constructed over the sands and rubble from Phases 1 and 3. After their use, they were filled with a series of windblown sands and sediments (from c. 0.10-0.30m). Cattle and deer bones from a floor layer in Structure yielded a radiocarbon determination of 1535-1115 cal. BC (Lowe 1998, 36), and this date may be employed as a Late Bronze Age *terminus post quem* for the subsequent sand accumulation (Lowe 1998, 36).

From Phase 5 onwards, deposits of windblown sand become a less frequent occurrence in the archaeological sequences, and form only a small component in discrete areas. In

Phase 5, windblown sand was only identified in a low (c. 1m high) mound comprising rubble, midden and sands which underlay Structure 22 in Area 1 (Lowe 1998, 40). No precise dimensions for the windblown sands were offered by the excavator. Limpet shell from the sandy loam at the base of the mound yielded a broad age Early-Middle Iron Age range of 625-190 cal. BC (GU-3268c) for its accumulation (Lowe 1998, 40), and therefore the accumulation of the windblown sands.

Only one windblown sand deposit can be confidently identified as belonging to Phase 6.1, comprising the post-abandonment deposits which infilled Phase 5's Structure 22. A basal deposit of 0.10m of yellow windblown sand was covered with a rapid backfill deposit of midden and rubble from the southeast, followed by c 0.45m of shell midden intermixed with windblown sand lenses and loam. Winkles and limpets from this deposit yielded determinations of 340 cal. BC-cal. AD75 (GU-3275c) and 235 cal. BC-cal. AD115 (GU-3061c) respectively (Lowe 1998, 54). This offers a broad Middle Iron Age date range for the accumulation of the windblown sand lenses in the shell midden, with the basal sand accumulating before this date. (GU-3061c) also offers a *terminus post quem* for the construction of the Phase 6.2 secondary enclosure ditch, which comprised silt-wash, enriched with sand and midden material (Lowe 1998, 82).

Excavation strategy

As at the Birsay Bay sites (see 4.4), St Boniface was investigated using the tapestry excavation technique. While this method has allowed for a relatively rapid characterisation of eroding sites and their chronologies, it also introduces some interpretative challenges. Due to the stratigraphic complexity of multi-period sites which are not fully excavated in plan, and deflation of deposits at high risk of marine and aeolian erosion, it can be difficult to build a truly representative and chronologically-secure understanding of deposits at the site.

It must be borne in mind that many of the radiocarbon dates are bulk in nature; that is, they are derived from a sample which contains multiple elements. In this case, many of the radiocarbon samples are comprised of a mixture of disarticulated animal bones and fragments, often deriving from more than one species (as is the case with 7 of the 27 radiocarbon determinations from St Boniface) (Lowe 1998, 97). This presents difficulties in that single entity samples (samples deriving from a single organism) are generally accepted as being the best type of sample for radiocarbon dating. This guards against the possibility that residual material may be contained within the mixed sample, thus providing a problematic average date (e.g. Ashmore 2004, 125; Horn 2016, 142-3). This becomes especially problematic when considering the high possibility of deflation of deposits at sites like St Boniface.

Additionally, the majority of the dates (19 out of 27) used to provide chronological brackets for the windblown sands at St Boniface derive from marine shells (specifically winkle and limpet). The dating of archaeological deposits using marine shell can be problematic, due to its susceptibility to the effects of the Marine Radiocarbon Reservoir

(Barber 2003, 215-6; Sharples 2012, 14). This effect can create an older bias on marine materials of c. 405±40 radiocarbon years (Harkness 1983). As the marine effect varies, in recent years it has become apparent that it is unsafe to simply correct the age by c. 405 radiocarbon years (Barber 2003, 215-6; Ascough *et al.* 2004). This is the conventional correction employed by Lowe for the St Boniface dates (Lowe 1998, 97). Only the Phases 1 and 3 sands were directly dated by radiocarbon, with the rest of the sand deposits only dated by their association with other radiocarbon dated deposits. This is problematic and ensures that only relative dates can be produced for the other sand lenses and accumulations identified at the site.

Provenance

St Boniface lies north of an extensive area of windblown sand (c. 1.7km) at the west of the island (Figure 4.35), which has been developing since the Neolithic (Carter in Lowe 1998, 185). This is the most likely source for the sand deposits observed at the site, as well as those at Knap of Howar. Little more information can be gleaned on the possible source of the sand, and the direction from which it was transported. Although palaeoenvironmental data can aid in the interpretation of the local environment of a site (and resultantly, the location of possible sand sources), given the piecemeal nature of excavation and varying collection strategies, only snippets of information on the environmental context of St Boniface may be gleaned.

Only a very small sample of animal and fish bone was recovered from the excavations, with samples mostly too small to provide quantitative data (McCormick in Lowe 1998, 146-7). Barley was the most commonly represented cereal throughout the site (Boardman in Lowe 1998, 158). Limpets (*Patella*) and winkles (*Littorina*) dominated the marine shell assemblages, indicative of rocky shore exploitation (Carter in Lowe 1998, 156). Low numbers of non-marine terrestrial shell were recovered, with numbers dominated by modern species which entered the remains at a later date. This makes it difficult to quantify their role in the environment during occupation of St Boniface. The small assemblage of freshwater species is indicative of a marsh or wet grassland environment (Carter in Lowe 1998, 157). Palaeoecological analysis was only undertaken on the Late Iron Age buried soil of Phase 7. Many of the pollen grains retrieved from the samples were found to be heavily deteriorated, and resultantly the dataset recovered was considered incomplete. The recoverable taxa suggest that the landscape at St Boniface was open throughout its occupation, dominated by wild grasses (*Gramineae*) and pastoral herbs (*Plantago* spp.) (Tipping in Lowe 1998, 167).

Living with sand at St Boniface

Much of the sand deposits at St Boniface are representative of the lack of use of various structures, with sand allowed to accumulate in empty spaces and structures. If sand drifted during the occupation of these settlements, which is not improbable, then it must have been either cleared away by the inhabitants or eroded and deplaced by later sands. The majority of structural remains at St Boniface are extremely fragmentary, and as a result it is difficult to ascertain any impacts sand accumulations might have had on settlement. The longevity of settlement activity in this location may indicate that the frequency of sand incursion was not considered problematic. It may be the case that even in the phases where no discernable, discrete accumulations of sand were identified, sand was still drifting in some small quantities; with larger accumulations being cleared or admixed into midden and other anthropogenic deposits. Alternatively, the periods in which sand deposits were not identified may genuinely reflect a lack of sand mobilisation at this time.

4.6.3. Discussion: windblown sand on Papa Westray

Windblown sand deposition on Papa Westray is dominated by prehistoric incidences, although precise dating for these accumulations remains an issue. Only the sites at Knap of Howar and St Boniface (both of which lie on the West Coast) are included in the summary of the evidence for sand accumulation on Papa Westray. The eroding sections containing sand deposits at King's Craig, Moclett, Cott, and Mayback display a lack of chronological and environmental data, and summaries should be sought in Appendix 1. The earliest dated incident of (very small-scale) windblown sand deposition occurred at Knap of Howar in the Early Neolithic between c. 3635-3370 cal. BC (*start_knap_of_howar*) and 3345-3020 cal. BC (OxA-16476) (Bayliss et al. 2017 [Supplementary Material], 14; 19). As at Skara Brae, the sand covering the remains of Howar after c. 3500-2850 cal. BC (SRR-344) is likely to have accumulated over several centuries or perhaps even millennia.

Neolithic sand accumulation took place at St Boniface at around 3020-2700 cal. BC (AA-9561)). This date was yielded on cattle bone from a basal sand deposit. It is possible that this bone was a later addition to the sand; nevertheless, it provides a *terminus ante quem* for the sand's deposition. If this is the case, it is worth reflecting on whether this basal sand is comparable to those identified at Bay of Skaill (Mainland) (dated to c. 3750 cal. BC-3050 cal. BC (SRR-978)), Links of Noltland (Westray), and Cata Sand (Sanday), which appear to represent the original ground surface upon which Neolithic communities began to settle. The Knap of Howar confuses this situation somewhat in that settlement appears to have been founded over soil and till with extensive sands appearing to have accumulated later in the Neolithic.

Both sites hold limitations when it comes to understanding Neolithic sandblow in the island; while St Boniface was excavated through the tapestry method (the limitations of which have been discussed previously), Knap of Howar was subject to extensive antiquarian excavations which removed many of the sand deposits contemporary with its occupation. Sand continued to accumulate at St Boniface in the Early Bronze Age, between 1610-1320 cal. BC (AA-9560) and 1535–1115 cal. BC (AA-9562)), and into the Middle Iron Age at c. 340 cal. BC-cal. AD115 (GU-3275c; GU-3061c)) as the settlement developed. These dates are the latest available for sand movement on the island at present, with the extensive coastal farm mound (which, as a site type, are usually characterised by their extensive windblown sand accumulations) containing no distinctive sand deposits. The eroding Papa Westray sites discussed in Appendix 1 all appear to comprise later deposits, which are likely to have accumulated in the Norse and Medieval periods. Being the smallest island, it is perhaps unsurprising that Papa Westray contains the fewest dated archaeological sites with evidence for windblown sand accumulation although this could easily be an artifact of excavation activity, which has been much more focused on the neighbouring island of Westray.

4.7. Westray

Westray is the most northwesterly of the Orkney islands, exposed to northerly and westerly winds and storms. This has created numerous areas of blown sand, from small and sheltered bays to the south and east, to larger extensive bays and links. The island is low-lying and cultivatable to the south and east, with a ridge of hills, steep slopes and cliffs to the west (Moore and Wilson 1998, 63). In contrast to Sanday - which is dominated by calcareous soils – Westray contains smaller pockets of these soils, to the northeast and southwest tips of the island. Most of the soils comprise mineral gleys with some peaty podzols on the west coast. With the exception of Berst Ness and Mae Sand, all sites with recorded deposits of windblown sand are clustered at the north of the island (Figure 4.45). The most extensive deposits of blown sand are located at Noltland, Mae Sand, Tuquoy, and Pierowall Links, with smaller pockets on the east coast.

The Pierowall Links landscape lies at the north-west of Westray, and encompasses a large area (at least 3-4km) of blown sand deposits along the westerly-exposed coastline and its hinterland. Within this large expanse lie the Links of Noltland and Pierowall sites. The extensive blown sand deposits attest to the dynamic geomorphological history of this exposed landscape. Numerous sites and stray findspots are recorded in the dune landscape, with many being exposed following historical sand movements and erosion within the dunes. Most notably, a series of Norse inhumation burials cut into the sand were discovered, excavated and recorded by William Rendall in 1839, George Petrie in 1841 and James Farrer in 1855 and 1863 (RCAHMS 1983).

Work on the Westray sites indicates that large swathes of the island were covered by sandblow through time (Table 40). The variety in date indicates that the presence of windblown sand is highly dependent on sediment supply and localised coastal geomorphology as well as of broader climatic drivers. Numerous historical sources refer to the dynamism of the sandy landscapes on Westray. The New Statistical Account records the exposure of graves inhumed in light and sandy soil following incidents of high wind (The Rev. John Armit 1841, 126, cited in Leask 1996, 127). The Bays of Tuquoy and Pierowall are described in detail in the Third Statistical Account. The presence of a submerged forest (possibly akin to that at Otterswick Bay, Orkney), was noted in the intertidal zone of the Bay of Tuquoy (Rev. Henry R. M. Fraser 1950, 232, cited in Leask 1996, 127-128). Areas of the coastline at Tuquoy underwent considerable marine and wind erosion throughout history, with its exposed location and soft drift deposits ensuring its susceptibility to such processes. The soils around Noltland contain high proportions of windblown sand, and historical sources make frequent reference to the limitations of cultivating the links here. Sand blowouts have buried or blown away cultivated land (Thomson 1990, 38).

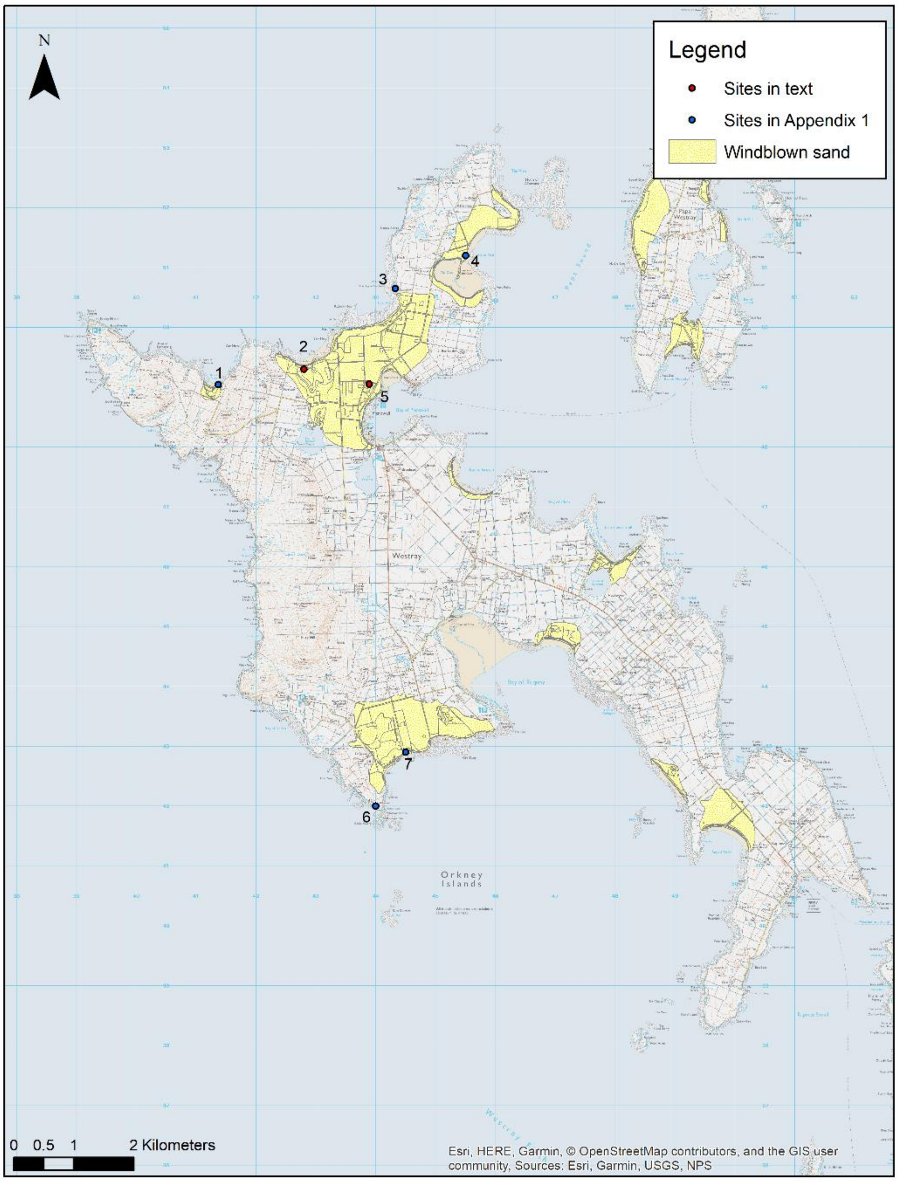

Figure 4.45. Westray sites. 1. Noup; 2. Links of Noltland; 3. Quoygrew; 4. Evertaft; 5. Pierowall Quarry; 6. Berst Ness; 7. Mae Sand.

Site	Site type	Period of human activity	Sandblow period	Reference
Links of Noltland	Settlement	Late Neolithic (from c. 3160–2870 to 2170–1840 cal. BC (*start_LoN; end_LoN*); Bronze Age (from c. 2170–1840 cal. BC (*end_LoN*)) – until c. 1000 BC.	Late Neolithic. Trench D: from at least 3160–2870 cal. BC until 2850–2640 cal. BC ((*last_Phase_II*); between 2230-2130 cal. BC (*Red_deer*), and 2200-1930 cal. BC (*last_Trench_D*) (Clarke *et al*. 2017, 72; Illustration 11); Trench C: before wall construction 2780–2340 cal. BC (GU-1693); *around* 2340–2035 cal. BC (GU-1432) until c. 2265–1975 cal. BC (GU-1690). Trench A: after 2470-2140 cal. BC (GU-1433) and 2480-2135 cal. BC (GU-1692), perhaps until 2470–2005 cal. BC (GU-1695) (Marshall *et al*. 2016, 29; Table 4). Burnt mound: Middle-Late Bronze Age (c. 1000BC). Cemetery: Late Neolithic - Early Bronze Age: before 1630-1460 cal. BC (GU-27901) and 1690-1510 cal. BC (GU-27908).	Clarke *et al*. 2017; Marshall *et al*. 2016; Moore and Wilson 2009; 2015; 2017
Pierowall Quarry	Chambered cairn, settlement	Neolithic (from at least 3040-2605 cal. BC (*start_pierowall_quarry*) to 2860-2600 cal. BC (*cairn_levelled*); Early Iron Age	Bronze Age (between 2860-2600 cal. BC; *cairn_levelled*) and 800-410 cal. BC (GU-1580); after the Early Iron Age (after 670-400 cal. BC (GU-1581))	Sharples 1984; Bayliss *et al*. 2017

		(from at least 800-410 cal. BC (GU-1580)		
Pierowall Lady Kirk	Palaeoenvironmental section	n/a	Early Iron Age (340±200BC <SUTL-879>); Medieval (AD1385±50 <SUTL-878>); Modern (AD1725±25 <SUTL-877>)	Sommerville 2003
Berst Ness	Settlement	Multiperiod**.** Neolithic, with use of cemetery into the Norse period	Unknown prehistoric	Moore and Wilson 2002; 2003; 2006
Evertaft	Midden	Iron Age (from at least cal. AD130-420 (AA-39134)).	Middle Iron Age (240±165AD), Late Pictish/early Norse (940±110AD)	Sommerville 2003; Barrett *et al*. 2000
Quoygrew	Settlement	Late Norse - Medieval	Between cal. AD677–959 (TO7118) and cal. AD1243-1381 (AA52358)	Sommerville 2003; Simpson et al. 2005; Barrett *et al.* 2012
Mae Sand	Midden	Unknown	Unknown	Moore and Wilson 1998
Noup	?Settlement	Unknown	Unknown	Moore and Wilson 1998

Table 40. Westray sites showing occupation and sandblow periods.

4.7.1. Pierowall Quarry

The site at Pierowall Quarry was partially excavated in 1981, in advance of quarrying for stone. The site is located on the low ridge connecting Westray with the Peninsula of Aikerness and Rackness, between the Bay of Grobust to the northwest, and the Bay of Pierowall to the east (Sharples 1984, 76). It lies within a large drift deposit of blown sand, known as the North Links, which accumulated following the abandonment of the site. The site was identified as an Early Iron Age settlement of the first and second millennia BC, overlying the remains of a Neolithic Maes Howe-type chambered cairn dating to the mid-third millennium BC (Sharples 1984).

Chronology and phasing

Eight radiocarbon determinations were recovered from excavated contexts at Pierowall, and are calibrated here using OxCal 4.3.

Neolithic occupation

The construction of a c. 18m diameter chambered cairn and revetment (which later collapsed) represents the earliest evidence for occupation at the site. A lack of suitable material ensured that a date for the construction of the cairn could not be established, with the earliest dated material being recovered from the collapsed revetment stones. These dates (3350-2600 cal. BC on sheep radius (GU-1586), 2900-2350 cal. BC on cattle scapula (GU-1587), and 2950-2300 cal. BC on sheep tibia (GU-1588)) offer a *terminus ante quem* for the cairn's construction (Sharples 1984, 117).

After the revetment of the cairn collapsed, it was levelled and paved (Sharples 1984, 79). A small platform with an associated rectangular structure above it was constructed. The rectangular structure contained occupation deposits, from which two dates were recovered (2890-2570 cal. BC (GU-1582) and 2900-2350 cal. BC (GU-1584)). Given that part of this structure had been destroyed by the quarry, its exact function, and relationship to the earlier monument, is unclear (Sharples 1984, 90). More recent chronological modelling of the Neolithic phases has provided a *terminus ante quem* for the construction of the cairn at 3040-2605 cal. BC (*start_pierowall_quarry*). The cairn is estimated to have been deliberately destroyed in 2860-2600 cal. BC (*cairn_levelled*) (Bayliss *et al.* 2016, 38; Figure S15).

Iron Age occupation

The Iron Age occupation phase constitutes the construction and occupation of a thick-walled roundhouse with widespread occupation, excavated into the previous cairn mound. A *terminus ante quem* of 800-410 cal. BC on cattle bone (GU-1580) has been offered for the construction of the roundhouse, which was surrounded by occupation deposits of up to 0.40m in depth (yielding a date on cattle bone of 670-400 cal. BC (GU-1581)), which reached at least 9m downslope of the roundhouse to the east.

Economy and environment

Cattle, sheep, pig and deer comprised the majority of the domestic mammal assemblage. The rapid nature of the salvage excavation meant that there was no systematic recovery system for cereal grains, and as such there is no significant evidence for the nature of arable activity at the site. Marine molluscs (the majority of which were limpets, followed by winkles), also played a notable role in the economy of the site, particularly in the Iron Age phase of occupation. The chronological groupings of the quantities of marine molluscs also have implications for an understanding of the surrounding environment; a near-complete absence was noted in the deposits associated with the Neolithic structure, with the majority of marine molluscs being recovered from the Early Iron Age occupation deposits.

The variation may be indicative of a change in environmental conditions in the vicinity of the site between the two periods of activity (Barlow in Sharples 1984, 112-3). On analysis of the Neolithic assemblages, the marine environment is suggested to have resembled a sheltered shoreline environment, with significant marine weed cover. In the Iron Age, the assemblages change to be represented primarily by mud and sand-dwelling species. Barlow argues that this shift is linked to the onset of increased windblown sand movement more widely, and coinciding with deposition of blown sand at the site itself following the abandonment of the Neolithic structures (Barlow in Sharples 1984, 112 and see below 'Sandblow').

Windblown sand at Pierowall Quarry

Approximately 0.20m of blown calcareous sand was noted to have accumulated over the site following the abandonment of the Neolithic tomb. A layer of shillet representing the decay of the sandstone used to construct the tomb was overlain by this windblown sand. It is interpreted as having been deposited in the Bronze Age (N. Sharples *pers. comm.*). With time, this sand overlying the remains of the cairn would have developed a covering of vegetation, with a few exposed stones likely to have attracted later settlers as a source of building material (Sharples 1984, 87). The foundations of the Early Iron Age roundhouse were constructed into the mound of the cairn. A date of 800-410 cal. BC (GU-1580) from cattle bone in the occupation soil provides a *terminus ante quem* for the roundhouse construction (Sharples 1984, 89), and for the sand which accumulated beforehand.

This sand layer was best-observed in the south-facing quarry section, where it was seen to begin c. 2-6m downslope from the cairn revetment (Sharples 1984, 87 and see

Illustration 11) and continued beyond where the cairn had collapsed. The deposit was consistent in its thickness, making it difficult to ascertain the direction from which it may have been mobilised.

The second sand layer measured at least 0.35m in thickness, and overlay the roundhouse which was partly dismantled and infilled. The sand was light brown sand in colour for the top 0.35m, before changing to a yellow shade. Where the two colours met, it was possible to identify furrow scars deriving from cultivation and it was suggested by the excavator that the darker brown colour of the uppermost portion of the sand layer derived from a process of fertilisation, perhaps using manure or mixed occupation deposits. This brown sand was overlain by an additional blown sand deposit which was covered by the modern turf (Sharples 1984, 89).

OSL dating

A test pit was excavated, and sands sampled for OSL dating by Sommerville (2003) near Lady Kirk, southeast of the Pierowall Quarry site. Although the test pit was not in the direct vicinity of the site, the dates recovered from it helps to contextualise later sand movements in the landscape. The deposits comprised a flagstone at the base (possibly representing archaeological remains, but not investigated further), overlain by three medium-grained calcareous sand layers, the lowest of which was separated from the upper two by a palaeosol. The lowest sand layer yielded an Early Iron Age determination of c. 340±200BC <SUTL-879>. The sand layer directly *overlying* the palaeosol was dated to the mid-late 14th century AD (AD1385±50) <SUTL-878>, and the uppermost to the early 18th century AD (AD1725±25) <SUTL-877>. This deposit may be related to the AD1765 hurricane, during which much of the island was inundated by sand (Fereday 1990 cited in Sommerville 2003, 107).

A gap of over a millennium (c. 1200 years) between the Early Iron Age and 14th century AD layers was identified; any sand which may have been deposited between these two phases (for example, dating to the Viking period) may have been eroded by subsequent geomorphological activities (Sommerville 2003, 305). It is unfortunate that no radiocarbon date was able to be recovered from the palaeosol to ascertain the period of its formation. Although the significant error on the Iron Age date must be noted, it is conceivable that this deposit is closely related to the uppermost sand deposit excavated at Pierowall Quarry, and may perhaps represent the same event.

4.7.2. Links of Noltland

The Links of Noltland lies on the northwest coast of Westray at Grobust Bay, c. 11km northwest of Pierowall Quarry (Sharples 1984). The site is situated within approximately four hectares of sand dunes and machair, and contains Neolithic and Bronze Age settlement activity (Figure 4.46). The coastal zone and its immediate hinterland are under significant threat from erosion, with Grobust Bay characterised by a high-energy geomorphological system prone to wind erosion (Figure 4.47). Areas of blowout at the shoreline stood in contrast to the low-lying marram dunes towards the hinterland in the 1970's (Mather, Smith and Ritchie 1974; 116-7), but this dune system has now been almost totally depleted and blown further inland, and is no longer replenished by offshore sediment sources (Moore and Wilson 2006, 9). Excavations reveal that extensive areas of the site were covered with windblown sand during the Neolithic and Bronze Age, as well as in the historic period.

The site was settled from at least c. 3160–2870 cal. BC (*start_LoN*) (Marshall *et al.* 2016, 10), and during this time was periodically inundated by windblown sand until its abandonment at c. 1000BC. The large quantities of sand would have significantly affected the quality of the agricultural land as well as the wider viability of settlement in this precarious zone. As such, it is likely that a 'tipping point' was reached at the Links of Noltland during the Middle to Late Bronze Age, during which time the decision was made to finally abandon the vicinity (Moore and Wilson 2017, 3). Sand continued to cover the landscape, houses, ritual structures, field systems and cemetery, allowing for a well-preserved archaeological landscape.

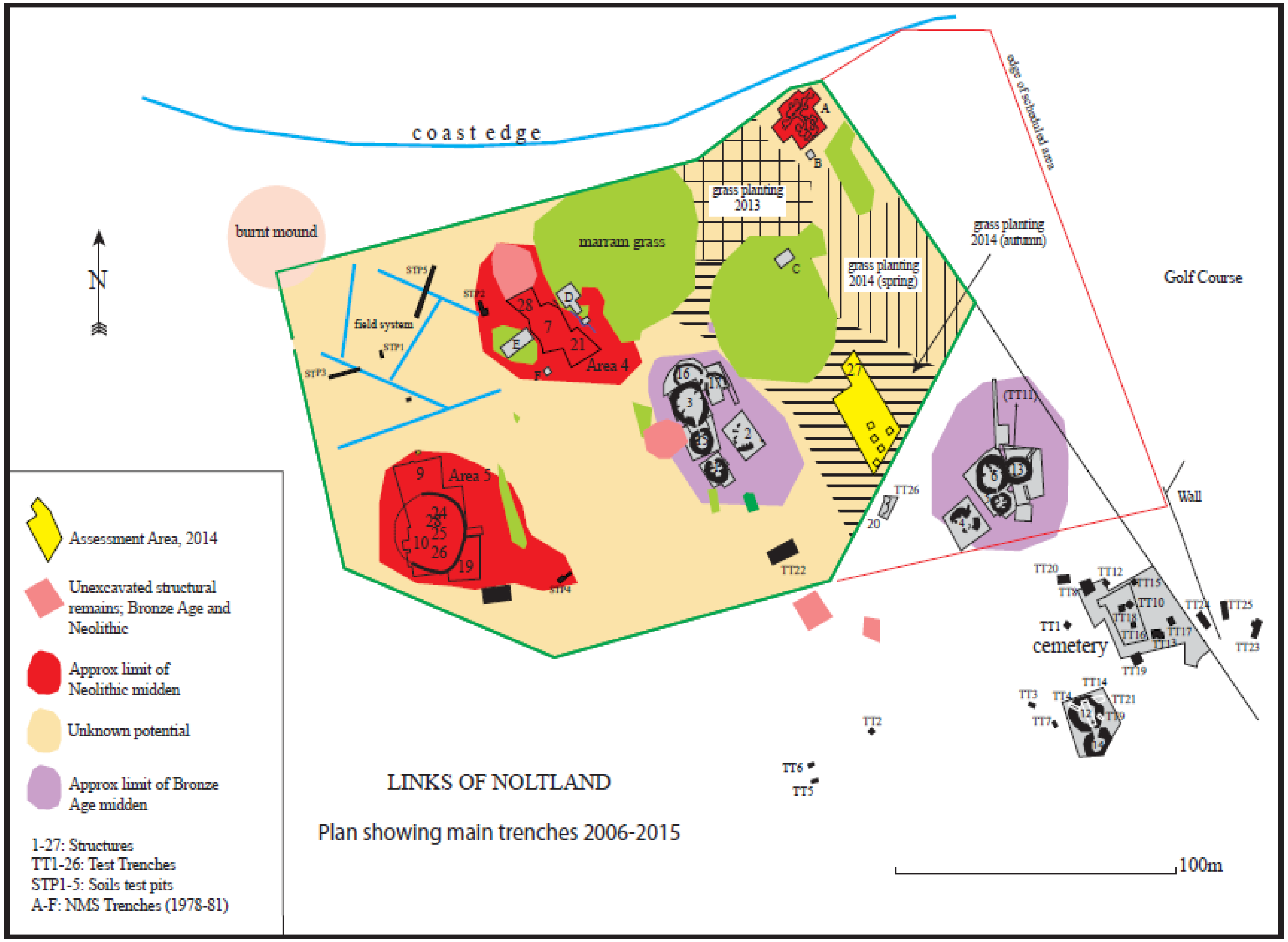

Figure 4.46. Links of Noltland site plan showing major trenches and features, and extents of the Property in Care (PIC) site in green, and the Scheduled Ancient Monument (SAM) site in red. Moore and Wilson 2016, 5.

Figure 4.47. Oblique aerial view of the eroding Links of Noltland excavation area, looking east. RCAHMS Digital Collections DP 143184.

History of excavation

The archaeological site is split into two managed zones; the Property in Care of Historic Environment Scotland (hereon referred to as PIC) is located in the sandy area to the rear of the bay (encompassing Neolithic and Bronze Age remains), while the Scheduled Ancient Monument (hereon referred to as SAM) area containing Bronze Age remains lies to the rear of the PIC. Bronze Age remains also lie outwith these areas (Figure 4.46). The remains at Links of Noltland have been the subject of assessments and excavations since the late 1970's. Consolidation of the remains was undertaken in 1986 (Owen 1986), and since this time both the PIC and SAM have been the subject of excavations and assessments (Moore and Wilson 2011, 14-16). The two most in-depth series of excavations comprise those undertaken by David Clarke and collaborators (1979-1981), and by EASE Archaeology (2007-present). While Clarke *et al.* excavated a series of Trenches (A-F) in the PIC, EASE Archaeology's excavations are defined within a series of Areas (1-6) in the PIC, as well as those in, and outwith, the SAM area (Figure 4.48).

Excavations by David Clarke et al.

From 1978-1981, what is now the PIC was excavated by David Clarke and a team for the National Museums of Scotland in the eastern, central, and western areas (Clarke and Sharples 1985). A series of trenches (A-F) were excavated (Table 41; Figure 4.48); while A-C, E, and F are awaiting publication, the remains in in Trench D have been the subject of recent investigations by the Times of Their Lives Project (Marshall *et al*. 2016; Clarke *et al*. 2017). Field walls, agricultural soils, butchery remains (notably, the remains of over 15 red deer carcasses (Clarke *et al.* 2017)), Neolithic structures, and an extensive deposit of anthropogenic remains termed the 'West Midden' (within which lay Trenches D-F) were all recorded. The 'Grobust' building - taking its name from the adjacent bay - lay to the northeast corner of the Links of Noltland in Trench A, and alongside Trench D formed the primary focus of the excavations. Radiocarbon determinations (Table 44) place most of these activities in the Late Neolithic, with settlement proving contemporary with Barnhouse, Skara Brae, and Pool Phase 3 (Moore and Wilson 2011, 14).

Area	Trench	Remains
Eastern	A	Upper parts of the Late Neolithic 'Grobust' building
	B	To confirm spatial extent of activities in eastern area
Central	C	East-West aligned field wall, overlain by Early Bronze Age occupation deposits. Sherds of beaker pottery recovered
Western	D	Cultivation remains, followed by midden accumulation, deposition of red deer remains and construction of a wall
	E	Ard-cultivated occupation deposits overlying a small length of walling, hearth, and clay oven
	F	Small amounts of anthropogenic material

Table 41. Summary of trenches and remains excavated by David Clarke. After Clarke *et al.* 2017, 60-61.

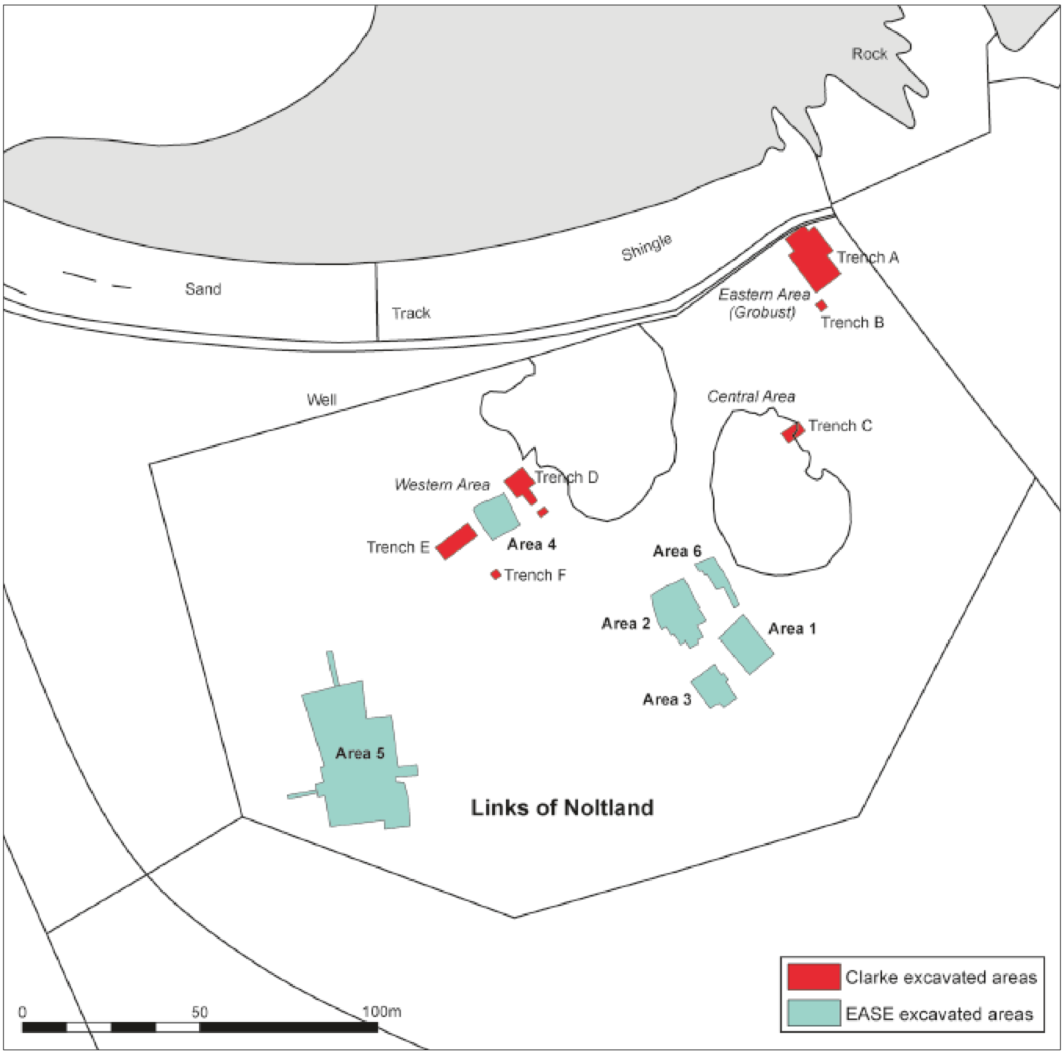

Figure 4.48. Excavated area at the Links of Noltland showing trenches excavated by David Clarke, and areas excavated by EASE archaeology. Clarke et al. 2016, 59; Illustration 1.

Excavations by EASE Archaeology

Following a series of assessments (2000-2006), rescue excavations by EASE Archaeology have taken place annually since 2007. Investigations revealed over 35 well-preserved Neolithic and Bronze Age structures, extensive middens, and a Bronze Age cemetery, all of which lie within a landscape of cultivation remains. The interim report on the 2007-2009 seasons of excavations have been published (Moore and Wilson 2011), while the results of the excavations from 2009 onwards currently remain in unpublished data structure reports (Moore and Wilson 2010; 2011; 2012; 2015; 2017). Since 2009, excavations have focussed on a variety of areas both within and outwith the PIC and SAM areas (Table 43). Given the extensive nature of the site and its excavation, it is worth summarising these activities (Table 42).

Year	Focus of excavations
2007	Rescue excavation, augur and geophysical surveys within and outwith the PIC area, revealing six Bronze Age and three Neolithic structures and their associated features. Clarke's 'West Midden' was also rediscovered, and was found to be comprised of two soil horizons separated by windblown sand
2008	Focussed on the southwest portion of the PIC in Area 5, revealing a further Neolithic structure (Structure 8), surrounding midden, field banks, and cultivation soils
2009	Continued excavation of Structure 8 and associated features. Outside the PIC, investigated remains included three Neolithic structures, a Bronze Age cemetery, and two Bronze Age structures
2010	Continued excavation of the Area 5 Neolithic settlement as well as its adjacent field system, and early investigation of the Bronze Age cemetery outwith the southern PIC area
2011	Continued excavation of the cemetery outwith the PIC, excavation of Bronze Age Structures 12 and 14 outside and south of the SAM area, and excavation of Structure 13 within the Scheduled Area (but outwith the PIC).
2012	Excavation of interior of previously-excavated 'Grobust' building (Structure 18), continued excavation of Area 5 of Structures 9, 10, and 19, and continued excavation of Structure 13.
2013	Excavation of Structures 7 and 21 in PIC area, as well as continued excavation of Structure 19 and cultivation soils in Area 5
2014	Excavation of Structures 6 and 13 and underlying Structures 22 and 23, and their wider landscape in SAM area southeast of the PIC area
2014	Excavation in Area 5, with completion of Structure 19. Excavation of Structures 24, 25, 26. Continued excavation of Structure 11 (first excavated during 2010 season), and associated features and surfaces in Area 5. Small-scale investigation of eroding features north of the PIC boundary at the coast edge. Assessment in advance of grass planting south of the PIC boundary
2015	Excavation of the well of an extensive burnt mound (no structure number) just north of the PIC boundary at the coast edge
2016	Continued excavation of the burnt mound

Table 42. Summary of features excavated by year at the Links of Noltland by EASE Archaeology. After Moore and Wilson 2015, 9-18; Moore and Wilson 2017, 6-8.

Area	Period	Structure/s
1	Bronze Age	2
2	Bronze Age	3, 15, 16
3	Bronze Age	1
4	Neolithic	7, 21
5	Neolithic	8-10, 19, 24-26, 28
6	Bronze Age	17
Western area	Neolithic	18 (Re-excavation of Clarke *et al.*'s Grobust House)
Outwith SAM	Bronze Age	12, 14
Outwith SAM	Bronze Age	Cemetery
SAM	Bronze Age	4-6, 13, 20
Western, PIC		Field system
Western, outwith PIC	Bronze Age	Burnt mound

Table 43. Summary of areas and remains excavated by EASE Archaeology. After Moore and Wilson 2015.

Chronology and phasing

A total of 33 radiocarbon dates are publicly-available for the Links of Noltland, the majority of which relate to the Neolithic occupation of the site. Unless otherwise stated, the date ranges quoted here were modelled using OxCal 4.2 (Bronk Ramsey 2009) and calibrated using IntCal13 (Reimer *et al.* 2013). It should also be noted that alongside the 33 publicly-available dates above, reference is also made in the discussion of Bronze Age sand mobilisation below to two additional determinations included in Moore and Wilson's unpublished 2010 report (GU-27902, 27903). Reference is also made to two unpublished determinations (GU-24425, 24431) contained in the Historic Environment Scotland 2010 radiocarbon database ((C14dates.mdb P. J. Ashmore 15 June 2003 (2010 database)).

Although radiocarbon samples have been recovered throughout the excavations, a full suite of determinations from the EASE excavations is yet to be published. Thus far, the remains excavated in Trench D (which lies at the centre of the bay, Figure 4.48) hold the most detailed chronological information. Nine dates yielded from the original excavations in Trench D (excavated by N. Sharples in the 1980's (Sharples n.d.)) have recently been expanded with the addition of a further nine dates on animal bone obtained by the Times of Their Lives project. Resultantly, 18 dates for the Late Neolithic remains in Trench D now exist. Eight additional determinations exist for trenches A, C, and E.

Seven radiocarbon dates are publicly available for the EASE excavations (Moore and Wilson 2011, 38-9). These relate to two periods of activity; firstly, to the Area 5 'midden' post-dating the abandonment of Structure 8 (Moore and Wilson 2011, 38-9) and secondly, the Middle-Late Bronze Age settlement and cemetery (Moore and Wilson 2011, 38). The Neolithic determinations available for remains excavated by both parties were incorporated into Bayesian model by Marshall *et al*. (2017) (Figure 4.49, Figure 4.50). Unfortunately, with the exception of Trench D and the Grobust structure, detailed phasing information is not yet available for the majority of the site and structures.

The available radiocarbon dates can be considered to be reliable in comparison to some other dates considered in this thesis. All dates published from the EASE excavations thus far derive from single bones from an articulated group (either animal or human). This has ensured that the dated entities are less likely to be intrusive. Meanwhile, older determinations on any bulk material have been recalibrated and critically considered by Marshall *et al*. (2016). Bone was prioritised for dating following the discovery that many of the flotted plant remains were significantly abraded and derived from infilling deposits (Moore and Wilson 2011, 38).

Area	**Number of determinations**	**Material**	**Reference**
Clarke excavations			
Western, Trench D	18	Unburnt mammal bone	Marshall *et al*. 2016
Western, Trench E	1	Mixed cattle and goat/sheep	Marshall *et al*. 2016
Central, Trench C	3	Red deer bone	Clarke *et al.* 2017
Eastern, Trench A	4	Mixed unburnt mammal bone	Clarke *et al.* 2017
EASE excavations			
Area 5 midden	5	Articulated sheep and cattle bone	Moore and Wilson 2011
Scheduled area	2	Human bone	Moore and Wilson 2011

Table 44. Published radiocarbon determinations for Links of Noltland by area and excavator. After Marshall *et al*. 2016, 25-30.

The Neolithic

Neolithic remains at the Links of Noltland were first investigated by in 1978 and 1981 (Table 41). Since the EASE excavations began, the Neolithic remains are now characterised by anthropic soils and c. 15 highly-preserved structures (Table 43), serving a variety of domestic, economic and ritual functions, with frequent incidences of structured deposition. Parallels for the nature and use of the structures can be seen at a number of other Neolithic Orcadian sites including Barnhouse (Mainland) and Pool (Sanday). Notable remains include the ‘Grobust’ building, the Structure 8 complex, and Structures 7 and 9. The majority of excavated Neolithic activity was focussed at the centre and west of the Bay, in EASE excavation Areas 4-6 and Clarke *et al.’s* trenches D and E. Chronological modelling of published radiocarbon dates by Marshall *et al*. (2017) (Figure 4.49) indicate that Neolithic activity at the Links of Noltland began in at least c. 3160–2870 cal. BC (*start_LoN*) (Clarke *et al.* 2017, 71-2; Illustrations 10 and 11), with the earliest dated activity located in Trench D. Neolithic activity ended at c. 2170-1840 cal. BC (*end_LoN*) Bayliss *et al*. 2017 [Supplementary material], 94; Table S4) (Figure 4.49).

Parameter name	**Parameter description**	**Posterior Density Estimate cal. BC (95% probability unless otherwise stated)**
start_LoN	Start of dated activity at Links of Noltland	3160–2870 cal. BC
first_Trench_D	First phase of cultivation (Phase I) and construction of seaweed barrier in Trench D, and second Phase of cultivation (Phase II)	3060–2865 cal. BC (93%)
last_Phase_II	End of cultivation activity	2850–2640 cal. BC
first_Phase_III	Refuse deposition immediately after Phase II cultivation	2795–2600 cal. BC (92%)
last_Phase_III	End of *extensive* refuse deposition	2500–2300 cal. BC (86%)
build_wall_[16]	Construction of wall [16]	2500–2225 cal. BC
Red_deer	Deposition of red deer heap against wall [16]	2230–2130cal. BC (86%)
last_Trench_D	Renewed agricultural activity on top of Trench D	2200–1930 cal. BC

Table 45. Chronological model for Trench D activity at the Links of Noltland, showing key parameters for cultural activity. After Marshall *et al*. 2017, 10-11; Figure 2.

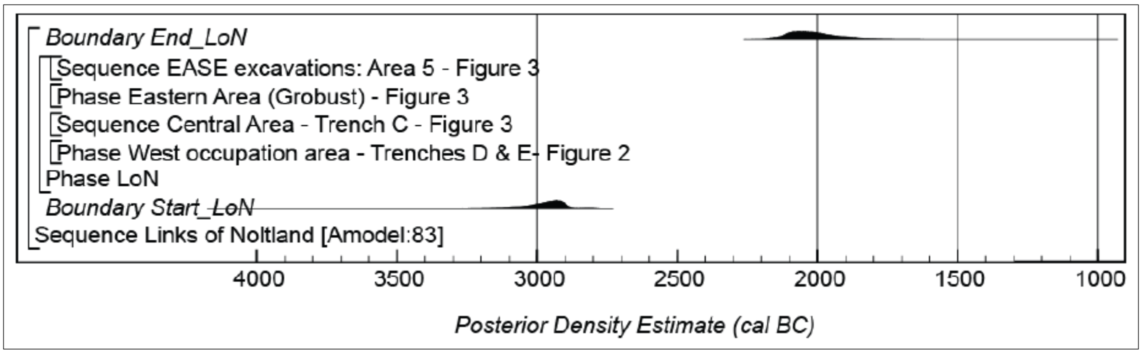

Figure 4.49. The chronology of third millennium cal. BC activity at Links of Noltland. Marshall et al. 2016, 20).

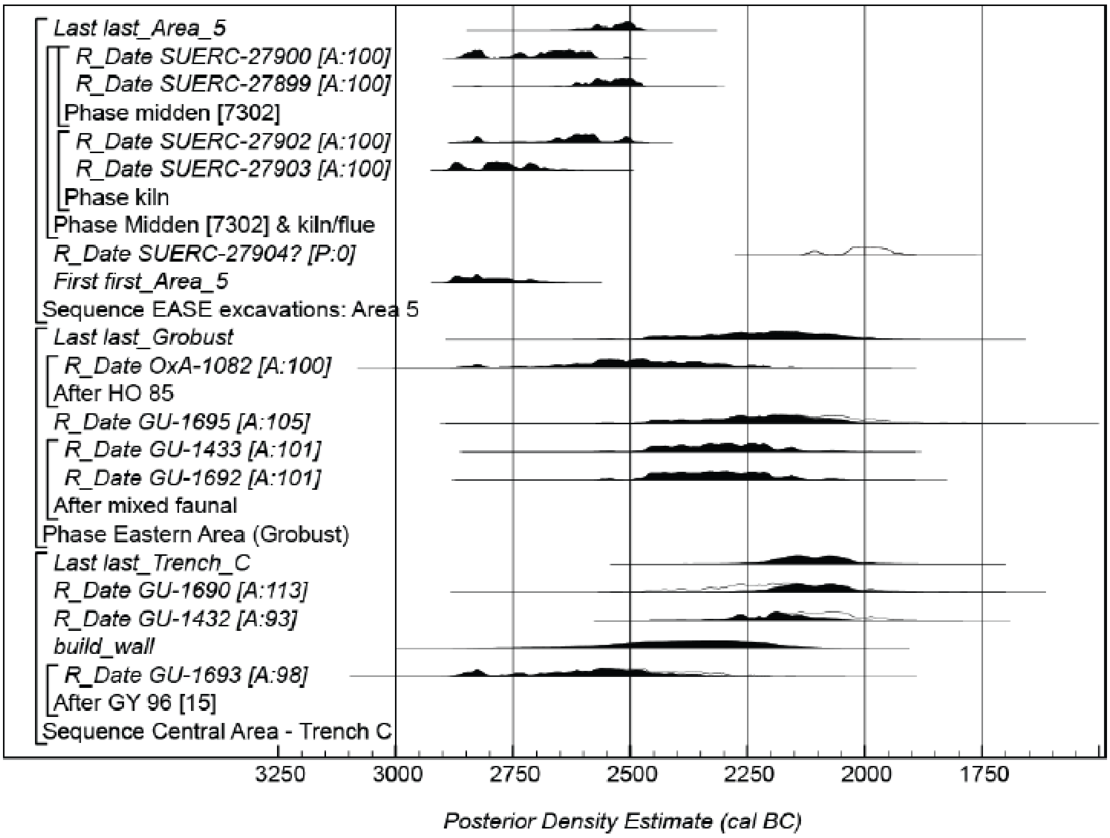

Figure 4.50. The chronology of activities from the Central Area, Eastern Area (Grobust) and Area 5 (EASE excavations). Marshall et al. 2017, 22; Figure 3.

The Bronze Age

The Bronze Age remains at the Links of Noltland comprise a cemetery containing over 100 individuals, a burnt mound complex, field systems, and c. 15 structures, many of which are paired. The remains broadly cluster in three areas; within the south-central area of the PIC, within the SAM, and immediately southeast of the SAM (Figure 4.46). Many of the structural remains comprise paired oval buildings, such as Structures 16 and 17 (Areas 2 and 6) and Structures 5 and 6 in the SAM. Other notable remains include the cemetery outwith the SAM (to the southeast) containing over 100 individuals, and the burnt mound complex north of the PIC, at the coast edge.

The chronology of Bronze Age activity at the site is less clear due to a lack of available determinations on deposits other than those from cemetery inhumations (Table 44). The chronological model for the latest activity in Sharples' Trench D, however, appears to suggest that activity began in the early second millennium cal. BC, at c. 2170-1840 cal. BC (*end_LoN*) (Clarke *et al.* 2017). Determinations from two skeletons in the cemetery outwith the SAM place their deposition in the Early-Middle Bronze Age (Moore and Wilson 2011, 38), c. 1630-1460 cal. BC and 1690-1510 cal. BC) (GU-27901, 27908) although Bronze Age settlement is estimated to have continued at Links of Noltland until c. 1000BC (Moore and Wilson 2015).

Windblown sand at Links of Noltland

All areas of the Links of Noltland saw windblown sand deposition during the Neolithic and Bronze Age. From the start of its occupation at 3160-2870 cal. BC (*start_LoN*) and up until its abandonment around c.1000BC (no scientific dates are currently available for this late phase), episodes of sand drifting and larger-scale inundations affected the occupied landscape. Augur surveys across the site reveal a complex series of anthropogenic soils and middens frequently containing high levels of windblown sand (>70%) - indicative of the frequent mobilisation of dune sands in the vicinity (Poller in Moore and Wilson 2007b, 14-15).

Archaeological and micromorphological evidence indicates that the largest sand inundations took place in the Bronze Age, during which point several structures were inundated by windblown sand either during (leading to their abandonment, as seen at the burnt mound) – or after their main phases of use. The Neolithic phases are represented by smaller layers and lenses of windblown sand within floor and midden deposits, indicative of smaller-scale, yet regular, sand mobilisation, followed by larger deposits which settled into disused structures and activity areas. Given the lack of available radiocarbon dates for the wider settlement, a few specific areas and their associated remains, which provide insights into the nature of sand deposition at Noltland, are focussed on here.

The Neolithic

As at Skara Brae, it is clear that the windblown sand deposits which came to characterise the Links of Noltland and its landscape developed prior to Neolithic occupation; the earliest remains from Clarke *et al*.'s Trenches A and D were founded directly upon or within this natural sand, which generally measured between c. 0.50-0.60m in depth in Trench D, and deeper still in Trench A. The evidence for windblown sand deposition in four key areas is discussed here; Clarke *et al*.'s Western Area (EASE Area 4), EASE Area 5, and Clarke *et al*.'s Central and Eastern Areas (Figure 4.48).

The Western Area (EASE Area 4)

The Western Area contains EASE Area 4, located c. 50m from the coast edge (Figure 4.51) and c. 50m from the settlement in Area 5. Both are characterised by periodic settlement and abandonment throughout their occupation.

Figure 4.51. EASE Area 4 under excavation. Structures 7 and 21 are visible in the foreground. K. Baxter.

Trench D

The T-shaped Trench D was located to the immediate northeast of EASE Area 4, with a further 2m x 2m square trench to its south. The total area of the excavations comprised some 48 square metres (Clarke *et al*. 2017, 62). Trench D was the only one of the NMS trenches to be excavated to natural through c. 1.1m of stratigraphy, and resultantly offers an important view of the earliest activity in this area of the Links. The earliest activity recorded in the trench comprised two phases (I and II) of initial cultivation activity over a pre-existing natural sand surface (Figure 4.52) measuring c. 0.50-1.00m in depth and extending across the excavated area (Clarke *et al*. 2017, 63; Illustration 6). Turf lines identified in this sand deposit (Sharples n.d., 3) suggest it accumulated over a considerable period of time during which some vegetation was able to colonise and stabilise the sand before the next incursion took place.

Figure 4.52. Ard marks cutting the natural sand surface at the base of Trench D. Clarke et al. 2017, 68; Illustration 8.

The cultivation activity comprised an ard-cultivated, midden-enriched soil containing evidence for episodes of refuse dumping including a band of limpet shells. The sand components of this soil increased in its upper portions, with numerous brown and yellow sand lenses visible within the midden (Sharples n.d., 4), indicative of increasing sand mobilisation. This increase in sand components prompted the excavators to divide the use and accumulation of the cultivated soil into Phase I (prior to significant sand incursion) and Phase II (increasingly sandy soil) (Clarke *et al*. 2017, 63). Phase I and II activity took place between 3160–2870 cal. BC (*first_Trench_D*) and 2850–2640 cal. BC (*last_Phase_II*), for at least 55-330 years (Clarke *et al*. 2017, 10; Illustrations 10 and 11). An E-W orientated, c. 0.38m deep ditch was also cut into the underlying sand in Phase I and infilled with grey silty sand, possibly functioning as a seaweed barrier fence to inhibit livestock movement (Clarke et al. 2017, 63; Sharples n.d., 25).

Following this period of cultivation activity, a change in function within the area was evident, represented by a marked increase in the primary deposition of refuse containing large amounts of marine shell as well as articulated animal and fish bone, and pottery (Phase III) (Clarke *et al*. 2017, 65 A lack of discernable windblown sand layers between the cultivated material and the midden may indicate that deposition of the midden took place directly afterwards (Sharples n.d., 29). It is notable that no windblown sand was observed in the earliest layer of midden (layer 21) observed in a single square (Sharples n.d., 30), with bulk sheep bone yielding a determination of 2795–2600 (92%) (GU-1694). This allows a *terminus post quem* for the accumulation of this patch of midden given the bulk nature of the dating sample. This sample and other determinations on sheep and cow bone from the midden deposits were used to model Phase III activity to between 2795-

2600 cal. BC (at 92% probability) (*first_Phase_III*) and 2500-2300 cal. BC (at 86% probability) (*last_Phase_III*) (Clarke *et al*. 2017, 72; Illustration 11).

These deposits appear to have continued to accumulate during and after the construction of a N-S boundary wall in Phase IV (c. 2500-2225 cal. BC (*build_wall_[16]*)), against the east side of which the remains of at least 15 red deer were deposited in Phase V, in 2230-2130 cal. BC (83% probability) (*Red_deer*), covered and surrounded by c. 0.20m of sandy sediment. These remains and their significance both within the site and within the wider context have seen continued speculation (Sharples 2000; Clarke *et al*. 2017). The remains were later covered (either accidentally, following wall collapse or purposefully) by stones from the wall. A c. 0.15-0.20m deep layer of windblown sand covered the deer remains and abutted the wall in Phase VI (Clarke *et al*. 2017, 66-8; Illustration 6).

The sand was not identified at the west side of the wall, perhaps suggesting that it was mobilised from the east before coming to rest against the wall. It is also worth noting, however, that sand may have also been deposited on the west side but was removed or integrated with the cultivation soils which were then developed in Phase VII. Ard marks in the windblown sand deposit are indicative of the area being taken back into cultivation. The latest dated materials (vole remains) were incorporated into the ploughsoil in 2200-1930 cal. BC (*last_Trench_D*) (Clarke *et al*. 2017, 72-3; Illustration 11). Phase VIII also saw the construction of a NE-SW wall which was later robbed out. The final deposit was a layer of windblown sand (no dimension) covering the excavated area.

Structures 7 and 21

Excavations by EASE demonstrated that the remains in Trench D (above) lay less than 10m east of the Late Neolithic Structure 7, and northeast of Structure 21. Resultantly, it is possible that some of the later activities identified in Trench D were associated with occupation of these structures or their predecessors (Clarke *et al*. 2017, 63), although they currently possess no radiocarbon determinations. Again, the earliest deposit in the area was windblown sand overlying till (c. 0.25m deep) (Moore and Wilson 2014, 38). This surface was overlain by c.1m of midden accumulations, sandy soils, and windblown sand lenses, into which the structures were built (Moore and Wilson 2014, 19).

At least two phases of activity took place in Structure 7 (Figure 4.53). Its original interior comprised intramural cells and box beds with a southern entrance, surrounded with a double-faced wall filled with rubble. No discernible sand layers were identified in the early floor deposits (Moore and Wilson 2014, 25). Two new intramural cells were constructed during this period of remodelling; one in the northwest corner, and another at the west side of the entrance passage. This second cell and its associated occupation deposits were found to overlie clean white calcareous sand (no dimensions) which had banked up against the earlier wall face and was overlain by the refacing described above.

The excavators suggest that this earlier sand movement may have driven the structural modifications (Moore and Wilson 2014, 26) although with no dimensions or dates available it is difficult to ascertain whether this is the case. If this is a natural sandblow, its position suggests that it was mobilised by a northerly wind. Late in the occupation, two cattle skulls and an antler fragment were deposited inside the central hearth, after which the structure was filled with midden dumps and rubble (Moore and Wilson 2014, 19).

Figure 4.53. Early (left) and late (right) phases in Structure 7. Moore and Wilson 2014, 17.

Structure 21 lay to the immediate south of Structure 7. Like Structure 7, it was partially constructed over an earlier occupation surface as well as areas of clean windblown sand on the north side. No discernible sand deposits were identified in the interior floor deposits. As in Structure 7, the final activity in the structure comprised the deposition of animal remains (two cattle skulls, a sheep skull, and other bones) inside the hearth (Moore and Wilson 2014, 36) before the structure was filled with rubble. The hinterlands of Structures 7 and 21 contrast with their interiors in that extensive windblown sand deposits are identifiable. Sondages north and east of Area 4 revealed the presence of over 1m of midden deposits and lenses of windblown sand which continued to accumulate during and after their occupation. Complex midden-enriched soils thought to be contemporary with the rectilinear Structure 7 accumulated against its exterior walls (Moore and Wilson 2007a, 23), becoming notably sandier on the west side of the building (c. 80-90%) (Moore and Wilson 2007a, 23), perhaps indicative of the direction of sand mobilisation.

Area 5, Structure 9

Structure 9's use appears to be contemporary with the accumulation of early midden deposits in the area (Moore and Wilson 2010, 13). It was constructed directly over till and a silty clay ground surface, and featured a cruciform interior with four recesses (Moore and Wilson 2011, 75). Thirty cattle skulls were recovered from the foundations of the structure (Figure 4.54), presumably having been deposited before its construction (Moore and Wilson 2010, 25). Two yielded ranges of 2840-2480 cal. BC (GU-22458) and 2580-2460 cal. BC (GU-22459) (Moore and Wilson 2010, 12), offering an estimation for the construction of Structure 9. If the structure was built over till and silty clay deposits with no notable existing sand components, these determinations also provide chronological context for decreased windblown sand movement in this area in the 28th-24th centuries cal. BC. This stands in contrast to Area D, where increasing sand incursion into cultivation soils took place from at least 2850–2640 cal. BC ((*last_Phase_II*) (Clarke *et al*. 2017, 10).

Figure 4.54. Cattle skulls from Structure 9 foundations. Moore and Wilson 2010, 38.

Although no distinctive sand deposits were identified by eye within the interior deposits, micromorphological analysis highlighted the presence of windblown calcareous sand lenses and grains from the central floor deposits. In contrast, the recess floor sediments did not contain windblown sand. This may suggest that aeolian sand movement in the immediate landscape was heightened during the occupation of Structure 9 (perhaps entering from the south-facing entrance, or brought in by the inhabitants), but that it was kept out of the deepest interior of the structure (Hamlet 2014, 217). Alternatively, these sands may have been purposely brought in to be used as floor materials. After cessation of use, the deroofed remains of the structure was infilled with c. 0.20m of late midden deposits which extended across the centre of Area 5. An old ground surface developed over the top of the remains, associated with a field bank tentatively dated to the Bronze Age which lay across the north of Area 5 (Moore and Wilson 2010, 23).

Central Area, Trench C

Trench C lay c. 50m south of Trench A, within a narrow blowout surrounded by dunes. Although its primary deposits were not exposed, it nevertheless provides some useful chronological information. The earliest excavated features comprised a shallow scoop containing cattle bone, a stone-lined pit, and a turf stack, associated with sparse remains of ard marks (Sharples n.d.). Sand appears to have accumulated throughout the use of the area. An E-W aligned wall, perhaps functioning as a field boundary, was cut into the remains. A bulk sample of deer and cattle bone yielded a determination of 2780–2340 cal. BC (GU-1693), and a *terminus post quem* for the wall's construction. Light brown windblown sand accumulated against the south face, with the deposit containing partially-articulated deer bones reminiscent of a butchery area (Sharples n.d.; Marshall *et al.* 2016, 6). Bulk red deer bone from the butchery deposit was dated to 2340–2035 cal. BC (GU-1432) (Marshall *et al.* 2016, 6), post-dating the wall construction and offering a range for the accumulation of the windblown sand against it. A midden layer containing two beaker sherds sealed this material. Bulk red deer bone from the midden was dated to 2265–1975 cal. BC (GU-1690) (Marshall *et al*. 2016, 6; 12), offering a *terminus ante quem* for the butchery area and collapse of the wall.

Eastern Area, Trench A (Grobust)

At the northeast corner of the PIC, Trench A contained the remains of a Late Neolithic cellular two-roomed, semi-subterranean structure (Figure 4.55). A north (Room 1) and south (Room 3) cell joined by two passages (orientated roughly N-S and E-W) were constructed into a sand dune with a northeast-facing entrance. It was originally excavated by Clarke *et al*. before being completed by EASE (and named Structure 18). Following the laying of a midden 'lining' over the natural sand, the structure was built into the dune with further midden laid on the surrounding sand (Sharples n.d., 6). This was further confirmed by the excavation of two sondages to the west of the passage (1) and at the northwest corner of Trench A (2). While sondage 1 revealed three layers of white windblown sand differentiated according to relative inclusions of stone and animal bone, the sondage 2 remains comprised eight layers of windblown sand (no dimensions given), each of which was separated by thin dark lines c. 0.02-0.04m thick representing turf formation episodes (Moore and Wilson 2011, 70). These were overlain by three midden layers interbedded with white sand and silt (no dimensions), apparently serving a stabilising function in what was clearly a mobile sand environment (Sharples n.d.; Moore and Wilson 2011, 70).

The earliest occupation deposits associated with the structure interior excavated by EASE are extremely complex (Moore and Wilson 2011, 49-70). Given that neither the excavations nor any associated dates have yet been formally published (with few dimensions stated), it seems unwise to attempt to rehash these important sequences. In general, windblown sand deposits were confined to small, trampled layers within the floor deposits of the structure. Following its use, parts of the structure were blocked up and the interiors filled with ashy anthropic deposits. The deposits in Room 1 contained layers of shell midden interspersed with soil-rich deposits (Moore and Wilson 2011, 53), the uppermost of which were excavated by Clarke *et al*. The shelly deposits notably contained multiple articulated animal remains. A series of paths were laid within the midden, leading down into the structure.

During the blocking process, a number of important and extensive structural depositions took place in Room 1; items included cattle and sheep skulls, an eagle skeleton, and two complete vessels (Sharples n.d., 7). The significance of these deposits is discussed in Chapter 6. The roof of Room 2 appears to have collapsed in situ, prior to which some loose sand and midden accumulated within the chamber. The roof collapse was overlain by further sand, midden, and rubble deposits (Moore and Wilson 2011, 56). The loose sand in the interior may have accumulated during a period of dilapidation as the interior became less protected from the elements. The abandonment of the passageways was defined by a layer of windblown sand measuring 0.03-0.05m at its thinnest across the E-W passage, and becoming thicker into the N-S passage (no dimensions). The sand in the N-S passage contained the remains of c. 18 cattle skulls, and 6 sheep skulls (Moore and Wilson 2011, 59).

There are not enough determinations currently available to develop a detailed understanding of the chronology of the Grobust structure, particularly in relation to its earliest phases. Two determinations on bulk animal bone from the north passage provide a *terminus post quem* for the infilling of the structure; 2470-2140 cal. BC (GU-1433) and 2480-2135 cal. BC (GU-1692). Bulk red deer bone from deposits overlying the aforementioned pathways yield a *terminus ante quem* of 2470–2005 cal. BC (GU-1695) (Marshall *et al.* 2016, 29; Table 4).

Figure 4.55. View of the Grobust structure from the south. Moore and Wilson 2007b, 58.

The Bronze Age

The windblown sand deposits in Bronze Age contexts were often deeper and more extensive than their Neolithic counterparts; it is unfortunate, then, that few radiocarbon determinations dealing with the Bronze Age occupation phases are publicly available. As such it is more difficult to develop a strong understanding of windblown sand deposition in this period. Windblown sand in varying amounts formed a key component of sediments both within and outwith Bronze Age structures at the site (Hamlet 2014). Evidence for sand mobilisation and interaction with sand deposits in three areas are discussed here; Area 2 (south of Area 4), the area inside the SAM (Structures 4-6), the burnt mound at the shoreline, and the cemetery outwith the SAM (Figure 4.48). Many of the sites within the bay were constructed over existing windblown sand deposits which accumulated during the Late Neolithic, and as occupation developed, the middens which accumulated around them were covered by blown sands on a regular basis. An example of typical Neolithic cultivation deposits later overlain by the Bronze Age settlement can be seen in Figure 4.56.

Figure 4.56. Deposits of cultivated soil (with ard marks visible) and windblown sand beneath Structure 13. Moore and Wilson 2012, 31.

Area 2

The remains of c. 6 Bronze Age structures (1 to 3, 15-17) were identified in Area 2 within the PIC area, north of Areas 1 and 3. At the paired Structures 16 and 17, 0.40m of midden-rich deposits formed during the occupation of Structure 16, by which time Structure 17 had fallen out of use. Two distinct episodes of aeolian sand incursion were identified within this, divided by anthropogenic material formed by the *in situ* burning of peat as well as charcoal, dung and midden. The second of these sands is described as a “thin lense” but no precise measurements are given by the excavators. The contact between the sands and anthropic sediments were sharp, suggesting the rapid deposition of both sand and anthropic sediment (Hamlet 2014, 272). After it fell out of use, silty clay and rubble containing high proportions (c. 29%) of windblown sand infilled Structure 17 (Hamlet 2014, 283). Structures 1 and 3 formed a paired unit of oval buildings (with Structure 1 being constructed over the remains of Structure 15), while Structure 2 comprised a single building to the southeast of 1 and 3. All three structures were constructed over an old ground surface comprising sandy soils interleaved with windblown sands which overlay earlier remains (Structure 15) (Moore and Wilson 2006, 7; 2007a, 15-16). The three structures all displayed internal divisions and midden wall cores, presumably comprising redeposited material. After their use, the structures appear to have been robbed out and partially collapsed and deroofed, after which mixed midden-rich soils filled the interior followed by "deep layers" of c. 7 calcareous windblown sand deposits. One of the upper layers over Structure 3 (its exact position is unknown) yielded bone points, pottery, flint, steatite vessel sherds and stone tools (Moore and Wilson 2007a, 14). Turflines were identified between these sands, indicative of periodic stabilisation followed by more sand incursion.

Inside the SAM

The area inside the SAM (Figure 4.48) comprises the remains of c. four Bronze Age structures (4-6, 13), some of which appear to have been occupied simultaneously. The earlier Bronze Age Structure 13 was constructed over a sequence of shell-rich midden, cultivated soils and windblown sands which accumulated during the Neolithic. Following its abandonment, its interior was filled with accumulations of interleaving midden-rich soils, sandy silts, rubble spreads and clean windblown sands (Moore and Wilson 2012, 14; 30). The floor deposits of Structure 13 were notably sandy, with the mixing of sand into the fabric of the floors suggesting that sand was 'allowed' to accumulate here during its occupation (Hamlet 2014, 340). Alternatively, this sand may have been purposely brought in from outwith the structure.

Directly to the east of Structure 14 three stone structures 4, 5 and 6, appear to have been contemporary to one another, being tentatively dated to the Middle Bronze Age. Located to the west of Structures 5 and 6, Structure 4 was constructed into a deflated sand dune and comprised a double-faced, sub-circular structure with a rubble wall core and radial divisions. Structure 5 comprised a roughly circular structure with a rectilinear, recessed interior, a tank (reminiscent of that recorded at Pool, Sanday), and a double-faced wall containing a redeposited midden core. Its entrance faced toward the entrance of Structure 6, which comprised a large sub-circular building with a midden wall core and radial interior divisions. The floor deposits to the NE of the interior were interspersed with windblown sand lenses (Moore and Wilson 2007c, 10-13). After their occupation, the structures appear to have collapsed, and were inundated with windblown sand (no dimensions available) (Moore and Wilson 2007c, 9-10).

The burnt mound

In 2015-16, the well-preserved remains of an extensive burnt mound complex (with parallels across Orkney and Shetland – see Moore and Wilson 2017, 34-37) were excavated and recorded just outwith the SAM and PIC. As well as the burnt mound itself, a subterranean cellular stone structure entered via a 10m long passage, well, and well house, were also revealed. The site was inundated with at least 1m of windblown sand during the second millennium BC, with the deposit likely to have been thicker originally, prior to deflation (Moore and Wilson 2017). The burnt mound was also covered with smaller deposits of windblown sand prior to, and during, its use and construction (as seen in the stratigraphy of the burnt mound stone dump). Resultantly, although no radiocarbon determinations are currently available for this complex it is worth summarising the remains.

The complex was constructed over an area of plough cultivation scars and field banks filled and covered with windblown sand (Phase 1). This soil horizon in turn overlay a deposit of windblown sand interpreted as the original ground surface covering the natural clay (Moore and Wilson 2017, 12). The earliest use of the burnt mound (Phase 2) was represented by a complex pre-structural mound, followed by a further deposit of windblown sand, the construction and use of the subterranean structure (Phase 3), repairs and shorter episodes of reuse (Phase 4), and disuse, collapse and sand inundation (Phase 5).

Following five phases of use and activity, the burnt mound was abandoned following a massive sand inundation of the burnt mound and the chambered structure. The inundation damaged the roof covering the inner chamber, and destabilised the structure. The upper deposits overlying the central floor comprised collapsed structural stone, roofing and roof capping material. The building was not reinstated. No stabilisation or turf horizons were identified within the windblown sand (Moore and Wilson 2017, 33) suggesting a rapid deposition with additional deposits accumulating shortly afterwards. Three pits were dug into the sand inside the inner chamber (c. 1m below the sand's surface), with two containing intact, inverted pots typologically attributed to the Bronze Age, and one containing articulated cattle vertebrae (Moore and Wilson 2017, 33). The vessel illustrated in Figure 4.57 is a small, bucket-shaped vessel fitting within the broader flat rim ware type (O. Mason *pers. comm*.).

Some smaller-scale, short-lived burnt mound activity, evidenced by ashy deposits interleaved with more sand, may have also taken place after the site's inundation. The use of peat (a resource which rapidly expanded during the Bronze Age) for fuel as well as the multiple sandblow events reveal a complex environmental history at the site. Moore and Wilson suggest that although the upper levels of the well house were not recovered, it may have been roofed in order to protect it from blowing sand (Moore and Wilson 2017, 33-4).

That the pits and their contents were discovered c. 1m below the sand's upper surface indicates that sand continued to accumulate for some time after their deposition. If the pots are indeed Middle-Late Bronze Age in date, then their deposition (providing they were not curated) offers the broadest *terminus ante quem* for the sands into which they were deposits, before further sands accumulated above. The closest parallels for the vessel in Figure 4.57 are those from the burnt mound at Liddel, South Ronaldsay (Hedges, J. W.

1975, 50; Figure 9), where bucket shaped vessels of a similar size and colour were recovered (O. Mason *pers. comm.*). The site produced two radiocarbon determinations from organic materials which post-dated the site, both of which were calibrated to 1400-800 cal. BC (SRR-525; SRR-701) (Hedges, J. W. 1975, 82). Radiocarbon dating of the articulated cattle bone will provide better chronological control for these events, but in the meantime the comparisons with the assemblages at Liddel offer some possible context for the deposition of the vessels, and the accumulation of the sand.

Figure 4.57. One of the intact pots recovered from a pit excavated in the sand inundating the burnt mound structure. Moore and Wilson 2016, 17.

The cemetery

Excavations and investigation in the 2010 season took place outwith the eroding SAM area, within which 22 cremation burials and four cists containing multiple inhumations (which notably appear to have been deposited on successive occasions) were located. Further excavation in successive years has brought the total of excavated burials to over 100. It was difficult to identify relationships between the burial cuts, the old ground surface and the sequence of windblown sands encountered in this area due to the significant levels of deflation (Moore and Wilson 2011, 41-2; Moore and Wilson 2012, 46), but all appear to have been cut directly into underlying sands (e.g. Figure 4.58).

There are currently two published radiocarbon determinations available for the inhumations at the cemetery, yielding mid-late second millennium BC ranges of 1630-1460 cal. BC (GU-27901) and 1690-1510 cal. BC (GU-27908). The excavators state that these fit well with dates for Structures 4-6 c. 50m away (although no scientific dates have yet been published for these structures) (Moore and Wilson 2011, 38). An additional 14 determinations from verified complete human burials are unpublished (C14dates.mdb P. J. Ashmore 15 June 2003 (2010 database)). Although most of the determinations cluster around the 16th-15th centuries cal. BC, the earliest determination is at 2145-1970 cal. BC (GU-24425, at 92.5% probability), and the latest at 195-40 cal. BC (GU-24431). This is a notably late date considering the likelihood that occupation at the site had ceased by the Late Bronze Age (Moore and Wilson 2011). Further doubt is raised when its context is considered; it lies near the bottom of a cist of multiple inhumations with eight more interments above it – one of which yielded a date of 1630-1500 cal. BC (GU-22418), a determination more in line with the average dates for inhumations at the cemetery. This late date should therefore be approached with caution. In the absence of direct dates for the sand and ground surface into which they were cut, the Middle-Late Bronze Age ranges offer a *terminus ante quem* for their accumulation, which, if they represent the original ground surface, may have formed in the earlier Neolithic.

Figure 4.58. Cist burial F9358 cutting windblown sand deposits and stabilisation surfaces. Moore and Wilson 2012, 47.

Discussion: windblown sand at Links of Noltland

The Neolithic

The start of activity in Trench D took place between 3160–2870 cal. BC (*first_Trench_D*), offering a *terminus ante quem* for the development of the machair of Grobust Bay. The earliest-dated sand incursion during the Neolithic occupation of the Links of Noltland then took place in this western area from at least 3160–2870 cal. BC until 2850–2640 cal. BC ((*last_Phase_II*), with cultivated deposits became increasingly sandy in Trench D (Marshall *et al.* 2016, 25-7; Table 1; Clarke *et al*. 2017, 10; Illustrations 10 and 11). That windblown sand movement was an important dynamic in Area 4/Central Area is confirmed by the deposits surrounding Structures 7 and 21, where over 1m of midden and midden-enriched soils accumulated, interspersed by frequent lenses of windblown sand (Moore and Wilson 2007a, 23).

A comparative lack of sand deposits was noted during the Phase III midden accumulation in Trench D (Sharples n.d., 30), for which a range of 2795–2600 (92%) (GU-1694) on bulk sheep bone was yielded. This determination offers a broad age range for a lack of sand deposition in this phase of later midden accumulation. It is not made clear by the excavators whether notable sand deposits were visible in the rest of the Phase III midden; if this lack of sand accumulation continued, then it can be posited that reduced sand ingress took place between c. 2850–2640 cal. BC (*last_Phase_II*), and 2500-2300 cal. BC (*last_Phase_III*) (Clarke *et al*. 2017, 10-12). Radiocarbon determinations will clarify the relationship between the structures, and the chronology of windblown sand accumulation (or a lack thereof). The latest episodes of sand deposition in the area took place after the deposition of the red deer remains in 2230-2130 cal. BC (83% probability) (*Red_deer*) and before c. 2200-1930 cal. BC (*last_Trench_D*) (Clarke *et al*. 2017, 72-3; Illustration 11).

Central and Eastern Areas

Trench C findings reveal that sand in the Central Area was accumulating at around the same time as the Phase II sand in Trench D, at c. 2780–2340 cal. BC (GU-1693) before the construction of a field boundary. It continued from around 2340–2035 cal. BC (GU-1432) when sand blowing north accumulated against the south face of the boundary until c. 2265–1975 cal. BC (GU-1690) (Sharples n.d.; (Marshall et al. 2016, 6; 12). Dates on bulk animal bone from underlying deposits allow at least a *terminus post quem* for the infilling of the Grobust building with extensive sand deposits, which took place after c. 2480-2135/40 cal. BC (GU-1692, 1433).

Area 5

Area 5 presents an interesting contrast to the remains discussed above in that the evidence for windblown sand deposits is more ambiguous. At Structure 9 (constructed around 2840-2460 cal. BC (GU-22458, 22459) (Marshall *et al.* 2016; Moore and Wilson

2010, 12), although no distinctive sand deposits were identified by eye within the interior deposits, micromorphological analysis highlighted the presence of windblown calcareous sand lenses and grains from the central floor deposits. In contrast, the recess floor sediments did not contain windblown sand. This may suggest that any sand was kept out of the deepest interior of the structure (Hamlet 2014, 217). Structure 8 is worth considering too. Occupied until c. 2890-2660 cal. BC (GU-27903), its interior again contained less windblown sand particles than others investigated.

Area 5 is located on a prominent edge of an escarpment overlooking Grobust Bay (Moore and Wilson 2008, 10). It is possible that the elevated position ensured that less sand was able to accumulate in the immediate vicinity during occupation here. There is also evidence to suggest that Structure 8 was enclosed by a thick outer wall (measuring at least 2m in thickness) the remains of which were identified at the western edge of the trench, c. 4m from Structure 8 (Moore and Wilson 2009, 17). It is worth considering whether little sand appears to have accumulated during the occupation of Structures 8 due to the presence such walls, which may have served a sheltering or windbreaking function. The construction material from a field bank covering the Area 5 Neolithic settlement contained no calcareous sand components (Hamlet 2014, 288), perhaps suggesting that sand movement was relatively stable during its construction, or that its position on higher ground afforded it some protection from sand incursion.

The Bronze Age

The lack of available radiocarbon determinations necessitated that the summary of Bronze Age evidence for sand movement was essentially descriptive. Nevertheless, some broad conclusions can be drawn. Micromorphological studies indicate that the Bronze Age sediments across the site displayed high proportions of calcareous windblown sand (Hamlet 2014, 129; 328), and this is confirmed by the presence of sand within the infill of nearly all of the excavated structures. Most of the sand deposits discussed above comprise material which appears to have moved into and around structures following their abandonment (e.g. Structures 1-3), or possibly driving their abandonment (for example, the burnt mound). The prevailing use of the complex burnt mound as it become frequently inundated by windblown sand is a testament to its importance within the settlement.

There is extensive evidence of construction into earlier sand deposits, for example in the use of the cemetery (as also noted at Birsay Bay (4.4)), and in building over sands which covered the Neolithic remains and making use of the rich midden resources these older deposits provided. Radiocarbon determinations radiocarbon determinations available for the inhumations at the cemetery, yielding mid-late second millennium BC ranges of 1630-1460 cal. BC (GU-27901) and 1690-1510 cal. BC (GU-27908). These dates offer a *terminus ante quem* for the sands into which the graves were dug, which appear to have continued to accumulate around them afterwards.

The large quantities of sand would have significantly affected the quality of the agricultural land as well as the wider viability of settlement in this precarious zone. As such, it may be that a ‘tipping point’ was reached at the Links of Noltland during the Middle to Late Bronze Age, during which time the decision was made to finally abandon the site (Moore and Wilson 2017). After the abandonment, sand continued to inundate the landscape, houses, ritual structures, field systems and cemetery, thus leading to the preservation of this archaeological landscape. Post-Medieval activity later refocussed on the Links area, with the construction of 18^{th}-19^{th} century kelp pits onto the c. 0.43-3.08m of calcareous sand overlying the Area 5 cultivation deposits (Moore and Wilson 2009, 13; Hamlet 2014, 116).

Living with sand at Links of Noltland

The Links of Noltland is an important site with a complex environmental and settlement history, and it is difficult to do justice to it without the availability of more extensive scientific dates, and palaeoenvironmental reconstructions for the site or even the wider island. Nevertheless, some conclusions can be drawn, and some discussion points raised. Sand movement at the Links was mobilised in varying quantities from around the mid-fourth to early first millennia BC, and manifested in numerous ways within the archaeological context. A key theme at Links of Noltland (especially in the Late Neolithic period) is that of conspicuous consumption and structured deposition. This is explored further in Chapter 6, but it is important to note that the use and extensive deposition of large quantities of animal bone took place within a landscape similar to others which have been described as ‘marginal’, for example at Tofts Ness (Dockrill *et al.* 2007). Other key interactions with sand included its use in the creation of floor deposits, as a construction foundation, and its integration with anthropic sediments.

Micromorphological studies at Links of Noltland have played an important role in characterising occupation sediments (including interior floors, exterior deposits, foundations and structural infill) and their formation (Hamlet 2014). Neolithic anthropic sediments were analysed from Structure 7 in Area 4 and 8 in Area 5, while Bronze Age sediments were analysed from the interiors of Structures 13 and 17, and dumped deposits associated with Structure 13 (Hamlet 2014, 286). As at Skara Brae, the matrix of early anthropic sediments comprised silty clay, fuel residues, anthropogenic waste, and quartzose sand originating from eroded glacial till. No *calcareous* sand was observed in the Neolithic sediments studied in Structures 7 and 8. It is not clear whether the Neolithic sands recorded in Trench D, which are just described as ‘windblown’, were calcareous or minerogenic (Clarke *et al.* 2017).

This highlights two issues; firstly, the strong spatial variation in levels of aeolian sand deposition but secondly, the need for radiocarbon dating of the sediments analysed beyond the artefactual and structural typology relied upon by Hamlet in the absence of available radiocarbon dates. If some of the earliest windblown sand deposits were indeed mineral sands with little to no calcareous material, then this implies that more than one source of sand lay in the vicinity of the landscape, with the dominant sand source changing into the Late Neolithic and Bronze Age.

Cattle and sheep followed by pig dominate the Neolithic faunal assemblages published thus far, with economic strategies comparable to those at Skara, Pool, and Tofts Ness (Moore and Wilson 2011, 41-3). The picture for the Bronze Age is less clear, as is the significance of arable farming. As at other sites (Point of Buckquoy, Skara Brae), red deer played an important symbolic role at the Links (Moore and Wilson 2011, 41), as evidence by their frequent occurrence in structured depositions within the decommissioned houses and other areas. This is discussed further in Chapter 6.

As at Skara Brae and Tofts Ness, the anthropogenic amendment of soils and sediments was a key socio-economic activity at Noltland. Hamlet has argued for chronological pattern in land management strategies which sees vegetation clearance in the Neolithic followed by tilling, cultivation, and application of cultural material (type 2), before developing into cultivation of middens and other anthropic sources *in situ* (type 3). This then shifted in the Bronze Age to far larger-scale redeposition of anthropic material into increasingly sand-dominated landscapes in order to fertilise and stabilise important agricultural land (type 1) (Hamlet 2014, 345). It is interesting to note Hamlet's distinction of the third strategy, observed in deposits downslope of the Area 5 settlement remains. These cleared soils were then cultivated by ard and eventually covered by aeolian sand (Hamlet 2014, 328). It is worth considering whether this strategy and its intensification during the Bronze Age led to the destabilisation of sand deposits in the Late Neolithic and particularly the Bronze Age.

4.7.3. Discussion: windblown sand on Westray

The data for Westray is dominated by the Neolithic and Bronze Age sand incursions at Links of Noltland, and the Bronze Age and later incursions at Pierowall Quarry and its environs. and it is these sites which formed the basis for the discussion. Five other sites (Berst Ness, Evertaft, Quoygrew, Mae Sand, and Noup) offering a variety of dated and undated evidence for windblown sand deposits may be found in Appendix 1. Noltland and Pierowall Quarry lie on opposite ends of the northern area of the island, within the same extensive windblown sand deposit stretching from the Bay of Pierowall in the east to Grobust Bay at the west. The machair system across this part of Westray is likely to have formed during the Late Neolithic-Bronze Age (2nd millennium BC), when the most extensive sands were mobilised at Noltland, and which covered the remains of the cairn at Pierowall quarry (Sharples n.d.). The source of this original spread into the east is unclear, but it seems likely that the sediment budgets in the Atlantic-facing Grobust Bay played a key role in the formation.

The earliest dated windblown sand incursions took place at Links of Noltland, from at least 3160–2870 cal. BC (*start Trench D*) (Clarke *et al*. 2017, 72) continuing into the Late Bronze Age when the bay appears to have been abandoned. Bronze Age sand deposition also took place at Pierowall, after the destruction of a cairn in 2860-2600 cal. BC (*cairn_levelled*) and before the construction of an Early Iron Age roundhouse at 800-410 cal. BC (GU-1580) (Sharples 1984; Bayliss *et al.* 2016, 38). The sands at Pierowall are far more discrete and are likely to represent fewer episodes which can be distinguished. This is in contrast to Noltland, where the density and continuous deposition of sand here makes it difficult to disentangle precise events.

Prehistoric sand deposition of unknown date also took place at Berst Ness, at the far south of Westray, while at the posited settlement at Evertaft, on the northeast coast, saw middens covered by windblown sand during the Middle Iron Age (240±165AD) and Norse (940±110AD) periods (Sommerville 2003). Later sand deposits at the Quoygrew fish midden (at the northernmost point of the machair described above) accumulated between cal. AD677–959 (TO7118) and cal. AD1243-1381 (AA52358) (Simpson et al. 2005, 365; Table 1). The eroding sites at Mae Sand and Noup remain uninvestigated in any detail.

4.8. North Sanday

The island of Sanday is low-lying (with its highest point at c. 30m OD) and like its neighbouring islands of Westray and North Ronaldsay, is characterised by the windblown sand drift deposits which cover around a third of the island (Lamb, R. G. 1980, 7), totalling c. 2187ha (Dargie 1998b, 218). Low-lying machairs form much of this geomorphological feature, with the exception of the south-west of the island where sand has been blown against a hill of c. 50m in height (Mather *et al.* 1974, 84). High dunes can be observed at Newark Bay to the east of the island (Lamb, R. G. 1980, 7). The sand deposits at the north of the island are far more extensive than those at the south, which are more discrete. While the eastern shoreline is characterised by its long, sandy beaches and dune systems such as Lopness and Tres Ness and Plain of Fidge and Sty Wick in the hinterland, the west coast is rockier and more exposed, with smaller pockets of blown sand (Mather *et al.* 1974, 84; Sommerville 2003, 75).

The geology of Sanday is comprised of Devonian Old Red Sandstone, although it can be further divided into Rousay flags to the low-lying east and north, and Eday sandstone to the hillier, rockier, more undulating south and west areas (Mykura 1976, 80-3; Bond, J. in Hunter, J. *et al.* 2007, 169). The island's soils are generally well-drained and fertile owing to their development over windblown calcareous sand. The soils are comparatively easy to cultivate and therefore provided an attractive settlement location and rich archaeological potential, with over 200 sites identified (Lamb, R. G. 1980, 7). The fertility of the soils ensured high land rental prices in historic periods (Davidson *et al.* 1986, 45) (Bond, J. in Hunter, J. *et al.* 2007, 169).

Sanday has undergone a number of significant geomorphological changes in the earlier Holocene and more recent past (e.g. Rennie 2006), notably in the formation of extensive dune systems which have shaped the island as we see it today. These changes can be clearly identified in stratigraphic palaeoenvironmental sections, and resultantly also on and immediately around archaeological sites (Table 46). Many coastal dune sections are actively eroding, revealing archaeological sites and palaeoenvironmental evidence (Sommerville 2003, 75). Ten sites with windblown sand deposits are located in Sanday (Figure 4.59), with eight lying in North Sanday. Four of these are discussed here (Tofts Ness, Meur, Lopness, and Scar) with the rest in Appendix 1. South Sanday (specifically Pool) is discussed in Chapter 5.

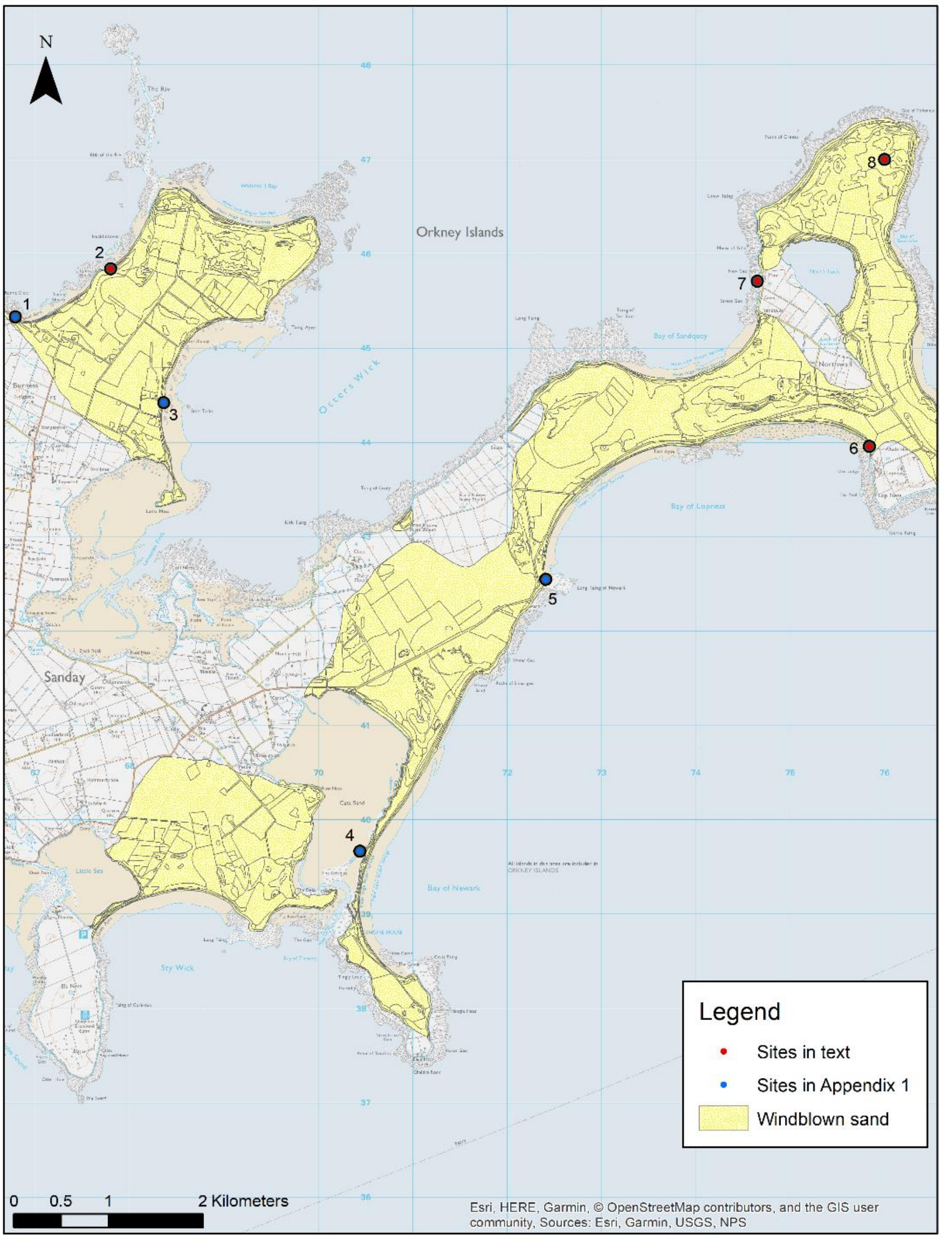

Figure 4.59. North Sanday sites. 1. Woo; 2. Scar; 3. Northskaill; 4. Cata Sand; 5. Lopness. 6; Long Taing of Newark; 7. Meur; 8. Tofts Ness.

Site	**Site type**	**Period of human activity**	**Sandblow period**	**Reference**
Tofts Ness	Settlement	3330–2910 cal. BC (*start Tofts Ness 1*) to 2120–545 cal. BC (*end Tofts Ness 2*) with Bronze Age ‘hiatus’ (Bayliss *et al.* 2017 [Supplementary Material], 94).	Late Neolithic (2260±100BC) <SUTL-602-3, 612-3, 616-7>); Early-Late Bronze Age (between 1880-1600 cal. BC to 1680-1440 cal. BC (*span 3*) and c. 11th-9th centuries BC <SUTL-95, 103-6>); possibly before c. 1740-1520 cal. BC (SRR-5249) Late Bronze Age (after 11th-9th centuries BC <SUTL-95, 103-6>) and before 1450-900 cal. BC (GU-2183) to 770-410 cal. BC (GU-2208) only Late Bronze Age-Early Iron Age (After c. 1000-200 cal. BC (GU-2207), possibly 625±185BC <SUTL-608-9, 611, 614-5, 618>	Sommerville 2003; Dockrill *et al.* 2007; Bayliss *et al.* 2017
Meur	Burnt mound, well	Early-Late Neolithic; Bronze Age-Early Iron Age (from at least 3336-3023 cal. BC (GU-41721) until at least 40 cal. BC-cal. AD87 (GU-37107).	Neolithic (c. 2475-2299 cal. BC (GU-36668)); Middle Bronze Age (1297-1115 cal. BC (GU-36245); Late Bronze Age-Early Iron Age (c. 810-540 cal. BC (GU-15746).	Gardner 2017a; 2017b

Lopness	Cist burial, palaeoenvironmental section	Early Bronze Age (remains interred at c. 1890-1520 cal. BC (GU9481; 10382)).	Middle Bronze Age (1015±140BC) <SUTL-890-891>, Medieval (c. AD1515±35) <SUTL-884-889>).	Sommerville 2003; Inness 2009
Scar	Structural remains, boat burial	Late Iron Age/Pictish (cal. AD430-640 (GU-3825); Norse (remains interred at c. AD895-1030 (AA-12595-97)).	Unknown prehistoric; before cal. AD435-650 (GU-3825); Late Iron Age/Pictish-Norse (between cal. AD435-650 (GU-3825)) and c. AD895-1030 (AA-12595-97)). Norse (shortly after c. AD895-1030).	Owen and Dalland 1999
Quoy Ness	Midden, possible farm mound	Unknown	Unknown	SCAPE ShoreUpdate 2013
Woo	Midden, structures	?prehistoric	Unknown	Moore and Wilson 1999; SCAPE ShoreUpdate 6803
Northskaill (Langskaill)	Farm mound	Possible Bronze Age activity; 13th century cal. AD	At c. cal. AD1040-1280 (SRR-2352)- cal. AD1290-1430 (SRR-2353)	Davidson *et al.* 1988
Long Taing of Newark	Farm mound	Possibly Norse-Early Medieval (10th-14th century)	?Norse, Medieval. No dates recovered	Moore and Wilson 1999; SCAPE

				ShoreUpdate 6681
Newark	Farm mound	10th-14th centuries AD	?Norse	Moore and Wilson 1999; SCAPE ShoreUpdate 6682
Cata Sand	Settlement	Early Neolithic	Early Neolithic	Cummings *et al.* 2016; 2017; 2018
Pool	Settlement	Neolithic-Norse (with Late Bronze Age-Early Iron Age hiatus in Phase 4) (from at least 3210–2935 cal. BC (*start Phase 2.2-2.3*) to 2460-2280 cal. BC (*end Phase 3*); from at least cal. AD 200-800 (GU-2244) to c. 1020-1220 (GU-1808)	The Neolithic, over the archaeological site between Phases 2.1 and 2.2 (between 3889±303BC <SUTL-75a, 78a, 79, 82, 83> and 3606±282BC <SUTL-26, 27, 30, 35> (Spencer and Sanderson 2012, 3548-9), and between 2.2 and 2.3 (c. 3210-2935 cal. BC to 2815-2650 cal. BC (*start Phase 2.2-2.3; end Phase 2*) (Macsween et al. 2015, 15; Figure 9). Late Bronze Age-Late Iron Age (between 1090-920 cal. BC (UBA-32509) and AD660-780 (UBA-32508))	Hunter *et al*. 2007; Macsween *et al.* 2015

			Late Iron Age-Norse (between cal. AD660-780 (UBA-32508) and AD1377±341 <OSL-2>	

Table 46. Sanday sites showing occupation and sandblow periods.

4.8.1. Tofts Ness

Tofts Ness is a multi-period site occupied from the Neolithic to the Early Iron Age, lying on the most northerly tip of Sanday within a much larger prehistoric landscape containing enclosures, banks, and over 300 cairns and mounds (Dockrill *et al.* 2007, 407). The peninsula comprises a landscape of low-lying machair, bounded by a loch (North Loch) to the south, and an active dune system along the east coast. It was excavated by the University of Bradford in advance of ancient monument scheduling from 1985-88 (Dockrill *et al.* 2007). Three deposits of windblown sand over the site, interpreted as distinct events, were identified during the excavations. Excavation concentrated on Mound 11, while geophysical survey, augur survey, and test pit excavation were undertaken in the wider landscape (Dockrill *et al.* 2007, 113-139). Two trench groups (each denoted by a letter) were excavated on Mound 11; Areas C, D, E, and J to the north, and Areas A, B, H, and G to the south (Figure 4.60). Tofts Ness is an important site as it demonstrates active interaction and engagement with the sand deposits through clearing and integration with improved agricultural soils. Again, a pattern of landscape and settlement longevity through reuse of older areas, building materials, and agricultural land can be identified. Further consideration is given to the significance of the site in Chapter 6, but it is worth devoting considerable attention to the site here.

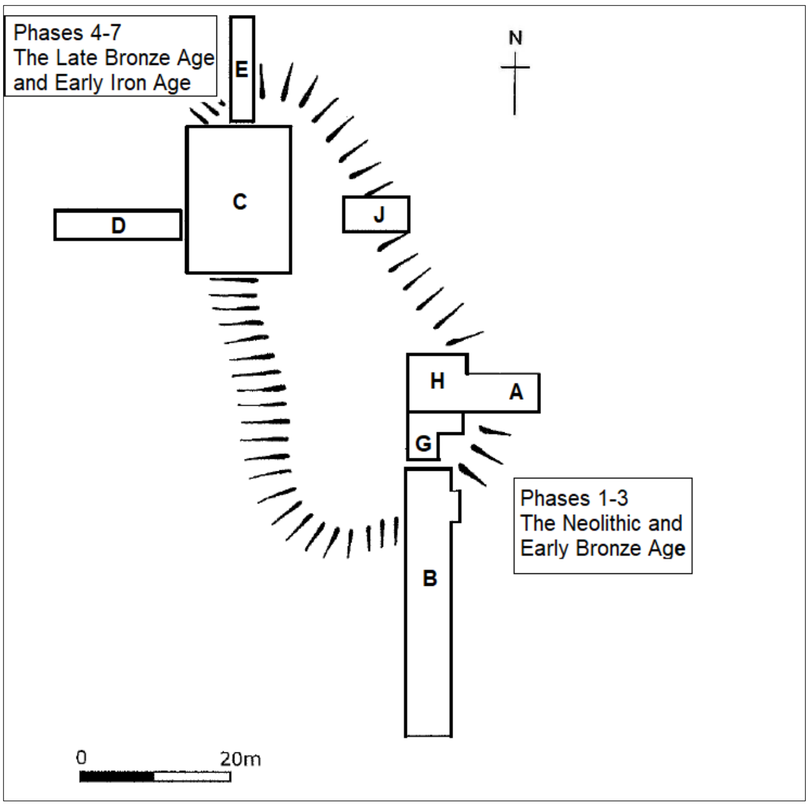

Figure 4.60. Mound 11 excavated areas. Adapted from Dockrill *et al.* 2007, xiv.

Chronology and phasing

The excavated portion of the settlement comprises six phases. Phases 1-3 represent the Neolithic and Early Bronze Age settlement investigated to the south of Mound 11, while Phases 4-7 represent the Late Bronze Age-Early Iron Age remains excavated in the northwest corner of Mound 11 (Dockrill *et al.* 2007, 41-72). The phases are summarised below, retaining the subdivisions (e.g. Phases 1-3; Phases 4-7) employed in the monograph. Twenty-seven radiocarbon determinations are available for the settlement at Tofts Ness; eight from Phase 1, four from Phase 2, three for Phase 3, and four for Phase 6. An additional eight determinations were yielded from soil samples from Mounds 4, 11, and 8. Of these samples, 18 can be considered as deriving from conventional archaeological dating materials (cattle bone, peat, and wood). The remaining dates were taken from acid insoluble fractions of soil samples from anthropogenic soil horizons (Simpson *et al.* 1998 cited in Ambers 2007, 143). All radiocarbon results were calibrated using IntCal98 (Stuiver *et al.* 1998) and OxCal v2.18 (Bronk Ramsey 1995). For such a rich and complex site there is a disappointingly small number of age determinations within the radiocarbon chronological sequence; notably, there are no radiocarbon results available for Phases 4 and 5 from the initial excavation.

Phases 1-3: The Neolithic and Early Bronze Age.

Phases 1-3 comprise the remains of Neolithic and Early Bronze Age activity at the south of Mound 11. The remains were overlain by a sandy soil bearing evidence of ard cultivation, sealed by an extensive cover of windblown sand (Dockrill *et al.* 2007, 13).

Phases 1 and 2

The earliest deposit in the excavated areas comprised a buried soil overlying the natural clay, both of which displayed ard marks. These were overlain by the Neolithic Phase 1 remains, comprising a sub-circular cellular stone building (Structure 1) (Figure 4.61) contained in Areas A, G, and H, which lay to the south of Mound 11 (Figure 4.60). As at other Neolithic settlements (for example, at Pool, Skara Brae and Barnhouse), the walls of the building were of an 'onion-skin' construction, whereby the wall comprises both an inner and outer face, with a wall core of turf and midden (Dockrill *et al.* 2007, 31). Phase 1 is subdivided into 1.1 (construction of Structure 1), 1.2 (later modification, with creation of a second central hearth), and 1.3 (abandonment, where midden and soil sealed the floor of Structure 1) (Dockrill *et al.* 2007, 19-23). The building was associated with midden accumulations and tip deposits which were further expanded in Phase 2. Phase 2 comprises the expansion of the tip deposits in Areas A, B, G, and H created in Phase 1 with the notable inclusion of articulated bull remains, with no notable structural evidence apart from a box-like feature of unknown function (Dockrill *et al.* 2007, 24).

Figure 4.61. Neolithic Structure 1 at Tofts Ness, sealed by Neolithic midden, with Iron Age windblown sand at the top of the section. Dockrill and Bond 2009, 36.

The tell-like tip deposits are an important component of the Neolithic and Early Bronze Age remains at Tofts Ness (and indeed, at many other early settlements in the region). A reddish-brown soil comprises the matrix of these deposits, and contains midden deposits, artefacts, animal bones, and limpet shell. The deposits extended across Areas A, B, G, and H, reaching a maximum depth of 1.25m in Area B, and are sealed by a buried soil (Dockrill *et al.* 2007, 14). The earliest deposits are contemporary with Phase 1's Structure 1, while the latest date to the Early Bronze Age. The majority of the material is comprised of fuel residue, namely burnt soil and ash deriving from dung, turf, peat, and possibly seaweed (Dockrill *et al.* 2007, 15).

Extensive buried soils also comprised a key deposit associated with the Neolithic remains, with some visible spatial differentiation between non-enhanced soils, and those which had been enhanced with anthropogenic materials (Dockrill *et al.* 2007, 36; Table 2.1). These soils originated in Mound 11 and shallowed out towards the edges. They underlay the majority of the excavated areas of the mound, with non-anthropogenic soil extending to the west of the excavated area for over 70m. The ard-cultivated arable soils were interleaved and enhanced by midden deposits and manure (Dockrill *et al.* 2007, 36). Cattle bone from the primary cultivated soil in Area A was dated to 3360-2920 cal. BC

(GU-2210). Molluscan and micromorphological data from environmental samples indicates that these phases were associated with periods of vegetation clearance, grassland vegetation, and increased land-use (Dockrill *et al.* 2007, 35).

Eleven dates (seven from Phase 1, and four from Phase 2) on cattle bone are available for the Neolithic deposits (Table 47). All derive from bone from midden contexts, and although excavators do not make clear whether these bones are bulk or articulated samples (with the implication being that these disarticulated bones may have been reworked from elsewhere (Macsween *et al.* 2015, 21)), they showed no signs of redeposition and seem to have been deposited shortly after death. Resultantly, they should provide fairly reliable dates once a marine offset is considered. The dates generally seem to support the archaeological evidence, with Phase 1 samples yielding Neolithic dates and Phase 3 samples yielding Bronze Age dates. Phase 2 dates cover a long period with some overlap between Phases 1 and 3.

Lab ID	**Sample (All Area A) and context**	**Phase**	**Date cal. BC (at 95% probability)**
GU-2209	Cattle bone, ash floor	1	3350-2910
GU-2210	Cattle bone, primary midden	1	3360-2921
GU-2205	Cattle bone, primary midden	1.3	3030-2850 or 2820-2680
GU-2366	Cattle bone, primary midden	1.3	3350-2700
GU-2367	Cattle bone, primary midden	1.3	2920-2620
GU-2368	Cattle bone, primary midden	1.3	2900-2300
GU-2369	Cattle bone, primary midden	1.3	3030-2580
GU-2105	Cattle and sheep bone, later Neolithic midden	2	2200-2180 or 2150-1880
GU-2206	Cattle bone, later Neolithic midden	2	2920-2490
GU-2362	Cattle bone, later Neolithic midden	2	3100-2500
GU-2364	Cattle bone, later Neolithic midden	2	2140-1640

Table 47. Radiocarbon dates from the Neolithic Phases (1 and 2) at Tofts Ness. After Ambers in Hunter, J. et al. 2007, 147 and Macsween et al. 2015, 21.

Bayesian statistics were first applied to the radiocarbon dates for Phases 1-3 during the development of the monograph, in order to calculate time spans for each phase (Table 48). Phase 1, it has been suggested, took place between 3350-2970 cal. BC and 3270-2910 cal. BC, although not enough determinations were available to calculate a true span for this Phase (Ambers in Dockrill *et al.* 2007, 145). In this model, the dated bones from Phase 1.3 would have been deposited over 120-310 years between 3110-2860 cal. BC and 2860-2600 cal. BC (*span 1.3*; Ambers in Dockrill *et al.* 2007, 152; Illustration 5.4). Phase 2 deposition took place over 660-900 years, between 2820-2560 cal. BC and 2110-1690 cal. BC (*span 2*; Ambers in Dockrill *et al.* 2007, 152; Illustration 5.4). Stable carbon isotope values for sheep bone collagen also place Phases 1-3 in the Neolithic, Late Neolithic and Bronze Age respectively (Ambers in Dockrill *et al.* 2007, 144-5; 148).

Phase	**Period**	**Activity start**	**Activity end cal. BC (at 95% probability)**
1	Early Neolithic	3350-2970 cal. BC	3270-2910
2	Late Neolithic (*span 2*)	2820-2560 cal. BC	2110-1690
3	Early Bronze Age-Iron Age (*span 3*)	1880-1600 cal. BC	1680-1440
4		Undated	Undated
5		Undated	Undated
6	Early Iron Age	1450-900 (GU-2183); 1000-200 (GU-2207); 770-410 (GU-2208); 770-410 (GU-2544)	

Table 48. Mean radiocarbon dates for occupation at Tofts Ness for Phases 1-3, and raw dates for Phase 6. Ambers 2007, 145-8.

More recent modelling was undertaken on the Neolithic radiocarbon determinations by Macsween *et al.* (2015), displaying broad agreement with the spans described above. This model places the beginning of Phase 1 activity to between 3330-2910 cal. BC (*start Tofts Ness 1*) and 2880-2695 cal. BC (*end Tofts Ness 1*) (Macsween *et al.* 2015, 21-2; and see Figure 4.62). This model demonstrates that Phase 1 at Tofts Ness is partially contemporary with Phases 2.2 and 2.3 (and the deposition of windblown sand) at Pool (Macsween *et al.* 2015, 21; and see Chapter 5). The four radiocarbon determinations for Phase 2 are problematic as they fail to form a coherent data group (Figure 4.62). Macsween *et al.* suggest two scenarios; firstly, that activity in this phase was either a relatively short period of occupation at c. 2000 cal. BC. Alternatively, activity may have lasted from the second quarter of the third millennium cal. BC to the end of the third millennium BC (Macsween *et al.* 2015, 23).

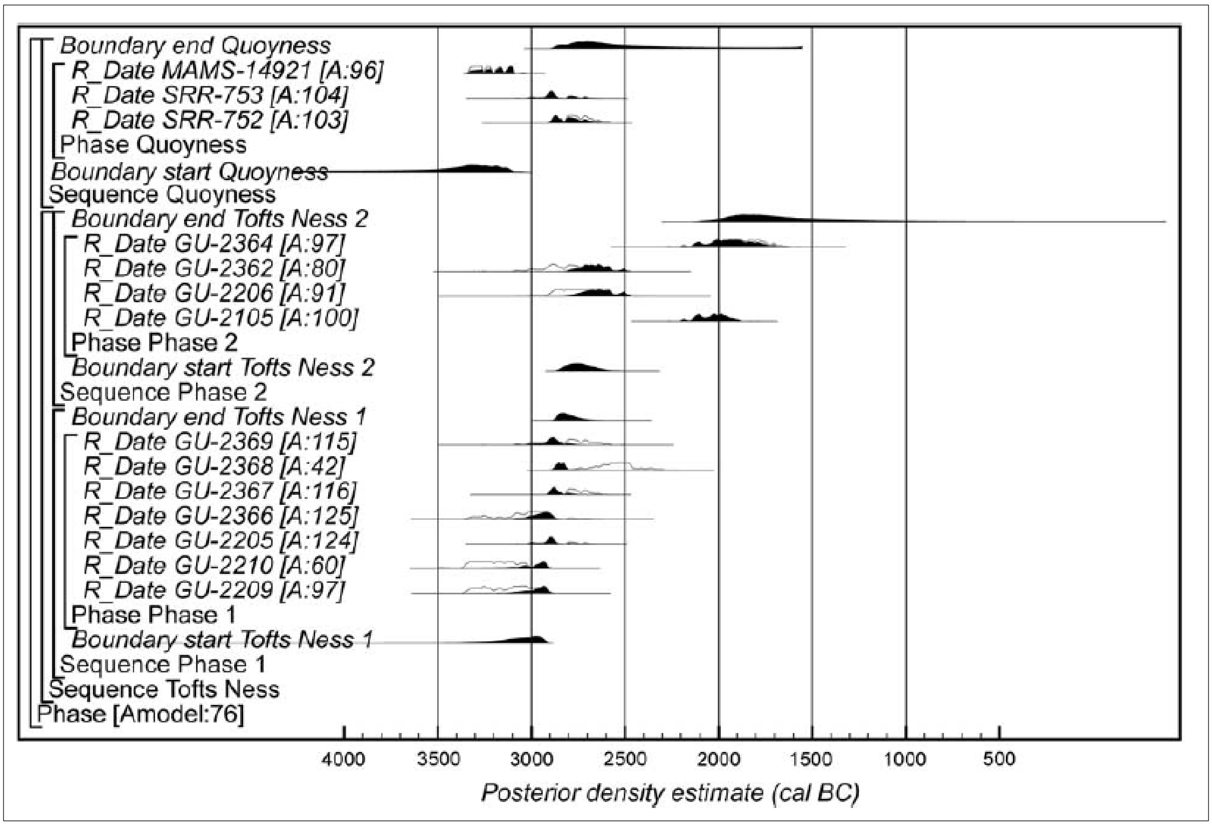

Figure 4.62. Probability distributions of radiocarbon dates from Tofts Ness as modelled by Macsween et al. 2015. (Note: this distribution also includes the radiocarbon dates from Quoyness, Sanday, which informed discussion in the above paper). Macsween et al. 201

Phase 3

Phase 3 comprised the fragmentary Early Bronze Age structural remains excavated at the north of Area B. The remains comprised a subcircular structure (Structure 2), as well as pits, slots, and postholes cut into the Phase 2 midden and ash tips. As with the Neolithic remains, the Bronze Age structure forms part of an undoubtedly larger complex outwith the excavated areas (Dockrill *et al.* 2007, 24-6). Structure 2 was subjected to extensive robbing after its occupation ceased, and was infilled with rubble and midden material. This was then sealed by a sandy buried soil attributed to Phase 5 (Dockrill *et al.* 2007, 29). Three radiocarbon determinations are available for Phase 3 (Table 49), one from the aforementioned infill, and two from the midden associated with the occupation of Structure 2 in Areas A and B. Based on these dates, a span of 50-230 years has been suggested for Phase 3 (1880-1600 cal. BC to 1680-1440 cal. BC (*span 3*; Ambers in Dockrill *et al.* 2007, 152; Illustration 5.4).

Lab ID	Sample and context	Phase	Date cal. BC (at 95% probability)
GU-2104	Cattle bone. Area B, midden filling Structure 2	3	1690-1430
GU-2361	Cattle bone. Area A, primary midden	3	1880-1520
GU-2363	Cattle bone. Area B, primary midden	3	1880-1510

Table 49. Radiocarbon dates from the Phase 3 middens at Tofts Ness. After Ambers in Hunter, J. et al. 2007, 147.

Phases 4-7: The Late Bronze Age and Early Iron Age

The later prehistoric remains were investigated at the north of Mound 11, in Areas C, E, D, and J. The earliest investigated remains comprised a primary buried cultivation soil thought to be contemporary with the Phase 1-3 occupation, measuring c. 0.08-0.10m. This soil was overlain by a calcareous sand deposit measuring c. 0.08-0.12m (Dockrill *et al.* 2007, 44; 98-9; Section 37). This sand was identified in the north sections (Section 37) of Areas C and D, and did not continue in the sequences investigated outwith the settlement (see below). Its absence here is attributed to its incorporation into the cultivated soil (Dockrill *et al.* 2007, 44).

Phase 4

The Late Bronze Age remains of Phase 4 comprised two structures uncovered in Area C; a corner of a small oval structure containing a rectangular stone-lined tank (Structure 3) and a large roundhouse (Structure 4) with double faced walls. Some morphological similarities between Structure 3 and the structure associated with the burnt mound at Liddel (South Ronaldsay) have been noted (Dockrill *et al.* 2007, 73-4). Structure 4 comprised an early example of a fully-developed roundhouse. It was found to contain a network of drains cut into the natural clay beneath its paved floor. Excavation was undertaken with some difficulty as the water table was encountered; it was found that the drain to the east of the hearth (oriented NW-SE) led to the structure's entrance, where it fed into a circular stone-lined bowl interpreted as a soakaway (Dockrill *et al.* 2007, 48).

Only the Structure 4 roundhouse was dated; a lack of suitable materials for radiocarbon dating meant that the structure was dated firstly by its stratigraphic association with other remains, and secondly by five thermoluminescence (TL) dates from a fired clay deposit forming the base of the central hearth (Table 50) (Dockrill *et al.* 2007, 44). The thermoluminescence process dates samples by measuring the time elapsed since mineral materials within a sample were last heated in antiquity (Duller 2008, 4; 22). The dated samples from Tofts Ness all yielded a Late Bronze Age date concordant with the stratigraphic evidence, although it is also important to note their considerable error margins. Both structures appear to be contemporary with one another, given that both were sealed by the same destruction level (including midden and rubble spreads) indicative of demolition following a cessation of use (Dockrill *et al.* 2007, 45-6; 49).

Lab ID	Context	TL date BC
SUTL-95	F98 fired clay (hearth base), Structure 4	870±440
SUTL-103		960±440
SUTL-104		990±270
SUTL-105		1050±330
SUTL-106		930±310

Table 50. Thermoluminescence (TL) dates from the central hearth base in Structure 4, Phase 4. After Dockrill et al. 2007, 44.

Phase 5

Phase 5 denotes the period between what has been interpreted as "a major sandblow event" after the abandonment of Structures 3 and 4, and before the construction of the Phase 6 roundhouse (Structure 5) (Dockrill *et al.* 2007, 52). The true dimensions of this sand are difficult to ascertain due to post-depositional cultivation activities, but the remains measured from c. 0.18-0.80m in depth (Dockrill *et al.* 2007, 92-95 (Sections 34-35)). No structural features associated with this sand were identified, and little significant detail of the nature of this important sand deposit is given in the monograph. No datable material was recovered from this deposit.

Phase 6

Phase 6 comprised the construction, modification, and use of the Early Iron Age Structure 5 roundhouse, and the accumulation of associated occupation deposits. It is further subdivided into Phases 6.1 (construction and primary occupation), 6.2 (interface between late primary occupation and Phase 6.3 occupation), 6.3 (major phase of occupation), and 6.4 (continued occupation, refurbishment, and the deposition of a further layer of windblown sand) (Dockrill *et al.* 2007, 53-65). Structure 5 is an Early Iron Age roundhouse, and appears to have been a standalone structure with an infield and annex. Typologically, the house fits within Armit's 'simple Atlantic roundhouse' scheme, sharing parallels and contemporaneity with structures at Bu (Hedges 1987a), Pierowall (Sharples 1984), and Howe amongst others (Ballin Smith 1994) (Armit 1991, 183; Dockrill *et al.* 2007, 76). The infield associated with Structure 5 extended over the older element of Mound 11 to the south. Ard-cultivated sandy soils which developed over the Phase 5 windblown sand deposit were identified in Areas A-E and J (Dockrill *et al.* 2007, 76).

Only four dates are available for Phase 6 (for 6, 6.3 and 6.4) (Table 51), with no dates for preceding or post-dating layers to constrain them. This, along with the fact that most determinations fall into the Iron Age plateau on the calibration curve, means that this phase can just be assigned to the Early Iron Age although the extensive evidence of building repair and remodelling is indicative of several centuries of occupation (Dockrill *et al.* 2007, 52). Wood from Structure 5's floor deposit yielded a notably early determination of 1450-900 cal. BC (GU-2183), while a thin peat layer from Area C (which formed as a late ground surface between sand layers) yielded a date of 770-410 cal. BC (GU-2544). Cattle bone from the Area C midden and the Structure 5 wall core yielded determinations of 770-410 cal. BC (GU-2208), and 1000-200 cal. BC (GU-2207) respectively. Given that (GU-2207) is from bone recovered from Structure 5's wall core, it is possible that its comparatively early date stems from the sample having been redeposited from an earlier context. Stable carbon isotope values support an Early Iron Age date (Ambers 2007, 145-8).

Lab ID	**Sample and context (All Area C)**	**Phase**	**Date cal. BC (at 95% probability)**
GU-2544	Thin peat layer, Area C	6	770-410
GU-2183	Wood from Structure 5 floor	6.3	1450-900
GU-2208	Cattle bone, midden butting rebuilt annexe wall	6.4	770-410
GU-2207	Cattle bone, from Structure 5 secondary wall core	6.4	1000-200

Table 51. Radiocarbon dates from Phase 6 at Tofts Ness. After Ambers in Hunter, J. et al. 2007, 147.

Phase 7

Phase 7 denotes the abandonment of the Structure 5 roundhouse, and of the excavated portion of the site as a whole. The deroofed roundhouse and its annexe were filled with sand and rubble, with the associated Phase 6 infield also being covered with a layer of white windblown calcareous sand measuring between 0.05m-over 1.0m, again interpreted as an "extensive event" (Dockrill *et al.* 2007, 72). No material was dated from this phase.

Windblown sand at Tofts Ness

At least two significant windblown sand layers were deposited over the settlement and arable fields at Tofts Ness. One, termed the 'temporary abandonment horizon' took place in Phase 5, with c. 0.18-0.80m of calcareous sand being blown over deposits and Structures 3 and 4 (Dockrill *et al.* 2007, 52). Another took place after Phase 6 (termed the 'final abandonment horizon'), when 0.05-1.0m of windblown sand was deposited over the previously deroofed Early Iron Age Structure 5 and its annexe (Dockrill *et al.* 2007, 72). Modern ploughing disturbed this second sand deposit, and as such it is difficult to ascertain whether these dimensions are accurate, or whether the sand was originally deeper (Dockrill *et al.* 2007, 52). Given that the arable fields were ploughed – and the sand integrated with the buried soils – following the Phase 5 sandblow, this also makes it difficult to ascertain the true dimensions. The identification of a possible third horizon is discussed in the OSL dating section below.

As described above ('Chronology and phasing'), the greater availability of radiocarbon dates, and the refined modelling by Bayliss *et al.* (2017), ensure that the chronology for the Neolithic and Early Bronze Age phases of occupation is now fairly well-understood. The same cannot be said for the later prehistoric phases of Tofts Ness, which is unfortunate given that it is during these periods when the most extensive windblown sands were deposited. The sand deposits at Tofts Ness have been further constrained in two ways; firstly, by a programme of fieldwork to retrieve samples for Optically Stimulated Luminescence (OSL) dating (Sommerville 2003; Sommerville *et al.* 2007), and secondly, by the radiocarbon dating of a series of buried soils sandwiched by windblown sands in the wider Tofts Ness landscape (Dockrill *et al.* 2007, 113-139).

Luminescence dating

Sampling for OSL dating at Tofts Ness produced 18 determinations from two sand layers, across nine test pits (Table 52). These were originally excavated to re-expose and sample the soils and midden recorded during the original excavations, in order to investigate the cultivated soils and their extents (Guttmann 2001, 124). All lay in the vicinity of the excavated trenches, with the exception of Test Pit 2 which was located in Area A, and Test Pit 1 in Area J (Sommerville 2003, 80 and see Figure 4.63). The remaining seven test pits were excavated in an ESE orientation outwith the limit of excavation. Test Pits 5, 6, 8, and 9 all contained two sand layers, with the rest containing one sand layer (e.g. Test Pit 3: see Figure 4.64 and Figure 4.65). All contained buried soil deposits. Test Pit 1 contained no sand layers (Sommerville 2003, 80-85).

The two sand layers identified in Test Pits 5, 6, 8, and 9 will be referred to as the Lower and Upper Sand Layers. These layers were separated by buried soils, with the soil between the sands in Test Pit 5 radiocarbon dated to 800-405 cal. BC (GU-9243) (Figure 4.64). The Lower Sand layer was hypothesised to equate to Dockrill *et al.*'s Phase 5 'temporary abandonment horizon', while the Upper Sand Layer was thought to correspond to the late Phase 6 sand (the 'final abandonment horizon'). The OSL samples were generally in stratigraphic order within their respective test pits. A wide range of ages can be identified, with some samples <SUTL-604, 606, 607> yielding a comparatively young age. Given that these lie close to the modern ploughsoil, they were likely to have been exposed during modern ploughing. Upon analysis of the determinations, it becomes immediately apparent that the dates do not always fit well with the excavated site sequence.

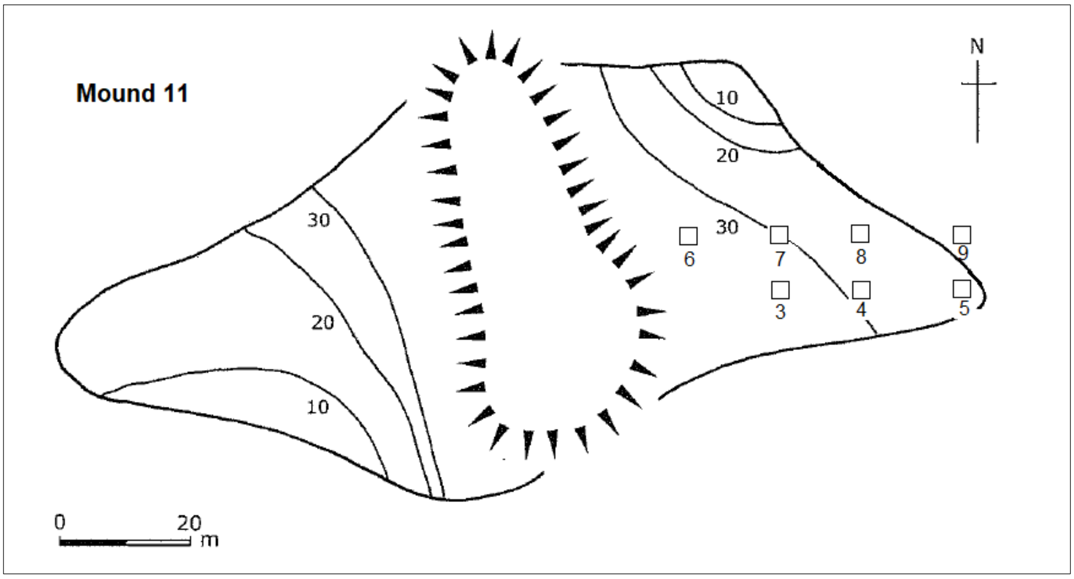

Figure 4.63. Location of Test Pits 3-9 and soil contours adapted from Guttmann 2001, 125 and Dockrill *et al.* 2007, 120.

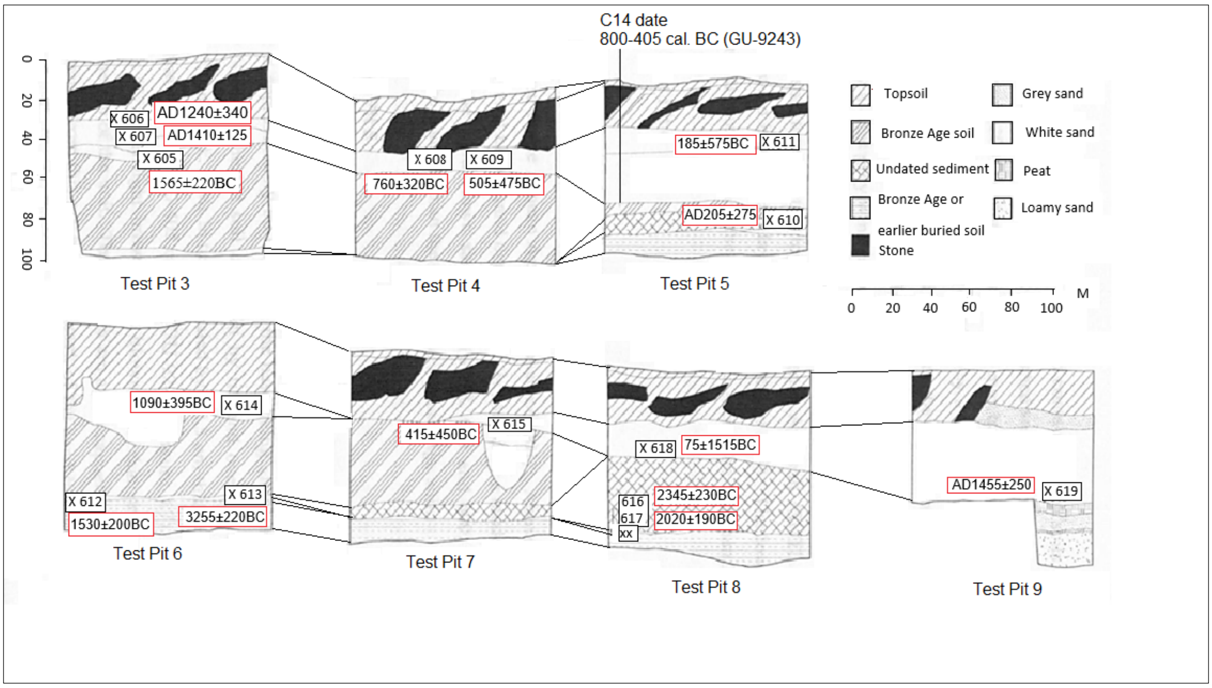

Figure 4.64. Stratigraphic sections of Test Pits 3-9, showing locations of OSL samples and their corresponding dates. The black lines indicate possible relationships between the deposits. After Sommerville 2003, 83.

Figure 4.65. Tofts Ness Test Pit 3 showing sand layer disturbed by modern ploughing. Sommerville 2003, 87.

The Lower Sand Layer.

In Test Pits 2, 4, 6, and 8, two samples were collected from the Upper or Lower Sand Layers. Given that the dates were in error of each other, a weighted mean age for these sand layers could be calculated. The weighted mean for the samples taken from the Lower Sand Layer place its deposition to the Late Neolithic period (2260±100BC) <SUTL-602, 603, 612, 613, 616, 617> (Sommerville 2003, 276) (Table 52). If the Lower Sand Layer identified in Sommerville's Test Pits is the same sand that covered the excavated portions of Mound 11 in Phase 5 (after the cessation of use of Structures 3 and 4), then there is poor agreement between the OSL dates and the TL dates from the Phase 4 Late Bronze Age roundhouse, which place its last use to the 10th-9th centuries BC (Table 50). The mean date for the Lower Sand Layer (2260±100BC) is too early when the nature of the settlement, its material culture and the dates given by the excavators are considered. It is possible, then, that the OSL data highlights the occurrence of more than two sand inundations which took place before and during the life of the settlement. If this is the case, then it is possible that any sand which accumulated during the occupation of the Late Neolithic settlement at Tofts Ness was either cleared from the settlement, or did not enter the settlement in any significant quantity.

The Upper Sand Layer

OSL samples yielded a weighted mean of 625±185BC for the Upper Sand Layer, based on determinations from <SUTL-608, 609, 611, 614, 615, 618> (Sommerville 2003, 276) (Table 52). This places its deposition to within the Late Bronze Age-Early Iron Age. Sommerville's determinations from the Upper Sand Layer generally fit better with the few radiocarbon determinations available for Phase 6. Four radiocarbon determinations were recovered from Phase 6 materials, all of which produced age ranges spanning the early Bronze Age (GU-2183) to the Middle Iron Age (GU-2007). An early date for Phase 6.3 was yielded by a sample of wood (species not stated) from the floor of Structure 5 (1450-900 cal. BC (GU-2183)). Wood often presents a problematic dating material given that an old wood species with an unknown age at death can present an older bias (Becker *et al.* 2012, 20; Horn 2016, 143). This is particularly pertinent in the Northern Isles where a resource as scarce as wood may have been reused multiple times (Ambers in Dockrill *et al.* 2007, 143).

The radiocarbon dates from the last subphase in Phase 6 (6.4) yielded two determinations: 770-410 cal. BC (GU-2208) and 1000-200 cal. BC (GU-2207) respectively. These determinations fit relatively well with those yielded by the radiocarbon samples for Phase 6.4. Additionally, a TL date of c. 410±290BC is cited by Sommerville as having been produced from a Phase 6 hearth (D. Sanderson *pers. comm.* in Sommerville 2003, 282) although it was not possible to obtain any further information on this determination. The varying survival of the Neolithic and Iron Age sand deposits may derive from differential activity taking place on the site, which allowed erosion or clearance of sand to occur in some areas but not in others. On the other hand, survival of some sands may have been promoted by the rapid accumulation of the soils overlying the sands (Sommerville 2003, 282).

Lab ID <SUTL->	Test Pit	Sand layer (above or below Bronze Age soil)	Age (years before 2000AD)	Age (BC/AD)	Weighted mean age (BC/AD)	Period
604	2	Upper	265±80	AD1735±80	625±185BC	Little Ice Age
602	2	Upper	4735±400	2735±400BC		Neolithic
603	2	Upper	4100 ±510	2100±510BC		Neolithic
606	3	Upper	750±340	AD1240±340		Medieval/Little Ice Age
607	3	Upper	590±125	AD1410±125		Medieval/Little Ice Age
605	3	Upper	3565±220	1565±220BC		Bronze Age
608	4	Upper	2760±320	760±320BC		Bronze Age
609	4	Upper	2505±475	505±475BC		Iron Age
611	5	Upper	1815±575	185±575BC		Iron Age
610	5	Lower	1795±275	AD205±275	2260±100BC	Iron Age
614	6	Upper	3090±395	1090±395BC		Bronze Age
612	6	Lower	3530±200	1530±200BC		Neolithic
613	6	Lower	5255±220	3255±220BC		Neolithic
615	7	Upper	2415±450	415±450BC		Iron Age
618	8	Upper	2075±1515	75±1515BC		Iron Age
616	8	Lower	4345±230	2345±230BC		Neolithic
617	8	Lower	4020±290	2020±190BC		Neolithic
619	9	Upper	545±250	AD1455±250		Medieval/Little Ice Age

Table 52. Table showing age of Tofts Ness samples. The samples are in stratigraphic order within their respective Test Pits. The lower sand layers are shaded to differentiate them from the upper sand layers. After Sommerville 2003, 277.

Radiocarbon dating

A series of radiocarbon determinations on acid insoluble fractions from buried soils outwith Mound 11 (Figure 4.66) allow some additional chronological constraint to the windblown sands (Table 53) interbedded with the buried soils. These determinations generally yielded Bronze Age dates for the development of the buried soils, thought to be contemporary with the Mound 11 buried soils. Although the manner in which these sequences are described in the monograph is somewhat confusing, they seem to confirm the presence of two distinct windblown sand deposits separated by a Bronze Age buried soil which measured between c. 0.15-0.32m in depth. In the test pits near Mounds 8 and 11, natural grey boulder clay was reached at the base. Approximately 300m north of Mound 11 in Area Z, however, a further series of at least three windblown sands at c. 1.33m deep separated by buried land surfaces were identified but not dated (Dockrill *et al.* 2007, 126-7).

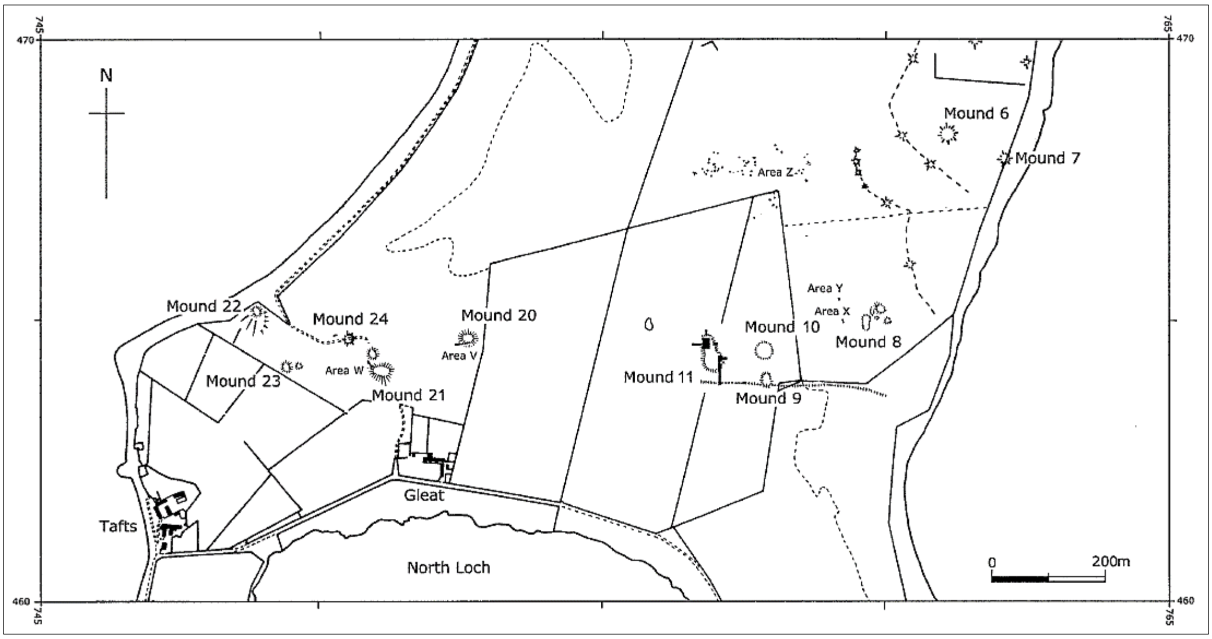

Figure 4.66. The immediate landscape context of Mound 11, showing the location of sampled mounds mentioned in the text. Dockrill *et al.* 2007, 114.

Mound 4

A test pit c. 20m south of Mound 4 (one of the most northwesterly mounds, lying some 40m from the shoreline) also revealed c. 0.20m of sandy silt loam stratified between layers of windblown sand (no dimensions given). An augur survey revealed that this soil extended c. 90m south of Mound 4, and was identified as an infield of just under a hectare. The bottom of the soil yielded a determination of 1390-1010 cal. BC (SRR-5245), while the top of the soil dated to 400-200 cal. BC (SRR-5244). This suggests the soil was established in the Bronze Age and continued to develop into the Early Iron Age (Dockrill *et al.* 2007, 128) and offers a *terminus ante quem* for the accumulation of the windblown sand directly below it, which must have been deposited before the Middle Bronze Age.

The nature of the deposits underlying this windblown sand is unclear, and it may be that further windblown sands existed below this.

Mound 8

Two areas in the vicinity of Mound 8 (Areas X and Y) were investigated. A test pit in Area X, c. 50m to the west of Mound 8 revealed additional buried soils interleaved with windblown sands (Sequence 8/1). A deposit of c. 0.30m of buried soil yielded a determination of 1980-1520 cal. BC (SRR-5243) for the top of the soil, and 400-130 cal. BC (SRR-5242) for the bottom. In Area Y (c. 25m north of Area X), c. 0.20m of buried soil at the edge of the infield of Mound 8 (Sequence 8/2) yielded a determination of1740-1520 cal. BC (SRR-5249) for the bottom of the soil and 1220-920 cal. BC (SRR-5248) for the top (Dockrill *et al.* 2007, 125). The soil in Area X overlay 0.15m of sandy loam, 0.04m of sandy soil, 0.05m of sandy loam soil, and a white windblown sand (dimensions not given).

Mound 11

The Mound 11 infield deposits were investigated c. 30m to the east of the mound (Figure 4.67). These comprised c. 045m of sand and sandy soils, overlying c. 0.32m of sandy loam. The top of this loam yielded a radiocarbon determination of 900-790 cal. BC (SRR-5256) while the bottom yielded a date of 1520-1310 cal. BC (SRR-5247). This soil was described as being similar to the buried soil investigated in Area J (Dockrill *et al.* 2007, 120), and the associated radiocarbon determinations offer a *terminus post quem* for the deposition of the overlying sand.

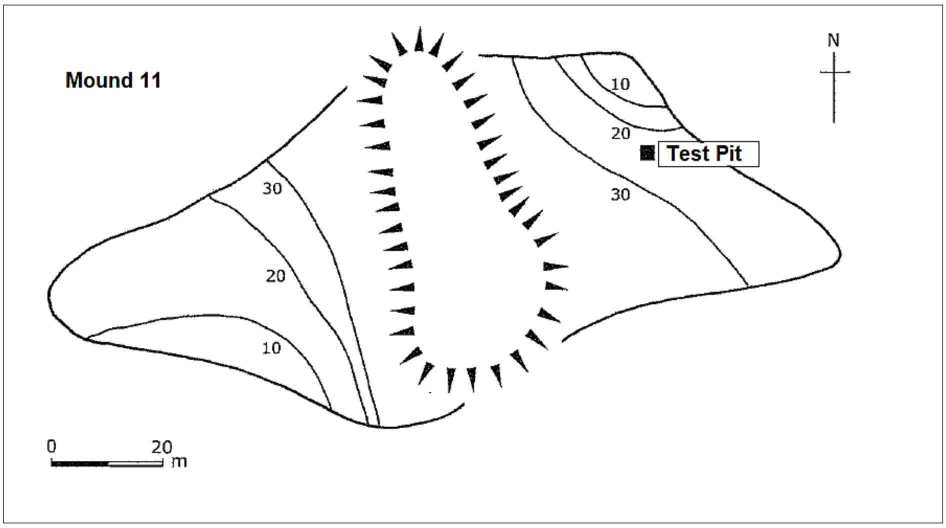

Figure 4.67. Mound 11 showing location of Test Pit and soil depth contours. After Dockrill *et al*. 2007, 120.

			Calibrated age ranges AD/BC		
Lab ID	**Mound**	**Depth (cm)**	**68% probability**	**95% probability**	**Context**
SRR-5256	11	36-41	895-880 cal. BC or 834-795 cal. BC	900-790 cal. BC	Sandy loam between windblown sand layers: Bottom
SRR-5247	11	55-60	1490-1480 cal. BC or 1450-1380 cal. BC or 1340-1320 cal. BC	1520-1310 cal. BC	Sandy loam between windblown sand layers: top
SRR-5244	4	30-33	400-350 cal. BC or 300-210 cal. BC	400-200 cal. BC	Sandy silt loam between windblown sand layers: top
SRR-5245	4	50-53	1370-1360 cal. BC-1320-1110 cal. BC	1390-1010 cal. BC	Sandy silt loam soil between windblown sand layers: bottom
SRR-5242	8/1	36-41	cal.AD230-350 or cal. AD370-380	cal. AD130-400	Sandy silt loam soil between windblown sand layers: top
SRR-5243	8/1	108-113	1880-1620 cal. BC	1980-1520 cal. BC	Sandy silt loam soil between windblown sand layers: bottom
SRR-5248	8/2	59-64	1130-1000 cal. BC	1220-920 cal. BC	Sandy silt loam soil between windblown sand layers: top
SRR-5249	8/2	78-83	1740-1710 cal. BC or 1690-1600 cal. BC or 1560-1530 cal. BC	1740-1520 cal. BC	Sandy silt loam soil between windblown sand layers: bottom

Table 53. Radiocarbon dates from Tofts Ness soil samples. Ambers in Dockrill *et al*. 2007, 148

Provenance

Laboratory analysis of the Tofts Ness sands sheds light on their composition. All samples derived from medium to coarse-grained calcareous sands containing c. 40%-70% shell fragments with a grain size of 250-500µm. Given that the calcium carbonate content did not notably vary between samples, it was at first deemed likely that the sands were composed of similar material and derived from the same source (Sommerville 2003, 80; 270). Further laboratory analysis complicated this initial interpretation, and appeared to suggest the possibility of either different provenances for some sand deposits, or that sands derived from material combined from more than one source (Sommerville 2003, 272).

Artificial irradiation doses administered during the OSL process revealed a difference in sensitivity between the samples. The majority of lower sand layer samples (e.g. <SUTL-610, 612, 613, 616 and 617>) responded well to artificial irradiation doses, while those from the upper sand layer (with the exception of <SUTL-602 and 605>) had a more scattered response to irradiation doses (Sommerville 2003, 270). Furthermore, upon in-situ and lab-based measurement of their beta and gamma dose, samples from the lower sand layer <SUTL-605, 616 and 617> were found to have a higher internal dose rate than other samples. Based on these results, it can be suggested that the lower and upper sand samples derived from different sources, or that samples contained a combination of high and low sensitivity grains from different sources.

The partial bleaching (i.e. 'resetting') of windblown sand during deposition can lead to an older bias in OSL dates. In order to identify partially bleached sediments (and therefore potential dating errors), a technique (known as the psi (ψ) ratio) was employed. The ratio is determined by comparing the shapes of the natural and regeneration decay curves from feldspar within each sample. The decay curve of well-bleached samples will be similar to the regenerated decay curve, displaying a high decay curve. Partially bleached samples will hold a residual component (i.e., they have not been fully 'reset' during deposition) while flattens the shape of the decay curve (Sommerville 2003, 210-11). At Tofts Ness, partial bleaching of the sampled sands does not seem to have been a notable issue; again, suggesting that more than two episodes of windblown sand deposition took place (Sommerville 2003, 272). It may be that numerous discrete sand layers were deposited over the Tofts Ness area from at least two separate sources through the last 4000-5000 years.

During Sommerville's research all modern beaches were sampled to provide a comparative dataset, and to test whether sand provenance could be ascertained. A modern beach source failed to be identified in the Tofts Ness samples, suggesting that the source of the sand is likely to now be located offshore (Sommerville 2003, 279). During relative sea level rise in the Holocene, the low-lying islands in the Orkney archipelago and their till capping deposits have eroded and submerged. These tills now lying offshore from Sanday include Baa Gruna (off the Bay of Newark to the east), the Riv (east of Whitemill Bay), and Start Point (south of Tofts Ness). These deposits would have comprised a key sediment supply for the development and replenishment of beach and dune complexes (Sommerville 2003, 248; May and Hansom 2003; Rennie 2006, 224).

Discussion

When considering the excavated evidence and the chronological data, it can be surmised that at least three episodes of windblown sand deposition took place at Tofts Ness. Three deposits were visually identified during the excavations at the site and the vicinity; the first was deposited in late Neolithic Phase 3/Early Bronze Age Phase 4, the second in Late Bronze Age Phase 5, and the third in Early Iron Age Phase 7. The first excavated sand was only identified in the north section (S37, Dockrill *et al.* 2007, 98-9) of Areas C and D at the northwest corner of Mound 11. It comprised a discrete deposit of c. 0.08-0.12m of calcareous sand overlying the buried soil contemporary with Phases 1-3. This small deposit predates Phase 4 structural activity. Little is made of this deposit in the monograph, perhaps because it was far smaller and deemed less significant than the

Phase 5 windblown sand “event”. The sand was not knowingly identified in the anthropogenic soil sequences investigated by the excavators in the areas outwith the settlement. It may have originally been larger in its extent before being cleared out of used areas and/or incorporated into cultivation soils by the occupants (Dockrill *et al.* 2007, 44).

The Phase 5 sand (c. 0.18-0.80m deep) sealed the rubble spread deriving from the destruction of Structures 3 and 4 while the Phase 7 sand (c. 0.05-1.0m deep) and rubble sealed the deroofed Structure 5 roundhouse, its annexe, and the surrounding infields. With the exception of the infill deposits and those blanketing the settlement, there is little evidence for the incursion of windblown sand into the interior of the structures during their occupation. A sand-filled orthostat slot at the east of the Structure 3 interior (Dockrill *et al.* 2007, 45) is likely to represent the incursion of sand following demolition and robbing of stone as opposed to sand incursion during the structure’s use.

Test pit excavation revealed that sand deposits extended out into the landscape, encompassing the associated infields. That two sand layers were observed in some test pits and not others again demonstrates the variability of sand and its deposition, in that it could be frequently moved and reworked thus complicating interpretations of its spatial and chronological distribution. Approximately 300m north of Mound 11 in Area Z, a further series of at least three windblown sands separated by buried land surfaces were identified but not dated (Dockrill *et al.* 2007, 126-7). This may indicate that the sands were originally far deeper to the north, perhaps due to being nearer to a coastal sediment source. Alternatively, the sands may have been deeper in these areas where less cultivation appears to have taken place.

Chronology

Caution must be advised with any interpretation of the scientific dates at Tofts Ness. While the Neolithic dates are now fairly robust due to a greater number of determinations and recent chronological modelling, those for the later periods are less than satisfactory – with no determinations available for Phases 4 and 5 and only four available for Phase 6, which preceded the final abandonment of the excavated areas of the site. A total of 18 determinations for the site itself is a small number considering the complexity of this multi-period site, and there is scope for gaps in the radiocarbon chronological to be filled by higher-precision AMS (Accelerator Mass Spectrometry) radiocarbon dating of the short-lived carbonised plant remains recovered during the original excavations. This technique was not an option at the time of excavation (Ambers in Dockrill *et al.* 2007, 143).

The varied nature of the individual luminescence dates ensures that interpretation of this data must also be approached with caution. During the OSL dating programme <SUTL-604, 606 and 607> were sampled from the Upper Sand Layer (with a weighted mean lying in the Early Iron Age) but yielded Little Ice Age date ranges. It is likely that these anomalies are due to the 'resetting' of the date for this layer as a result of ploughing activity (Sommerville 2003, 277-81). The TL dates for the Phase 4 hearth and the luminescence dates for the sands frequently display large standard deviations and resultantly, large possible age ranges of several centuries (Table 50, Table 52).

Neolithic sand

The earliest dated sand was that dated by OSL, to 2260±100BC. Although this date does not fit well with the excavated evidence at the site (in that a sand doesn't appear to have been deposited in the Neolithic remains), it is included here as it is possible that if the sand was deposited at the settlement, it was cleared by the inhabitants.

Phase 3/4 sand

This sand was deposited before Phase 4 construction activity began and given that it overlay the Phases 1-3 buried soil, it can be suggested that this incursion dates to the Early-Late Bronze Age. Its deposition at the site is bracketed by a date range of 1880-1600 cal. BC to 1680-1440 cal. BC for Phase 3 (*span 3*; Ambers in Dockrill *et al.* 2007, 145) and five TL dates (Table 50) yielding 11^{th}-9^{th} century BC dates for final occupation of Phase 4's Structure 4. It is worth looking to dates for the sands from the vicinity here. At Mound 4, a *terminus ante quem* of 1390-1010 cal. BC (SRR-5245) can be identified for a sand deposit, while at Mound 8 a *terminus ante quem* of 1740-1520 cal. BC (SRR-5249). These dates fit quite well with those from the site, and it is proposed that these are the same sands.

Chronology: Phase 5 sand

The lack of radiocarbon determinations for the preceding Phase 4, and a total of only four determinations for Phase 6, make it difficult to constrain a date range for the deposition of the Phase 5 sand. The five TL determinations currently stand as the only available dating evidence for Phase 4, yielding 11^{th}-9^{th} centuries BC dates. Given that these samples were taken from the fired clay base of the central hearth in Structure 4, the implication is that these determinations date the occupation of Structure 4 and the last use of the hearth. Structure 4 was already in a state of disrepair and sealed by midden and rubble deposits before the sand blew into the settlement (Dockrill *et al.* 2007, 45-6; 49).

Resultantly, these TL determinations do not offer any direct dating for the sand incursion but at the most offer a *terminus post quem* for its deposition, which must have taken place after the last firing of the hearth and use of the structure. The four determinations available for Phase 6 occupation (with dates widely ranging from 1450-900 cal. BC (GU-2183) to 770-410 cal. BC (GU-2208) only offer a *terminus ante quem* for the deposition of the

Phase 5 sand, which must have taken place before the advent of Phase 6 activity. That two of the four determinations were yielded from animal bone may also be approached with caution, due to the role of marine dietary input in radiocarbon calculations (Ambers in Dockrill *et al.* 2007, 143-4).

Chronology: Phase 7 sand

The Phase 6 radiocarbon determinations also offer a *terminus post quem* for the Phase 7 sand incursion, for which no datable material was recovered. Two determinations from midden butting Structure 5's annexe wall (770-410 cal. BC (GU-2208)) and cattle bone from Structure 5's wall core (1000-200 cal. BC (GU-2207) were yielded for the final portion of Phase 6 (Phase 6.4), prior to the deposition of the Phase 7 windblown sand. Structure 5 and the annexe appear to have been deroofed after their occupation, and filled with rubble and windblown sand in Phase 7 (Dockrill *et al.* 2007, 72).

Excavation strategy

The varying presence of sand in test pits at Tofts Ness further attests to the high spatial variability in the nature of sand deposition and reworking within the landscape and settlement environs. Given that the majority of test pits lie outwith the main settlement and excavation area, it is difficult to gauge the relationship between the dated sands in the test pits and those within the excavated area. More scientific dating of the sands which overlay the site itself would alleviate some confusion, as well as further investigation of the possible earlier sand layer identified in the test pits, which yielded far less determinations than the later, upper sand layer. Additionally, the excavation of the remains took place within a relatively small area of Mound 11. This ensures that we are afforded only a 'keyhole' view into these sand deposits, and may be missing important evidence which would fill many gaps in understanding. The possible existence of retaining walls, for example, beyond the excavated areas, may account for the varying presence of sand across the site.

Living with sand at Tofts Ness

The excavators state that in Phases 5 and 7, the deposition of a single layer of windblown sand over the settlement and infields took place after the settlement's abandonment, or at least a shifting to another part of the settlement. In the first instance, this abandonment is described as being temporary (although this does in fact comprise a number of centuries), and in the second instance, permanently (Dockrill *et al.* 2007, 52; 72). The evidence would appear to corroborate this; in both cases, the sand was deposited over houses which were already deroofed and partially demolished. The apparently demolished and piecemeal state of the structures underlying the windblown sand was used by the excavators as evidence for the active removal of valuable materials (including roofing materials) upon the abandonment of the settlement (Dockrill *et al.* 2007, 72), but there is no direct evidence for this explanation as opposed to the structures simply falling into disrepair after their use. In both cases, the deposits are described as single events with as opposed to accumulations over a longer period of time, perhaps driven by powerful storm conditions. No banding within the sands (indicative of periodic accumulation) was recorded. If this is the case and the sands were deposited in single events, then this would certainly have caused significant environmental change by turning the landscape from open, cultivated grassland to machair. This in turn aided the preservation of this complex prehistoric landscape.

Windblown sand became the dominant component within the Phase 6 occupation deposits (Dockrill *et al.* 2007, 52), attesting to the intensity and longevity of sand movement at varying scales, and indicating that after Phase 5, sand was still moving in some quantity throughout the occupation of the settlement. This is unsurprising given the change to an extensive machair environment. The dominance of windblown sand within domestic sediments was also noted at Skara Brae (A. Shepherd *pers. comm.*), and Links of Noltland, and this is likely to be the case at many more settlements. The continued enhancement of calcite soils with decomposing plant matter and other organic material from Phase 5 onwards also attests to this change in landscape. These additions would have aided in the mitigation of soil drying and resultant wind erosion while acting as a manuring agent (Dockrill and Bond 2009, 42). Much has been made of the deposition of sand at Tofts Ness and its potential for causing greater economic stress in the later phases of settlement (Dockrill *et al.* 2007, 52) and this is discussed further in Chapter 6.

4.8.2. Meur

Meur burnt mound lies on the northeast coast of Sanday, in a beach-cobbled embayment characteristic of a high-energy coastal environment. Initial excavations were undertaken in 2005 (Toolis *et al.* 2007), with further excavation and environmental sampling from 2014-2017 prompted by deterioration of the site (Hambly 2015). Excavation revealed the remains of a Bronze Age burnt mound (used between c. 1120-420 cal. BC) and associated structures including a tank, stone compartments, and two wells (dating to the Neolithic and Bronze – Iron Age respectively) (Hambly 2015, 148-9) (Figure 4.68). The site and its landscape were subjected to numerous small-scale incursions of windblown sand, firstly during the Neolithic when an early well was constructed, and into the Bronze Age and Iron Age during the construction and subsequent use of the burnt mound and associated well.

Figure 4.68. The burnt mound tank, Bronze Age-Iron Age well (left), and Neolithic well (right) at Meur. T. Dawson.

Chronology and Phasing

The Neolithic well

Although the 2014-2017 excavations have not yet been published, preliminary conclusions about the chronology and phasing of activity at Meur can be drawn. Activity in this area prior to the construction of the Bronze Age burnt mound is evidenced by the construction of an earlier, Neolithic well (Figure 4.68). Waterlogged seeds (of various species) recovered from the organic fills of the well yielded dates of 2885-2666 cal. BC (GU-43937) and 3336-3023 cal. BC (GU-41721) (both at 95.4% probability) (J. Hambly *pers. comm*.). All dates were calibrated using IntCal13 (OxCal 4.3) (Bronk Ramsey 2009).

The burnt mound

Two radiocarbon determinations on heather (*calluna vulgaris*) charcoal are currently available for the use of the burnt mound, both of which derive from the accumulations of shattered stone and charcoal byproducts from the use of the burnt mound. The earlier date of 1660-1508 cal. BC at 95.4% probability (GU-36248) derives from the packing for the construction of a hearth cell south of the later well (which contained re-deposited burnt mound material). A second radiocarbon determination of 1297-1115 cal. BC (at 94% probability) (GU-36245) was yielded from burnt mound material which then accumulated in the hearth cell (J. Hambly *pers. comm*.).

The Bronze Age well

Radiocarbon determinations for bulk bone (783 cal. BC-536 cal. B (GU-37108)), various waterlogged seeds (58 cal. BC-cal. AD68 (GU-43930)), and thistle (*asteraceae*) (40 cal. BC-cal. AD87 (GU-37107)) recovered from the primary fills of the later well suggest that this well and burnt mound may have remained in use from at least the later Bronze Age and into the Early-Middle Iron Age (J. Hambly *pers. comm*.).

Windblown sand at Meur

Micromorphological samples were taken to further inform understanding of the archaeological and environmental sequences at the site, and revealed the occurrence of multiple windblown sand lenses (Figure 4.69). Four columns (A-D) were recovered from the north (A), centre (B and D) and south (C) of the eroding section respectively (Figure 4.70). A sondage was excavated into archaeological deposits to the south of the site beneath the burnt mound profile, with column C inserted into this section to recover early, pre-burnt mound sediments. The samples comprised a sequence of humic peat deposits and soil formation lenses, which contained very small, yet regular, lenses of marine sand - indicating that sand mobilisation and deposition took place at the site prior to the construction and use of the burnt mound (J. Hambly *pers. comm*.; Gardner 2017a, 12). The lack of smaller sand particle sizes suggests that they were moved from beachfronts by high-energy depositional processes (T. Dawson *pers. comm*.; Gardner 2017a, 12-16). These humic deposits yielded radiocarbon dates of 2472-2299 cal. BC (GU-36249) and 2475-2299 cal. BC (GU-36668) (both at 95.4% probability) from humic acid and humin fractions respectively, and provide some chronological constraint for the deposition of the windblown sands.

Figure 4.69. Sand lenses intermixed with burnt mound material at Meur. J. Hambly.

In column A to the north of the site, the unit above the basal unit of peat ash (Unit B) (representing burnt mound waste products) comprised aeolian sand and marine shell. Given that column A samples were taken from a deep sequence of burnt mound material (containing midden, peat ash and other fired materials), it can be inferred that sand deposition also took place during the use of the burnt mound and accumulation of the burnt mound materials (c. 810-540 cal. BC (GU-15746)), yielded on articulated unidentified mammal bone) (T. Dawson *pers. comm.*). Further lenses of sand were also observed during the excavation of burnt mound deposits in a cell to the south of the hearth and tank. A radiocarbon determination of 1297-1115 cal. BC (at 94% probability) (GU-36245) on heather charcoal from burnt mound material in the hearth cell south of the well offers a date for its accumulation.

Figure 4.70. Site section of Meur burnt mound showing location of micromorphology samples (in red). Reproduced with permission of J. Hambly

Prior to the construction of the burnt mound, diatoms and humified materials indicate that the immediate area was a waterlogged, and episodically brackish, basin. The brackish wetland is further indicative of the occurrence of high-energy storms depositing thin lenses of marine and beach sand, perhaps accompanied by episodes of small-flooding or transgression. The waterlogged environment would have also been an attractive prospect for the constructors of the burnt mound. This is attested to not only by the presence of a natural water source (a key prerequisite to the successful use and operation of a burnt mound), but by additional micromorphology and x-ray fluorescence which revealed that turves and subcoastal peat were employed as a key source of fuel (Gardner 2017b). Over time this basin dried and a period of soil formation, followed by increased anthropogenic activity, began (Gardner 2017a, 18-20).

The sequential appearance of the sand lenses in columns A and C may be indicative of a depositional sequence linked to seasonal activity at the burnt mound, a possibility which has been noted at the burnt mound at the Links of Noltland (Gardner 2017a, 20). The relatively large grain size is used by Gardner to suggest their deposition by high-energy winter storms. The relatively small lenses of sand, however, may be indicative of a relatively distant sand source, with most particles falling, and thus being deposited, closer to the source. Speculative augur survey undertaken by the author in the field behind the burnt mound revealed shallow sequences of topsoil and subsoil over glacial till, confirming that these sand deposits were not particularly extensive. Resultantly, it is suggested that the likely source for the sand is the beach at the Bay of Sandquoy, lying c. 500m south of the site.

4.8.3. Lopness

The site at Lopness lies to the far east of the Bay of Lopness, which stretches across the north-east neck of Sanday. The site was first identified during sampling of a palaeoenvironmental section containing blown sands and midden for OSL dating (Sommerville 2003). The site comprised an eroding burial cist (Figure 4.71) constructed from beach flags. It contained a crouched female inhumation within a midden fill comprising collapsed material which entered the cist after the capstone broke (Innes 2016, 5).

Figure 4.71. The remains within the Lopness cist. Inness 2016, 9.

Chronology and phasing

Radiocarbon dating of the human remains and a lamb femur within the cist (calibrated using OxCal3 (Bronk Ramsey 2009) indicate that the female was interred around the Early Bronze Age, with the remains (when the Carbon 13 effect is considered) dated to c. 1890-1520 cal. BC (AA43651 (GU9481) and AA51418 (GU10382)) (Innes 2016, 17 and Table 54).

Lab ID	**Sample**	**Years BP**	**δ^{13}C**	**Date cal. BC at 95% probability**
AA-43651 (GU-9481)	Skeleton: left femur	3520±40	-18.0%	1890-1750
AA-51418 (GU-10382)	Lamb bone	3320±50	-18.4%	1640-1520

Table 54. Radiocarbon dates from the Lopness cist. Innes 2016, 13.

A vertical cliff section was sampled for OSL and radiocarbon dating c. 2m north of the cist burial. The deposits reached a maximum height of 2m (Figure 4.72), and comprised 10 stratigraphic units although much of the contact was gradational. These units largely comprised windblown calcareous sands, as well as a palaeosol (Unit 2), and a midden deposit (Unit 1) over glacial till (Sommerville 2003, 90 and Table 55).

Unit	Dimensions	OSL sample	Description
10	Units 6-10: 1m total depth	<SUTL-884>	Fine grained sand, c. 60% shell. Lies beneath modern turf and topsoil.
9		<SUTL-885>, <SUTL-886>	Medium-fine sand with a reduction in shell content from 63% from the top to 51% at the bottom.
7			Medium-fine grained, homogenous sand
6		<SUTL-887>	Medium-fine grained sand, grading into a coarse-grained sand in Unit 7
-			Thin palaeosol
5	Units 1-6: c. 1m total depth	<SUTL-888>	Alternating bands of dark and light sand, 71% shell.
4			White, medium-fine grained sand, 46% shell.
3		<SUTL-889>	Darker, medium coarse-grained sand, 63% shell content 30cm
2		<SUTL-890>	Coarse gained sand, 57% shell content 20cm
1		(GU-9247, GU-9247A, GU-9248), <SUTL-891>	Deep midden containing bone, charcoal flecks, shell, and occasional sand lenses. This deposit overlay glacial till.

Table 55. Stratigraphic units, radiocarbon (GU-) and OSL <SUTL-> sample numbers at Lopness. Adapted from Sommerville 2003, 287. See (Figure 4.72) for unit dimensions.

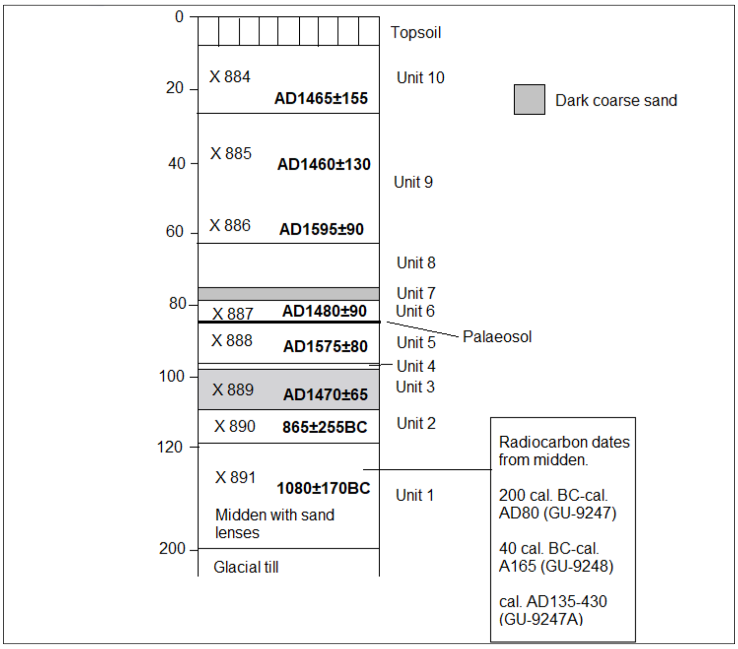

Figure 4.72. Section showing stratigraphic units, dimensions, OSL dates (in bold), and radiocarbon dates from the eroding section at Lopness. Adapted from Sommerville 2003, 91.

Windblown sand at Lopness

Eight samples for OSL dating and an additional three for radiocarbon dating were taken from an eroding section 2m north of the cist, in order to elucidate the chronology of the midden and sand accumulation (Sommerville 2008; Figure 4.72). Radiocarbon dating of marine shells and sheep bone from the midden, which was recorded by Inness (2016) as overlying the nearby cist, yielded ages which suggested that the uppermost portion accumulated from 200 cal. BC-cal. AD430 (GU-9247, GU-9247A, GU-9428). As the midden and the cist both overlay glacial till, the radiocarbon date for the cist inhumation (1890-1520 cal. BC) may provide a *terminus post quem* for the accumulation of the lower portion of the midden – if it is assumed to be the same midden.

Although the majority of the samples responded well to the laboratory irradiation process. the level of sensitivity varied. The reasons for this are discussed below. Resultantly, Sommerville suggests that the lower sands and sand lenses within the midden deposits <SUTL-890, 891> derived from a different source to that of the upper sand deposits. (Sommerville 2003, 242). As was also the case at Tofts Ness, modern beach deposits on Sanday (all of which were sampled by Sommerville) did not match the samples in terms of sensitivity, indicating that the original source for the sands may now lie offshore (Sommerville 2003, 283; 248).

Late Bronze Age OSL dates <865±255BC and 1080±170BC> were yielded for the samples within and above the midden deposit (<SUTL 890 and 891>) (Figure 4.72), which was dated by Sommerville to the Middle-Late Iron Age. This is problematic, and suggests a c. 500-year age discrepancy exists. Sommerville suggested that the older ages for the sands may be explained by two common errors, but did not conclude which date is more reliable;

1. Unbleached older sands were deposited over younger deposits, during darker conditions
2. The radiocarbon dates were underestimated if the marine reservoir effect was not fully considered.

The equivalent dose responses of the samples do not indicate that partial bleaching was a significant issue, and therefore Sommerville contends that the dates were not likely to have been overestimated. Although a marine reservoir effect (405±40 years) was applied before radiocarbon calibration of Sommerville's marine shell sample, the same was not applied to the sheep bone as the contribution levels of marine resources to the diet of the sheep was unknown. The samples for radiocarbon were collected from the uppermost portion of the midden deposit, and it is possible that the lower portion of the midden may have been deposited in the Bronze Age (Sommerville 2003, 289). Further radiocarbon sampling and age depth modelling throughout the stratigraphic units relating to the prehistoric period would help to resolve this issue.

The uppermost sand layers yielded Little Ice Age dates (c. 15^{th}-17^{th} centuries AD). Although there are some discrepancies in chronostratigraphic order of the samples, the dates lie within error of each other and therefore a weighted mean can be justified statistically (Sommerville 2003, 285). The upper sand layer yielded dates concurrent with sand deposition over a period of 200 years, from c. 15th-17th centuries AD. The weighted mean of the samples indicates a depositional date of c. AD1515±35 for the upper sand layers (Units 5, 6, 9, and 10; <SUTL-884-889>), and a Middle Bronze Age date of c. 1015±140BC for the lower sand layers (Units 1 and 2; <SUTL-890-891>) (Sommerville 2003, 287). The presence of occasional sand lenses in the midden suggest that small-scale sand incursions occurred during the accumulation of the midden, which may have taken place over a longer period of time.

The majority of recorded sand accumulation at this site therefore appears to have taken place during the Middle Bronze Age in the second millennium BC, and during the 16th century AD. The lack of OSL dates returned for sand movement in the Iron Age, Viking and Medieval periods at the site is likely to be due to the erosion of any intervening sand horizons which were not stabilised as rapidly as those deposited in the Bronze Age (if we are to accept the Bronze Age OSL date), and scouring of previous deposits during the Little Ice Age, when large-scale sand accumulations are recorded (Sommerville 2003).

4.8.4. Scar

The Viking boat burial at Scar is located to the north end of the eroding coastline of Burness, north Sanday. It sits within a low-lying area of sandy soils and windblown sand, noted to have been agriculturally-productive from at least the early Medieval period despite the landscape being frequently punctuated by episodes of sand mobilisation and inundation (Owen and Dalland 1999, 6-7). Excavation in the face of rapid erosion in 1991 revealed a Viking boat burial cut into calcareous windblown sand (Figure 4.73) with the remains of three individuals, a possible boat noost, the remains of a wall, and two gullies. The wall, gullies and boat noost all predated the burial, and were inundated with windblown sand in the Late Iron Age-Pictish period.

Figure 4.73. Scar boat burial, inserted into windblown sand. Historic Scotland Archive SC 723669

Chronology and phasing

The earliest investigated deposits in the trench at Scar comprised 0.05-0.15m of greyish-white calcareous sand, followed by 0.25-0.30m of brown calcareous sand. Both overlay natural boulder clay. The white sand was formed by successive episodes of windblown sand deposition, whilst the brown deposit may represent a buried, and more stabilised, ground surface with more organic, loamy inclusions (Owen and Dalland 1999, 23). This ground surface was cut by the later boat burial. To the east of the eroding section, a structure comprising of flattish, rounded stones and two parallel walls was observed but not fully excavated. This appeared to represent the remains of an elongated building which may have functioned as an earlier boat noost. The western side of this feature was cut by the pit containing the boat burial. This 'noost' collapsed and become covered by the white windblown sand later cut by the boat burial pit (Owen and Dalland 1999, 24).

Greyish-white windblown sand – comprising multiple layers and lenses indicative of repeated accumulations and stabilisations as opposed to a single deposit - covered the remains of the structure. A north-west aligned stone wall was exposed in the southern extension of the trench, on the windblown sands which overlay the structure. The upper courses of the wall had collapsed, with the toppled stones lying north of the wall within a sandy matrix, with a further layer of windblown sand accumulating above and around it. The grave pit also cut through these deposits (Owen and Dalland 1999, 25).

Four radiocarbon determinations were produced for the site (Table 56), calibrated using OxCal v.3 (Bronk Ramsey 1995). Bulk cattle bone from the rubble deposit yielded a Late Iron Age-Pictish radiocarbon date of cal. AD435-650 (GU-3825) at 93% probability for the collapse of the stone wall. Three human skeletons yielded Norse dates of cal. AD970-1260 (AA-12595), cal. AD880-1130 (AA-12596) and cal. AD730-1020 (GU-12597) at 93% probability. Although the excavated evidence indicated that the three individuals were interred at the same time, significant variation can be noted between the radiocarbon determinations. The numerous reasons for this are discussed in Owen and Dalland (1999, 162-5) and are not rehashed here. These determinations produced a weighted mean date of c. cal. AD895-1030 (AA-12595-97) for the three human skeletons from the boat burial (Dalland in Owen and Dalland 1999, 162-3) and it was concluded by the excavators that the field data, artefactual evidence and chronological data should all be considered together. They estimated that the grave most likely dates to the late ninth century and mid-tenth century but acknowledge that a still later date could be plausible (Owen and Dalland 1999, 165).

Lab ID	**Sample**	**Calibrated date cal. AD at 95% probability**
GU-3825	Bulk cattle bone	435-650
AA-12595	Juvenile skeleton	970-1260
AA-12596	Male skeleton	880-1130
AA-12597	Female skeleton	730-1020
Combined age of skeletons		895-1030

Table 56. Calibrated radiocarbon determinations from Scar. Owen and Dalland 1999, 162.

The radiocarbon determinations demonstrate an age difference between the wall and the burials of c. 430±70 years. The presence of an existing mound comprising this rubble and accumulations of windblown sand may have proved to be an attractive prospect for the diggers of the boat burial, and may have stood as a 'readymade' grave marker (Owen and Dalland 1999, 25). Following its deposition within the pit, a roof-like structure was constructed over the boat burial, forming a chamber. The boat burial was infilled and covered with flagstones. Within a century of burial, medium-coarse grained calcareous sand (200-400μm) filtered into this chamber, blanketing the human remains and their grave goods. These deposits comprise five calcareous windblown sand layers which varied in colour and inclusions, with more sands filling the gap between the boat and the burial pit. Molluscan assemblages from the sand deposits pre-dating the boat burial and those which infilled it attest to an open, sandy grassland environment (Carter in Owen and Dalland 1999, 217-9). At some point following the filtering in of the sands, the roof for the chamber collapsed. Apart from some evidence for the presence of otters, the boat burials appeared to have been relatively undisturbed until its more recent partial destruction by marine erosion, which led to its eventual discovery.

Windblown sand at Scar

The earliest deposits at the site attest to the presence of an extensive sandy landscape prior to the interment of the boat burial. The pit for the boat burial was cut through c. 0.5-0.15m of greyish-white calcareous sand and 0.25-0.30m of brown calcareous sand, which had accumulated around an earlier wall. This wall later collapsed, after which further calcareous windblown sands accumulated above it (no dimensions stated). Molluscan data from these sands confirmed the existence of a sandy, open grassland environment typical of many sandblow sites (Carter in Owen and Dalland 1999, 217-9). Cattle bone from the post-collapse wall rubble yielded a radiocarbon date of cal. AD435-650 (GU-3825) at 93% probability. This date offers some constraint for the accumulation of the sands at Scar, both before and after the boat burial was interred. While the early sands must have accumulated before cal. AD435-650 (GU-3825) when the wall collapsed, the sands which accumulated over the wall after its collapse must have done so *after* this date and before c. AD895-1030 (AA-12595-97), the approximate weighted mean date for when the boat burial – which cut these sands – was interred.

Sand continued to be mobilised following the burial of the boat in c. AD895-1030. The excavators estimate that within a century of its burial, windblown sands filtered through the capping and into the boat's chamber. At least five layers of sand (each differing in colour and inclusions) were identified, indicative of multiple incursions of windblown sand (Owen and Dalland 1999,

Considering the site lies within an extensive covering of windblown sand deposits, which stretch from Otterswick Bay in the west, to Quoybanks in the northeast and to Whitemill Bay in the north, it is impossible to pinpoint the precise source for the windblown sands at Scar, which could have been mobilised for some distance. On analysis of sand grains observed between the caulking and timbers of the boat it was found that an Orkney, Shetland and northern Mainland Scotland beach provenance for the sand could be discounted. It is possible that the sand became trapped in the caulking during its construction, which perhaps took place in Scandinavia (Dixon in Owen and Dalland 1999, 224-5).

4.8.5. Discussion: windblown sand in North Sanday

The North Sanday windblown sand record is undoubtedly the most diverse in terms of site types, comprising settlements, funerary remains, agricultural remains, and a burnt mound which are fairly evenly dispersed between the east and west coasts. The fertile qualities and gentle topography of the island has long made this a popular settlement location, and it is unsurprising that such a diverse wealth of remains exists. Only four sites were discussed within the chapter, with the Early Neolithic site at Cata Sand, and the eroding mounds at Woo, Quoyness, Northskaill, and Newark summarised in

Appendix 1. The decision was made to split Sanday into two investigative areas in order to explore key differences between the archaeology of windblown sand deposition in two diverse geomorphological contexts. While North Sanday is categorised by its extensive windblown sand deposits covering large swathes of the landscape, the south contains smaller, discrete pockets of sand and fewer recorded sand sites. Further rationale for this is articulated in Chapter 5.

As well as being diverse in type, the sites and their sand deposits are also diverse in date. The earliest securely-dated windblown sand deposits in North Sanday were those at Meur, having accumulated in the Middle-Late Neolithic at c. 2475-2299 cal. BC (GU-36668) during the use of the early well. There then followed a series of extensive windblown sand events across the Tofts Ness peninsula from at least c.1880-1600 cal. BC, and down into the Bay of Lopness at c. 1015±140BC. Sand continued to move through the Iron Age at Tofts Ness, at which point the prehistoric landscape appears to have been abandoned as it became a sand-dominated environment.

Sand accumulated at Scar before (from c. cal. AD435-650 (GU-3825)) and after (from c. cal. AD895-1030 (AA-12595-97)) the Viking ship burial in the dunes. The latest sand deposits were recorded at the Northskaill farm mound (Appendix 1), with sand playing a key role in its formation from c. cal. AD1040-1280 (SRR-2352)-cal. AD1290-1430 (SRR-2353), and again the Bay of Lopness in c. AD1515±35 <SUTL-884-889>). The island stands out in that it has received considerable attention from a PhD project seeking to establish OSL dating as a key means of dating windblown sands (Sommerville 2003). This project demonstrated varying levels of success, and it became clear that the method required further testing. This became one of the key aims of the field project at Pool, described in Chapter 5.

Chapter 5. Fieldwork at Pool, Sanday

After developing the dataset described in Chapter 4 (and Appendix 1), the multiperiod archaeological site at Pool, Sanday was selected to investigate in more detail to aid in answering the research questions and aims set out at the beginning of the project. Financial and time constraints ensured that from the outset this field project was designed to be speculative, with the intention of recovering preliminary data to better-inform future field projects beyond the scope of this thesis.

5.1. Site selection and relevance of fieldwork to the wider project

Several factors influenced the selection of Pool as a case study. It is a previously-excavated site with a long history of occupation, located in a dynamic landscape in terms of coastal process and evolution. Two thin sand layers (Figure 5.1) were recorded in the excavated part of the site. They appear to have been deposited in relatively quick succession across the excavated area, during the Neolithic period (Hunter, J. *et al.* 2007, 27; Macsween *et al.* 2015). Occupation at Pool was wholly or partially contemporary with other sites (such as Links of Noltland, Westray, and Tofts Ness, Sanday), which experienced multiple, more extensive episodes of sand deposition across the Neolithic-Bronze Age periods. The top of a peat deposit to the south of Pool, dated by the original excavators (Hunter, J. *et al.* 2007), indicated that prehistoric peat development was inhibited by the deposition of a further deposit of windblown sand in the Late Iron Age (Bond, J. in Hunter, J. *et al.* 2007, 170). This sand was deposited in the immediate landscape during the occupation of the settlement (Phase 6) – and yet, no evidence for this sand was identified by Hunter in the Phase 6 excavated areas. This presented an interesting problem warranting further exploration. Augur transects in 2014 also revealed other deposits of calcareous windblown sand not identified or explored by Hunter.

Figure 5.1. East-facing section at Pool, showing the two sand layers excavated by Hunter, J. et al. (2007). After Macsween et al. 2015, 6; Figure 4.

Sand deposition and problems of chronology

The Neolithic sand deposits at Pool were identified on the site during the original excavations; it was hoped that during this thesis field project this sand – and its extent – could be identified within the landscape, to develop a better understanding of the physical and visual impacts of this deposition. The deposition of the sands had been dated to various points in the Neolithic period by Hunter, J. *et al.* (2007) and Spencer, J. Q G., and Sanderson (2012) (both by thermoluminescence (TL) dating), and more recently by Macsween *et al.* (2015) (using radiocarbon dating and Bayesian modelling). None of these dates relate directly to the sand deposits. Rather, they provide constraints by dating the occupation deposits above and below the sand.

The original dating (published in the site monograph) for the Neolithic phases at Pool was problematic due to the lack of suitable material available for radiocarbon dating. Thermoluminescence dating of pottery from contexts bracketing the sand was therefore employed, constraining the deposition of the lower (earlier) sand layer to c. 3710±145 BC-3544±157 BC, and the upper (later) sand layer to 3544±157 BC-2192±65 BC (no lab codes available) (Hunter, J. *et al*. 2007, 61). Further TL dating on pottery from the bracketing deposits was undertaken by Spencer and Sanderson (2012). Weighted mean dates constrained the deposition of the lower (earlier) sand to between 3889±303BC <SUTL-75a, 78a, 79, 82, 83> and 3606±282BC <SUTL-26, 27, 30, 35>, and the upper (later) sand to between 3606±282 BC and 2162±133 BC <SUTL-11-13, 15-17, 20> (Spencer and Sanderson 2012, 3548-9).

Radiocarbon dating and Bayesian modelling of the occupation deposits bracketing the sands was later undertaken by Macsween *et al.* (2015). This model constrained the deposition of the lower (earlier) sand to before 3210-2935 cal. BC (*start Phase 2.2–2.3*), and the upper (later) sand to between 2815-2650 cal. BC (*end Phase 2*) and 2680-2515 cal. BC (*start Phase 3*) (Macsween *et al.* 2015, 15; Figure 9. These dates and how they compare are summarised in Table 57. More detail on phases of activity at the site can be found in section 5.4.

Phase	**Activity**	**Hunter, J. *et al.* 2007 weighted mean TL (lab codes unavailable)**	**Spencer and Sanderson 2012 weighted mean TL**	**Macsween *et al.* 2015 radiocarbon, at 95% probability**
3.2.	Structures			2510–2395 cal. BC (*end 3.1/start 3.2*) to 2460–2280 cal. BC (*end Phase 3*)
3.1.	Dark tips, structures	2235±262		2680–2515 cal. BC (*start Phase 3*) to 2510-2395 cal. BC (*end 3.1/start 3.2*)
2.3.	Reddish-brown tips and structures	2255±140-2192±65	2162±133 <SUTL-11-13, 15-17, 20>	Phases 2.2 and 2.3 merged by Macsween *et al*. 3210–2935 cal. BC (*start Phase 2.2-2.3*) to 2815–2650 cal. BC (93% probability; *end Phase 2*)
	Sand (upper, later)			
2.2.	Reddish-brown tips	3544±157	3606±282 <SUTL-26, 27, 30, 35>	
Sand (lower, earlier)				
2.1.	Reddish-brown tips	3710±165	3889±303 <SUTL-75a, 78a, 79, 82, 83>	
1.2	Structures			
1.1	Dark tips over till	3643±145		

Table 57. TL and radiocarbon dates for the Neolithic phases at Pool. After Hunter, J. et al. 2007, 61; Spencer and Sanderson et al. 2012; Macsween et al. 2015.

There is some disagreement between these dates, although all seem to confirm a Neolithic date for the deposition of the sands. Resultantly, it was decided that as part of this fieldwork project, an attempt would be made to directly date the sands using OSL

(Optically Stimulated Luminescence) to contribute to this chronology and to see if any resolution or confirmation could be offered. This was also a means of further testing the efficacy of the OSL dating method on windblown sands, which produces varying levels of success in the Northern Isles (see Chapter 4 and Appendix 1). It was decided that OSL determinations would first be generated for the sands deposited at the site itself. These results would then inform the level of confidence for this dating strategy for the rest of the sands encountered in the 2014 augur survey within the wider landscape. If the OSL samples for the sands yielded a low error Neolithic date, this would provide some confidence for the rest of the OSL dating strategy.

Further rationale

Previous research on episodes of sand movement on Sanday (Sommerville 2003; Sommerville *et al.* 2007) was undertaken at the north of the island, at Tofts Ness and Lopness. This fieldwork provides a comparable dataset for an area which varies geomorphologically. The south and west are generally rockier with more isolated patches of blown sand and dunes. The landscape of Pool is described as being fertile and sandy (Bond, J. in Hunter, J. *et al.* 2007, 170), while that of Tofts Ness is described as marginal and acidic due to peat growth (Dockrill *et al.* 2007), with larger swathes of machair pasture. A more developed dataset would enable chronological and morphological correlations to be drawn between the different sites, and highlight the conceptual distinctions made by the excavators.

As discussed at the outset of this work, one of the aims of this thesis was to advocate for a mixed-methods approach to the study of prehistoric sand movement which went beyond previous interpretations of marginality and catastrophe. It was intended that aspects of this study at Pool could be utilised to test this approach. This targeted investigation has been undertaken to answer Research Question 4 (Did coastal sand movement have a notable impact on settlements?) and to test the efficacy of a geoarchaeological approach and how it can be incorporated with excavated data and the interpretations of the excavators. In this way the relative usefulness and contribution of each method can be assessed in the hope that it will clearly demonstrate that an integrated approach using local-scale investigation is crucial to an understanding of the relationship between environmental change and social change. Detailed field project aims are located in 5.3.1.

It has been lamented that a successful and transferable field methodology for excavation and sampling on sand sites has been slow to emerge (Griffiths, D. 2015, 112), and it was hoped that this field project would contribute to the development of a distinctive field methodology. The site presented an opportunity to undertake a mixed-method field approach which combined chronological control in the form of radiocarbon and Optically Stimulated Luminescence Dating (OSL) with wide-area geophysical survey to identify environmental deposits and targeted sampling, as advocated by Griffiths and tested on landscape-scale surveys at the Bay of Skaill (Sandwick) (Griffiths, D. 2015, 112-5; Griffiths, D. *forthcoming*).

5.1.1. Site location and palaeolandscape context

The site is located at Pool Bay (Figure 5.4) on the south-west coast of Sanday, on the eastern edge of the Eday sandstone beds. The site comprises a large, deeply-stratified settlement mound which rises prominently within the low-lying coastal plain (Figure 5.5). The site has previously undergone significant coastal erosion, with a visible exposed coastal section which reaches up to 3m in height. Evidence of occupation spans the Neolithic to Late Norse period, although not continuously, with an episode of sand deposition during the Neolithic occupation on the site. The site itself lies in a bay to the north of an area of wet, boggy pasture (Figure 5.5), reflected in place names including North, South and West Mire (Lamb, R. G. 1980, 82). An immediate contrast can be noted between north and south Sanday in that while north Sanday is covered by extensive sands, the sands at the south of Sanday are far more discrete, lying in patches between more extensive clays and gravels (Figure 5.2).

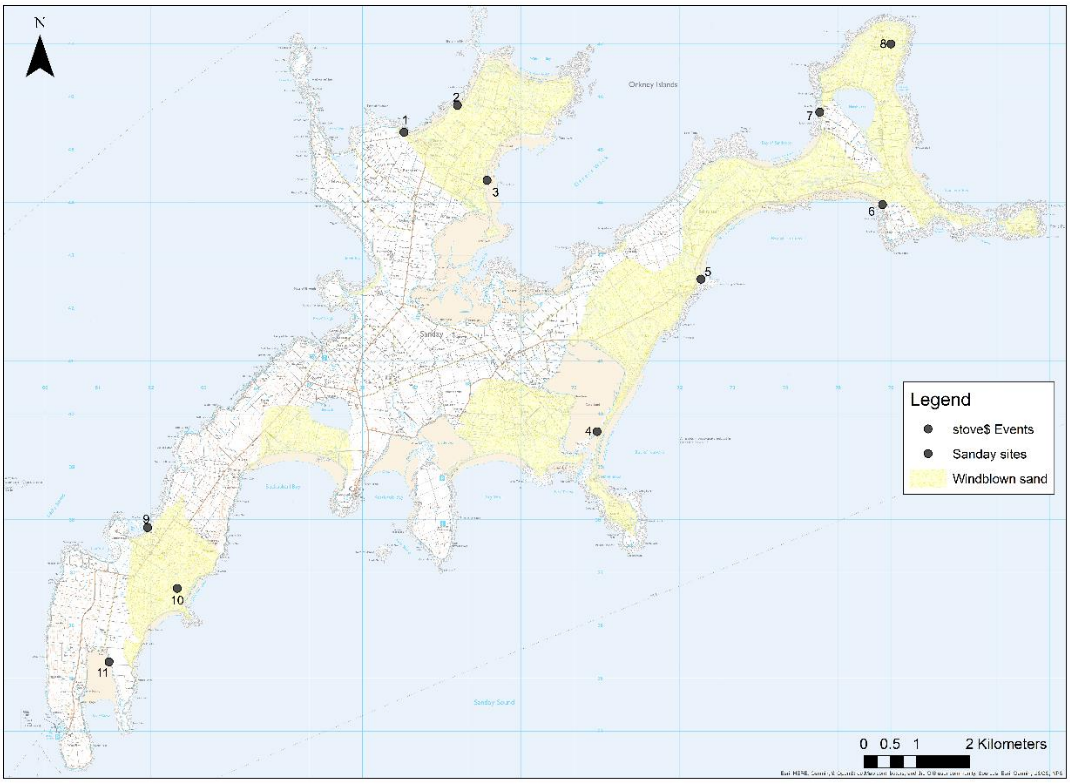

Figure 5.2. Sanday sites mentioned in the text and Appendix 1. 1. Woo; 2. Scar; 3. Northskaill; 4. Cata Sand; 5. Lopness. 6; Long Taing of Newark; 7. Meur; 8. Tofts Ness. 9. Pool; 10. Quoy Ness. 11. Stove.

The backslope of the hill behind the settlement comprises a moving dune system (Mather *et al.* 1974, 96-7; Bond, J. in Hunter, J. *et al.* 2007, 170-1), and calcareous sand outcrops onto the shingle beach in the bay (Figure 5.3). It lies within a relatively discrete band of windblown calcareous sand stretching across the steeper slopes up to Balfoursbrae, before widening out into the bays between the geos at the Croos, Quoyness, and Quoy Grew. These sands are discussed further in 5.7. Pool Bay lies northeast of the more sheltered Braeswick Bay (Figure 5.4), from which it is separated by the neck of land at Laminess. Braeswick lies outwith the body of windblown sand described above. Preliminary auguring at Braeswick undertaken by the Rising Tides project in early 2015 revealed the presence of thick peat sequences (reaching c. 0.45-0.50m in depth) in both the lower and higher-lying areas (Bates 2015, 8). The immediate landscape is therefore noted for its contrasts and discrete nature of the deposits, the significance of which will be discussed further.

Pool is similar to other settlements with Neolithic phases in the Orkney archipelago including Skara Brae, Knap of Howar, Bay of Stove and Tofts Ness, in that it lay close to a (now impounded) loch or freshwater body. This appears to indicate a preference for settlement in low-lying, coastal landscapes with access to multiple environmental niches and water sources during the Neolithic period. An eroding, humified peat-filled basin to the south of the site at Pool is indicative of the former existence of this freshwater loch, which may have had a shingle bar at its mouth. The top of a peat deposit overlain by calcareous windblown sand yielded a determination of cal. AD530-670 (GU-2545) at 93.7% probability (Bond, J. in Hunter, J. *et al.* 2007, 170), indicating that peat growth here was inhibited by windblown sand deposition during the late Iron Age.

Figure 5.3. Calcareous sand deposits outcropping on the Pool Bay foreshore. R. Bates.

Figure 5.4. The location of the archaeological site in its landscape context, with the extent of windblown sand deposits marked.

Figure 5.5. Pool in its wider boggy landscape setting. The mound can be seen to the left of the figure in the foreground, highlighted in the yellow box.

5.1.2. The archaeological site and history of excavation

First identified as an eroding coastal mound by Raymond Lamb in the 1970's, the site was recorded in the RCAHMS Inventory for Sanday (Lamb, R. G. 1980). Spanning c. 65m in length and c. 2-3m in height, its large and material-rich erosion face featuring middens, pits, hearths and structures, was noted as being of particular significance (Lamb, R. G. 1980; Hunter, J. *et al.* 2007, 9). Excavations from 1983-1988 by John Hunter and the University of Bradford revealed a complex and long-lived multiperiod site with evidence of occupation from the Neolithic through to the Norse period. The radiocarbon dating evidence for occupation at the site has recently been reviewed and expanded as part of the Times of Their Lives (ToTL) project (Macsween *et al.* 2015), which aimed to develop more precise chronologies for key periods during the European Neolithic.

5.1.3. The eroding section

The deposits in the eroding section comprise bedrock and sandy till below two distinct stratigraphic bands (Figure 5.6). The first, overlying the bedrock, comprises sandy-reddish brown deposits consisting of peat ash with at least one orange sand horizon which separates the first deposit from a second, of darker reddish tip-like deposits and lenses. Stone structures in this band are associated with Neolithic round-based and Grooved Ware pottery. A larger, darker deposit with midden layers and stone walling and flagged flooring lies above, containing a complex of Iron Age structures which were later remodelled and adapted in the Norse period (Hunter, J. *et al.* 2007, 11; Macsween *et al.* 2015, 4). This forms the second distinct stratigraphic band. During excavation, however, *two* sand layers were observed by the Hunter, which apparently subdivided Neolithic Phases 2.2 and 2.3. The sand deposits to have taken place during two singular sandblow episodes, as opposed to a gradual accumulation (Hunter, J. *et al.* 2007). On inspection of the eroding section during the fieldwork for this project, only one sand layer could be clearly visually identified by the author, although a possible location for a second layer is suggested (Figure 5.6).

The original excavations were undertaken under a rescue remit given the continued erosion of the site, which is exposed to gales from the northwest (Hunter and Dockrill 1982, 37). Using the depth of in-section deposits and with the hindsight of excavation, it was estimated that at least c.30m of the original site had been eroded by the sea by the time of excavation, comprising approximately 40% of its original size (Hunter, J. *et al.* 2007, 11). Although no timescale for this erosion process was offered by the excavator, the rate of erosion was described at the time as "alarming" (Hunter and Dockrill 1982, 37). Erosion currently seems to be relatively stabilised with little impact from non-extreme weather events (C. Parker *pers. comm).* A contour survey undertaken in 1981 (Figure 5.7) estimated the apex of the surviving mound to be slightly less than 8m OD with irregular dimensions, broadly sub-circular with a diameter of 70-80m. Archaeological remains to the northeast of the mound, and smoothing of the contours by modern ploughing, complicate this estimation (Hunter, J. *et al.* 2007, 11).

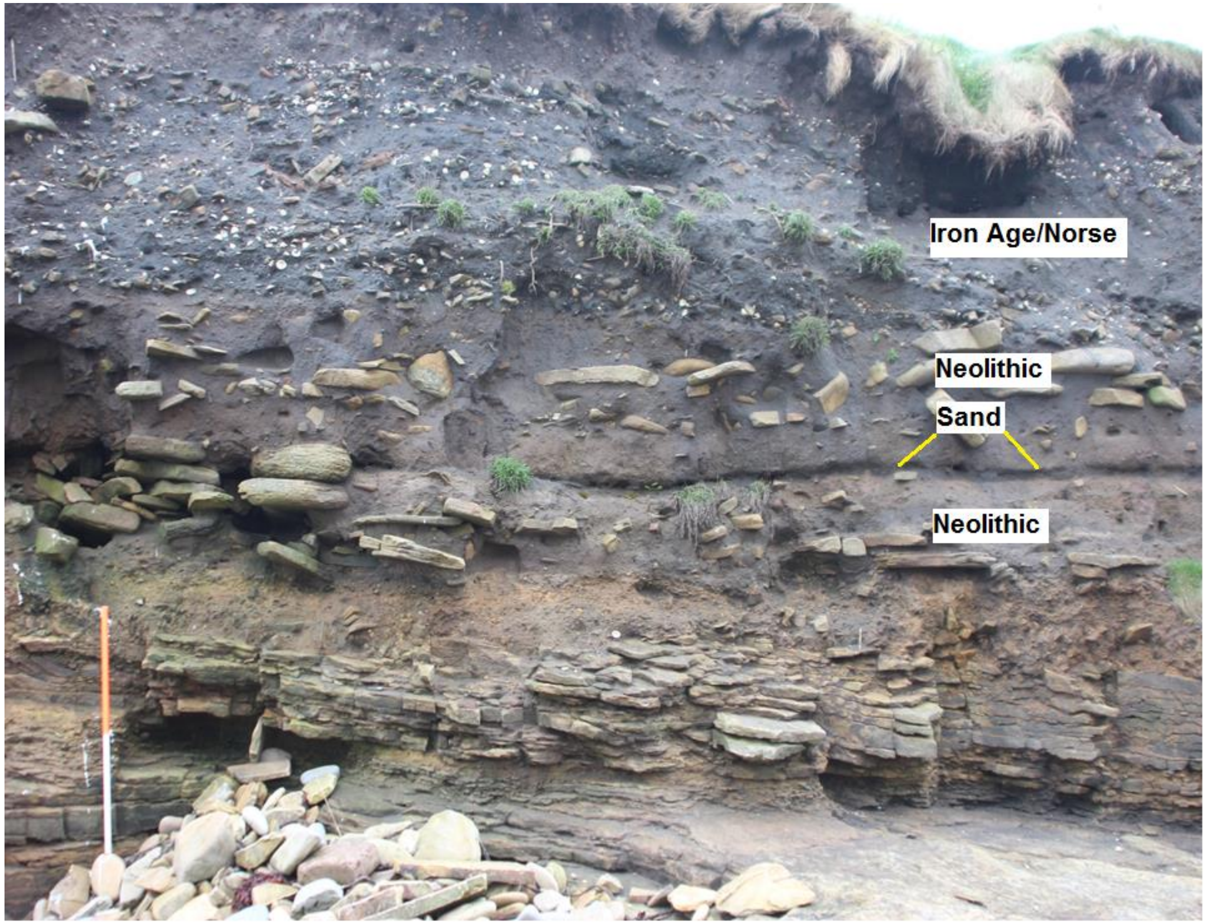

Figure 5.6. Stratigraphic horizons visible in the eroding section at Pool.

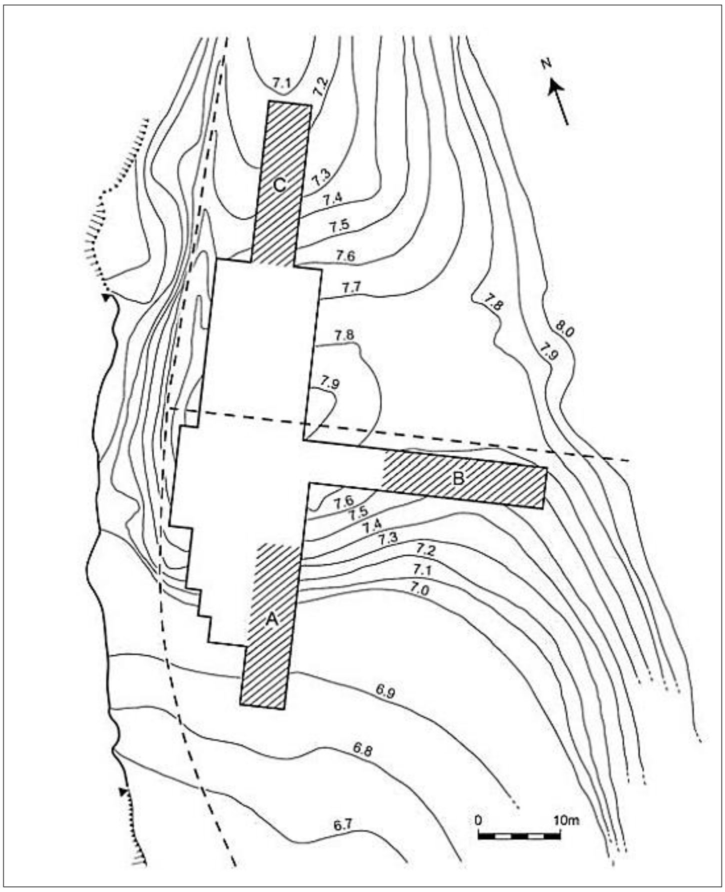

Figure 5.7. Contour survey with trench location. Hunter, J. *et al.* 2007, 17

5.2. Site phasing and chronology

This section summarises the stratigraphic phasing at Pool as interpreted by the original excavators (Hunter, J. *et al.* 2007). Both thermoluminescence (TL) and radiocarbon (C14) dates were commissioned during Hunter's excavations, with results demonstrating varying degrees of accuracy and success. The stratigraphic discussion within the 2007 report has been described as an 'interpretative narrative' as opposed to a systematic stratigraphic account (Macsween *et al.* 2015, 13). The dating of Neolithic phases of the site has recently been revisited by the Times of Their Lives project, and published by Macsween *et al*. (2015). It was during this reinvestigation that contradictions between Hunter's and Macsween *et al.*'s chronologies were identified.

Using a chronological model based on the 60 TL dates yielded on pottery from the Neolithic phases of the site (Model B, with outliers removed) (Table 58), Hunter *et al*. proposed that Neolithic occupation at Pool lasted from the early-mid 4th millennium BC through to the end of the 3rd millennium BC. This model placed the beginning of Grooved Ware use and associated activities at c. 3710±165 BC (no lab codes) (Hunter, J. *et al.* 2007, 61; Table 3.2); an early date for this phenomenon (Macsween *et al.* 2015, 11).

Problems with anomalous fading of feldspars in the thermoluminescence process are now well recognised as producing dates which hold a younger bias (R. Robinson *pers. comm.*; Duller 2008). Resultantly, it appeared that Hunter's dating of the beginning of Grooved Ware activity is slightly problematic in that it is notably early (Macsween *et al.* 2015). Unless otherwise stated, all radiocarbon determinations published by Hunter *et al*. were calibrated using curves developed by Reimer *et al*. (2004), and OxCal 3.10 (Bronk Ramsey 1995). Those published by Macsween *et al*. (2015) use IntCal13 (Reimer *et al*. 2013) and OxCal 4.2 (Bronk Ramsey 2009).

Phase	Samples	Model A	Model B
3.1	10	1468±262	2235±262
2.3b	10	2359±242	2255±140
2.3a	10	1868±173	2192±65
Sand			
2.2	10	2741±276	3544±157
Sand			
2.1	10	2796±395	3710±165
1.1	10	3242±312	3643±145

Table 58. Weighted mean TL dates for the Neolithic phases at Pool. After Hunter, J. et al. 2007, 61.

5.2.1. Phasing

After Hunter, J. et al. 2007

Phases 1-3: Neolithic. From the early-mid 4th millennium BC through to the end of the 3rd millennium BC (Table 59)

Phase 1

1.1. Dark tips comprising sand, midden and burnt organic material, overlying till.

1.2. Structures 1-3, S1 being earliest and S3 being latest, superimposing each other. All partially-surviving sub-circular structures, likely to have been backed with turf. These deposits contained round-based pottery sherds, with bioarchaeological evidence for herding of domesticates, and cultivation (Bond, J. in Hunter, J. *et al.* 2007). The dark tip deposits have been interpreted as structural components used as fills between casing walls.

Phase 2

2.1. Reddish-brown midden and tips, comprising ashy hearth deposits with pits and stone spreads, but no observable structures. The Phase 2.1 deposits are separated from Phase 2.2 by a layer of orange mineral sand extending across the trench and measuring c. 0.10-0.12m in depth, interpreted by Hunter, J. *et al.* as aeolian in origin (2007, 516).

2.2. Reddish-brown midden and tips overlying the first sand. These Phase 2.2 deposits are separated from Phase 2.3 deposits by a further layer of orange mineral sand extending across the trench and measuring c. 0.10-0.12m in depth.

2.3. Reddish-brown tips (from which two radiocarbon samples were retrieved; Table 59) and structures overlying the second sand. Structures 4-6. S4: cell-like building. S5: stratigraphically earlier than S4. A spread of flagged rubble. S6: partially excavated, sub-circular structure. Environmental evidence indicates an increased exploitation of the landscape and a change in crop species from naked to hulled barley.

Lab ID	**Sample material and context**	**Calibrated age range in cal. BC at 95% probability**
OxA-959	Phase 2.3, willow twigs from tips c. 1m below surface	3350-3200
OxA-947	Phase 2.3, willow twigs from tips c. 1m below the surface	3340-2870

Table 59. Radiocarbon determinations from Pool Phase 2.3.

Phase 3

3.1. A dark midden matrix, with hearth deposits and structures from which three radiocarbon dates were recovered (Table 60). Midden deposits were utilised not only as casing wall infills (which included deposited artefacts and bone) but as external surfaces where butchery took place. The change in midden colour and material may indicate a change in fuel sources (Hunter, J. *et al.* 2007, 73; see also Spencer and Sanderson 2012). Structures 7-13 comprise sub-circular buildings in varied states of preservation and a range of sizes, from large, substantial structures with focal hearths to ephemeral single faced structures. Structures 8 and 9 are paired. The phase 3 pottery style, technology, decorative technique and motifs contrast markedly with those from previous phases. It is during this phase that the widespread adoption and use of Grooved Ware becomes notable.

3.2. Structure 14. A sub-circular platform was all that remained of this structure. However, it was excavated, faced and reoccupied during the Iron Age, thereby forming a central and significant focus for settlement thereafter (Hunter, J. *et al.* 2007, 58).

Lab ID	**Sample material and context**	**Calibrated age range in cal. BC at 95% probability**
OxA-946	Phase 3.1, willow twigs from midden c. 2m from surface	3350-2920
OxA-960	Phase 3.1, willow twigs from midden c. 2m from surface	3350-2920

GU-2242	Phase 3.1, willow charcoal from midden c. 2m from surface	2850-2800

Table 60. Radiocarbon determinations from Pool Phase 3.1.

Phase 4

‘Abandonment’, or cessation of activity at the site, perhaps for as long as two millennia (covering the Bronze Age and earlier Iron Age). A narrow transition stratum into the later Iron Age is represented by pink former turf horizons indicating abandonment. It may be that this phase can be divided into two portions: a Neolithic abandonment (4.1) and later small structural events (4.2).

Phase 5

Poorly-preserved primary Iron Age occupation, dated by five thermoluminescence (TL) dates on ceramics with a weighted mean of 240±70AD (Table 61).

5.1. Paired structures (15 and 16) constructed into Neolithic midden remains.

5.2. Addition of structure 17, perhaps after an interval of abandonment given its construction upon a developed turf horizon. Heavily deconstructed later in the phase.

Lab ID	Phase	Date BC
SUTL-60	5.2	280±180
SUTL-61	5.2	320±130
SUTL-62	5.2	80±180
SUTL-63	5.2	380±130
SUTL-64	5.2	180±140

Table 61. TL dates from Phase 5. Hunter, J. et al. 2007, 530

Phase 6

Later Iron Age settlement, with construction of cellular buildings to form a nucleated settlement with frequent remodelling episodes. Six radiocarbon determinations indicate duration from the 3rd-8th centuries cal. AD (Table 62).

6.1. Structures 18 and 19 (paired unit akin to structures 15 and 16 (above) and with an early parallel at Sumburgh Airport, Shetland (Downes and Lamb 2000) which were to form the basis for the remainder of Iron Age settlement at Pool. There may have been direct continuity between structure 18 and structure 15.

6.2. Expansion developing from structure 18. Major interior reorganisation, and construction of cellular structures 20-22.

6.3. Changes to connections and passageways between units, formalising of structures 20-22 and decrease in importance of Structure 18.

6.4. Construction of structure 23, a long rectangular building replacing structure 22. A substantial focussing effect which altered prescribed movement.

6.5. Construction of revetments to midden at south of site to form a c.10m x 10m heart-shaped enclosure, with continued midden deposition. A large area of slabbing surrounded, allowing paved access from one side of the complex to the other. Further decline of Structure 18, and evidence for disuse of Structures 19 and 20.

6.6. Significant shift in spatial arrangement of site. Blocking of certain entrances and reflagging e.g. Structure 18. Activity restarts in Structure 19.

6.7. Increased contraction and decline of later Iron Age settlement. Further modification with final configuration of the Iron Age settlement represented by Structures 18 and 23.

Lab ID	**Sample material and context**	**Calibrated age range in cal. AD at 95% probability**
GU-2244	Phase 6.3, cattle bone from tips associated with structures 20-22	200-800
GU-2243	Phase 6.4, cattle bone from Structure 23 tips	210-660
GU-1999	Phase 6.6, cattle bone from midden (location unknown)	420-640
GU-2000	Phase 6.7, cattle bone from midden (location unknown)	430-660
GU-1809	Phase 6.7, cattle bone from a midden layer overlying a domestic floor.	600-820
GU-2001	Phase 6.7, cattle bone from a midden layer	610-870

Table 62. Radiocarbon determinations from Pool Phase 6.

Phase 7

The ‘interface’ period, described by Hunter as a “working guide” to the interface between native and Scandinavian cultures (Hunter, J. *et al.* 2007, 122). Iron Age/Pictish traditions continue to persist in the face of an increasing and dominating Viking culture. Significant structural remodelling took place in Phase 7. Nine radiocarbon determinations were yielded for this phase (Table 63), indicating a settlement duration of 5th-9th/10th centuries cal. AD.

7.1. Continued occupation at the south of the site in Structure 18 – the nucleus of the Iron Age settlement - and construction of subrectangular Structure 25 to the north of the site.

7.2. Encroachment of Scandinavian structures in the southern area of the site, with Structure 18 becoming subsumed, and Structure 25 falling out of use. Construction of Houses 26-8.

Lab ID	**Sample material and context**	**Calibrated age range in cal. AD at 95% probability**
GU-1998	7.1, cattle bone from midden	430-650
GU-2002	7.1, willow charcoal from midden	660-890
GU-2004	7.1, willow charcoal from midden	650-880
GU-1807	7.1, mixed animal bone from Animal bone from a stone-sided pit in a loam midden.	710-1050
GU-1810	7.2, dung from midden/loam layer below Structure 25.	660-880
GU-2003	7.2, cattle bone from Animal bone from midden layer stratified in a sequence in Structure 25	690-980
GU-2241	7.2, willow charcoal in a layer associated with a late Norse long-house.	710-970
GU-2006	7.2, cattle bone Animal bone from a midden layer stratified in a structural sequence.	710-990
GU-2005	7.2, mixed animal bone from a midden layer stratified in a midden sequence.	810-1030

Table 63. Radiocarbon determinations from Pool Phase 7

Phase 8

Norse settlement. Two radiocarbon determinations were yielded for this phase (Table 64), which commenced in the 10th century cal. AD, directly after Phase 7 with no discontinuity identified, and ended in the late 13th century cal. AD

Reorganisation of the settlement, during which time its character changes to become almost entirely 'Norse' in nature. Activity centres predominantly around Structure 29 and associated structures.

8.1. Phase of reorganisation and preparation for the construction of Structure 29, a NE-SW oriented Norse longhouse displaying similarities with Skaill Deerness House 3 (see Chapter 4; Buteux 1997). Large parts of the preceding Iron Age structures were infilled and consolidated, with the southern areas of the settlement becoming covered with black midden. A small hiatus of unknown duration between 8.1 and 8.2 is then evident, when occupation probably continued outwith the excavated area.

8.2. The construction and evolution of Structure 29. 8.2 has been further subdivided into Phases 8.2.1, 8.2.2, and 8.2.3, during which a number of changes to the shape of Structure 29 took place. During 8.2 diagnostic material culture became almost entirely Scandinavian in character with the exception of the pottery assemblages which continued to include Iron Age pottery which Hunter argues were not residual (Hunter, J. *et al.* 2007, 148). Structure 29 lay at the apex of the Neolithic mound, which was perhaps a deliberate decision by the Norse inhabitants (see Harrison 2016 for discussion of Norse 'mound' architecture). In 8.2.2 the Structure 29 appears to have changed from a dwelling to a working environment (Hunter, J. *et al.* 2007, 164)

8.2.3. In this phase, a shorter building (Structure 30) was constructed alongside Structure 29, which was slowing going out of use. The phase marks the final occupation of the excavated area, which fell out of use in the later 12th-early 13th century.

Lab ID	**Sample material and context**	**Calibrated age range in cal. AD at 95% probability**
GU-1806	Phase 8.2.2, mixed animal bone from the silty loam/midden foundation for Structure 29	970-1190
GU-1808	Phase 8.2.3, mixed animal bone from a midden layer sealing the wall of Structure 29	1020-1220

Table 64. Radiocarbon determinations from Pool Phase 8.

The deserted farmstead (no phase assigned)

A farmstead constructed around AD1800 and occupied until the Second World War now lies east of Pool Bay, under 100m from the excavated mound. It is now deroofed and dilapidated, and was employed as a tool store during the archaeological excavations (Hunter, J. *et al.* 2007, 523).

5.2.2. Times of Their Lives: dating overview and results

A revisiting of the site record for Pool has allowed for the refinement, and in some cases reinterpretation, of the original chronological sequence for Late Neolithic occupation at the site. The site was selected by the Times of Their Lives project (Macsween *et al.* 2015) to have new radiocarbon dates commissioned followed by the application of Bayesian statistics, whereby calibrated radiocarbon dates are combined with prior archaeological knowledge and statistically analysed (Whittle and Bayliss 2007). Neolithic occupation at the site spans key cultural periods, encompassing the transition from round-based Unstan pottery to Grooved Ware with applied decoration (Macsween *et al.* 2015, 2). As such, it was selected to contribute one of the aims of the project: to better-date the emergence of Grooved Ware and its wider cultural significance. The dating unfortunately does not improve the picture for pre-Grooved Ware phases. During both the original post-excavation process and the recent revisiting, both teams were met with considerable problems with selecting dateable materials, which hindered the scientific dating process. Organic preservation conditions were poor and chemical treatment during the original post-excavation process ensured that many samples were unsuitable for the later radiocarbon dating process (Macsween *et al.* 2015).

Twenty-six radiocarbon measurements are now available for Neolithic occupation at Pool, 21 of which were commissioned by the Times of Their Lives project. Twenty-three of the 26 radiocarbon dates are compatible with Hunter's recorded stratigraphy from the site. However, when the sequential phasing devised by Hunter was incorporated into the recorded stratigraphy and radiocarbon dates (thus forming the chronological model), some poor agreement with the sequential phasing was noted (Macsween *et al.* 2015, 296).

MacSween *et al.* refined the dating of Phases 2.2 and 2.3 by modelling the start to 3210-2935 cal. BC (*start Phases 2.2-2.3*), and the end of Phase 2 to 2815-2650 cal. BC (93% probability; end Phase 2) (Macsween *et al*. 2015, 15; Figure 9). Following these phases there was a relatively hiatus, presumably when the site was apparently 'abandoned' or occupation ceased, or at least when the main focus of activity moved to a different area of the settlement which was not identified, before reoccupation in Phase 3 from 2680-2515 cal. BC (*start Phase 3*) until the end of Neolithic occupation at Pool in 2460-2280 cal. BC (*end Phase 3*) ((Macsween *et al*. 2015, 15; Figure 9). This phase was marked by the appearance and use of Grooved Ware pottery with applied decoration, a notable change from the incised pottery of the previous phase.

As previously mentioned, Hunter's original TL dating of the Neolithic phases placed the appearance of Grooved Ware within phase 2.1 to 3710±165 BC – significantly earlier than that proposed by Macsween *et al.* Phases 2.2 and 2.3 (which were interpreted as being separated by the blown sand horizons) conflict with the newly available radiocarbon data, with Phase 2.3 appearing to not in fact be later than Phase 2.2. Macsween *et al.* offer two explanations for this inconsistency; firstly, Phase 2.3 *is* later than Phase 2.2, and the phases are separated by the upper sand layer across the site. Therefore, all the dated Phase 2.3 samples are reworked from an earlier date.

Alternatively, the ages retrieved from Phases 2.2 and 2.3 reflect the timing of the formation of the parent deposit. If this is the case, the red tips within Phases 2.2 and 2.3 are related to a continuous period of activity which may not be clearly separated by the sand horizons across the entirety of the excavated site (Macsween *et al.* 2015, 15).

Macsween *et al.* assert that both of these explanations contain problems which must be acknowledged. The second explanation would suggest that the apparently distinctive upper sand layer was misidentified or conflated with the lower sand layer (and perhaps other, less prominent episodes) by the original excavators (see Chapter 5 discussion). Photographic records in the sections appear to show two clear sand deposits (Figure 5.1), so this seems unlikely.

5.3. Project fieldwork at Pool

5.3.1. Fieldwork aims

Investigation for this project took place over two seasons, during 2014 and 2015. The aims of the fieldwork were:

- To further contribute to the baseline knowledge of periods of sand movement in northwest Europe

- To locate the Neolithic sands identified by Hunter, J. *et al*. (2007) in the wider landscape and its extent (as these were only identified on the site itself during the original excavation). It was hoped that identification of these sands would develop a better understanding of the physical and visual impacts of this deposition.

- To identify further horizons of windblown sand within the landscape, and to assess whether any of these correlated chronologically with those identified during excavation at the site, with the proposed hiatus at the site during the Bronze Age, and with horizons in different areas of the island.

- To gather samples for Optically Stimulated Luminescence and radiocarbon dating to date additional episodes of sand deposition identified during an augur survey. It was envisaged that OSL dating and would allow more clarity for the chronology of varying sand movements. If we are to assume that the inhabitants made use of their immediate landscape for economic purposes (such as cultivation and stock rearing), then it can be further hypothesised that if these additional episodes of increased sand movement did occur, then they may correlate chronologically with occupation of the site. This may have had a direct impact on land use and soil quality (as has been noted at Tofts Ness).

- To test the efficacy of the OSL dating method while providing chronological clarity on the deposition of the two Neolithic sand layers.

5.3.2. Methods

To achieve these aims, wide-area geophysical survey (Electromagnetic Conductivity, using a CMD Explorer by GF Instruments) was first conducted at the site to map the depth and nature of the superficial deposits in the Pool landscape (an approach advocated by Griffiths, D. 2011). This technique was employed as it previously proved effective at mapping buried sedimentary deposits in other coastal locations (Bates, C. R. *et al.* 2012), and rapidly measures data over a large area. Electromagnetic Conductivity instruments measure quadrature (ground conductivity) and InPhase (magnetic susceptibility) respectively, allowing for an estimation of sediment properties and their depths. Superficial sediments were mapped in parallel lines to depths of approximately 2m, 4m and 6m (Figure 5.8, Figure 5.9), with data positioned using Leica dGPS.

Following this survey, augur cross sections running in a NE-SW transect (Figure 5.10) were undertaken to ground-truth and identify the deposits and inform the selection of sequences for test-pitting. The survey data (Figure 5.8) revealed a promising picture of the surviving deposits, with low-conductivity, blown sand deposits represented by blues, purples and pinks surrounding – but not overlying - the site itself. High-conductivity peat and boggy deposits (as well as the archaeological remains at the site) were represented by green, yellow orange and crimson. These boggy deposits were most extensive at the southwest of the site.

A cluster of cores was initially taken in the lower-lying areas immediately behind the site, but the majority of these contained little in the way of material with many comprising topsoil and subsoil over till (e.g. Cores 7 and 23). This suggests that in the area directly behind the site, any previously-existing sands and peats had been eroded away. Resultantly, it was decided to move sampling further south of the site, within the low-lying boggy area which was found to have acted as a sediment trap with more fruitful sampling opportunities. Cores 1 and 2 (described in 5.4.8 and 5.4.9) proved particularly fruitful in terms of deposits, and a decision was made to sample these for radiocarbon dating. The cores contained extensive sand deposits, and as these could not be sampled for OSL from the core (given that they had been exposed to light), Test Pits 2 and 11 were excavated in the vicinity (Figure 5.10) to enable this sampling as well as further radiocarbon sampling.

5.3.3. Preliminary findings

The survey revealed extensive and varying deposits of windblown sand (marked in green) rising towards the back of the site to the southeast. Southwest of the site, a large, boggy area was identified as an impounded loch, with characteristic contemporary pond vegetation (such as *Sphagnum*). Speculative auguring revealed mixed sequences, ranging from areas of former pond or marsh inundated with calcareous windblown sand (composed primarily of calcium carbonate) and calcareous windblown sands interbedded with organic peats with visible, robust plant remains, and organic silty deposits. In comparison with those identified at Braeswick, the peats interbedded with sands at Pool were far thinner, reaching a maximum of 0.23cm depth in the areas investigated (5.4).

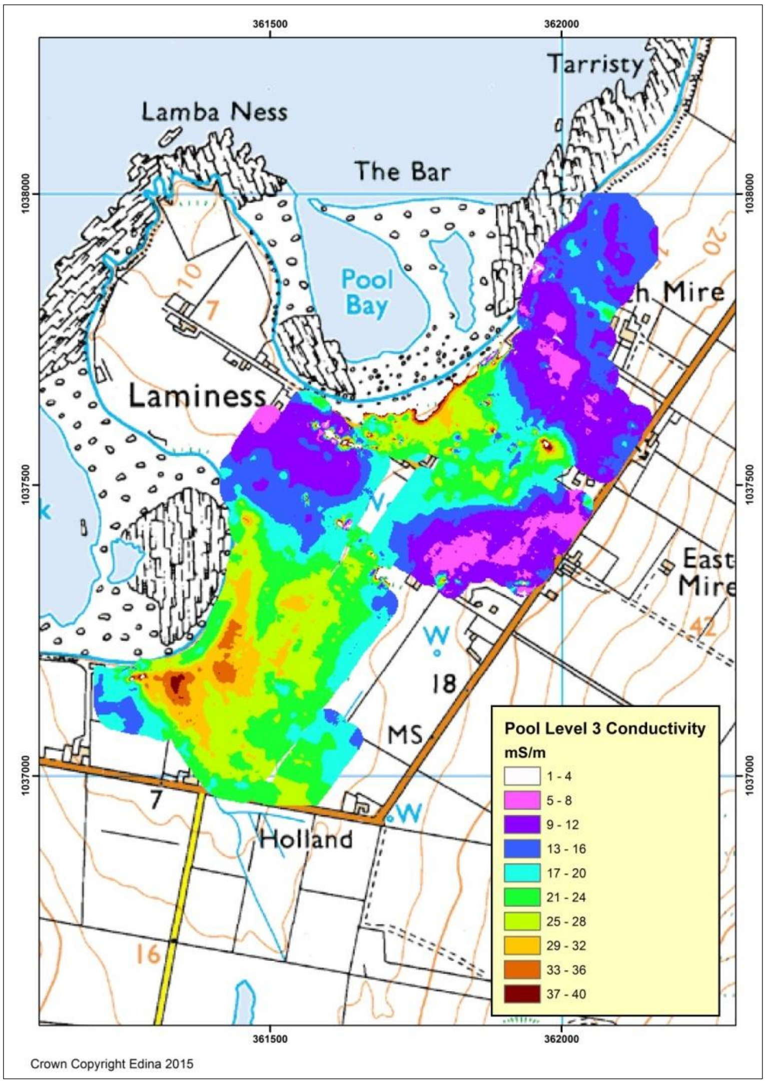

Figure 5.8. Electromagnetic Conductivity survey results at 0-6m depth. Low-conductivity, blown sand deposits are represented by blues, purples and pinks. High-conductivity peat and boggy deposits, as well as archaeological remains at the site itself, are represented by green, yellow orange and crimson. Survey undertaken by R. Bates.

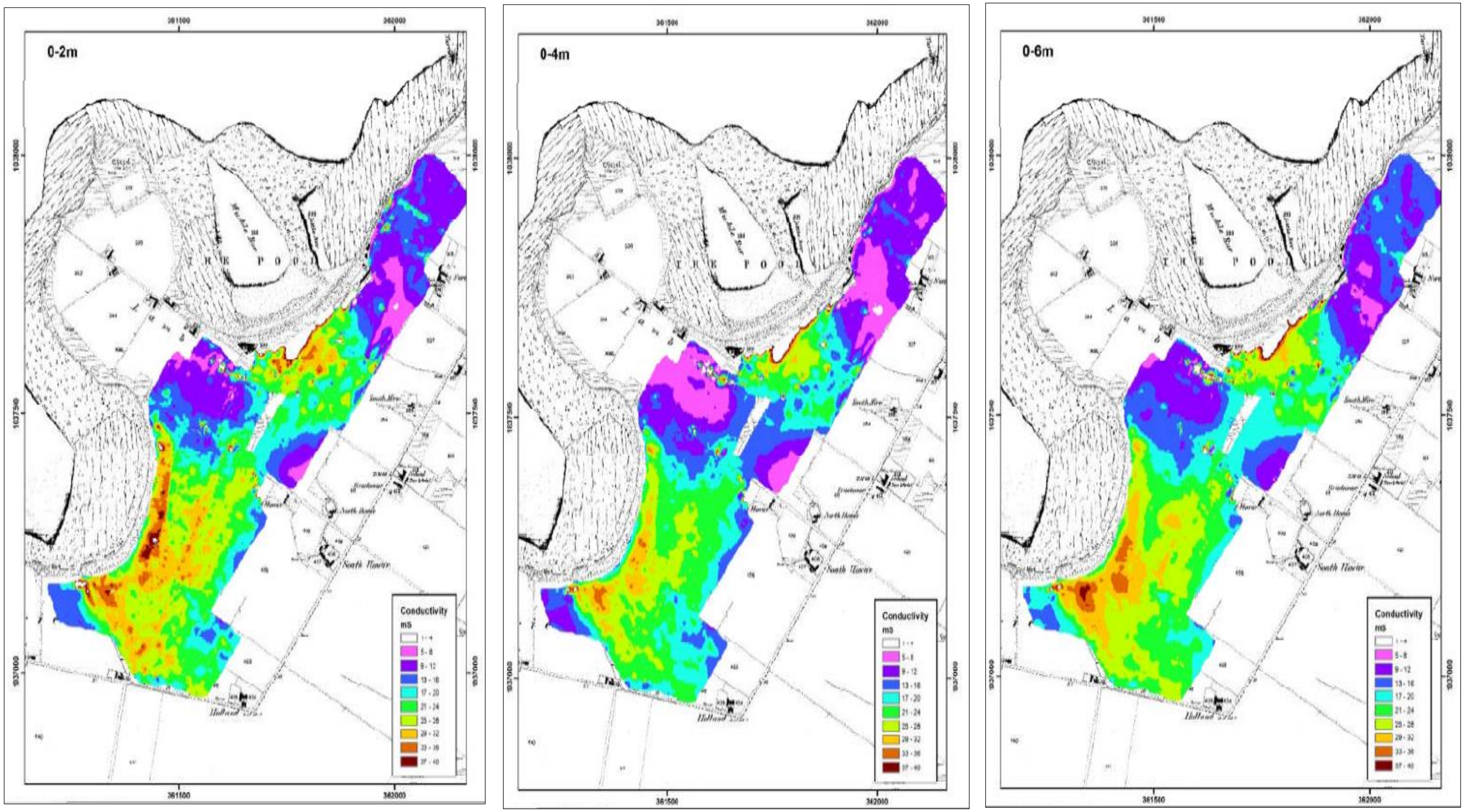

Figure 5.9. Electromagnetic Conductivity results displaying three depth maps, over a historic basemap: 0-2m, 0-4m and 0-6m. After R. Bates. Crown Copyright Edina Digimap 2015.

5.3.4. Recording and sampling

Seven test pits were to the south of the site, and 21 sediment cores taken in cross-sections through the landscape, behind and to the east of the site. Test Pits 1-4, 6, 9, and 11, and Cores 1 and 2 were selected for excavation, recording and sampling for radiocarbon and OSL dating. A sample from the visible sand layer directly covering the site at Pool was also taken from the eroding section for OSL dating. Each test pit measured c. 1m in width and c. 0.50m in length, and were excavated down to natural geology where practical. Sediments were recorded and numbered using the conventions recommended in Goldberg and MacPhail (2006). Each test pit was measured, logged and a section drawn and photographed. The section drawings and core logs were also digitised (see 5.5.4). Bulk samples were taken from each deposit with the exception of modern topsoil and subsoil, and an OSL sample taken from selected sand deposits. It is recommended that OSL dating is not employed alone as an unconstrained dating technique (Duller 2008). Accordingly, radiocarbon samples were taken from selected peat deposits in order to better-constrain and inform the interpretation of the luminescence dates. Samples were taken for rangefinder radiocarbon dating from Cores 1 and 2, and Test Pits 2 and 11. When sampling the peat, the potential presence of contaminants such as reworked materials, younger rootlets, which present the possibility of a young age bias, and humic acids (Piotrowska *et al.* 2011), were considered. Large bulk samples were taken where possible to ensure that plenty of material was available for macrofossil analysis and removal of possible contaminant materials. The use of multiple dating techniques, including luminescence, can be used for corroboration between chronological methods, thereby theoretically improving accuracy.

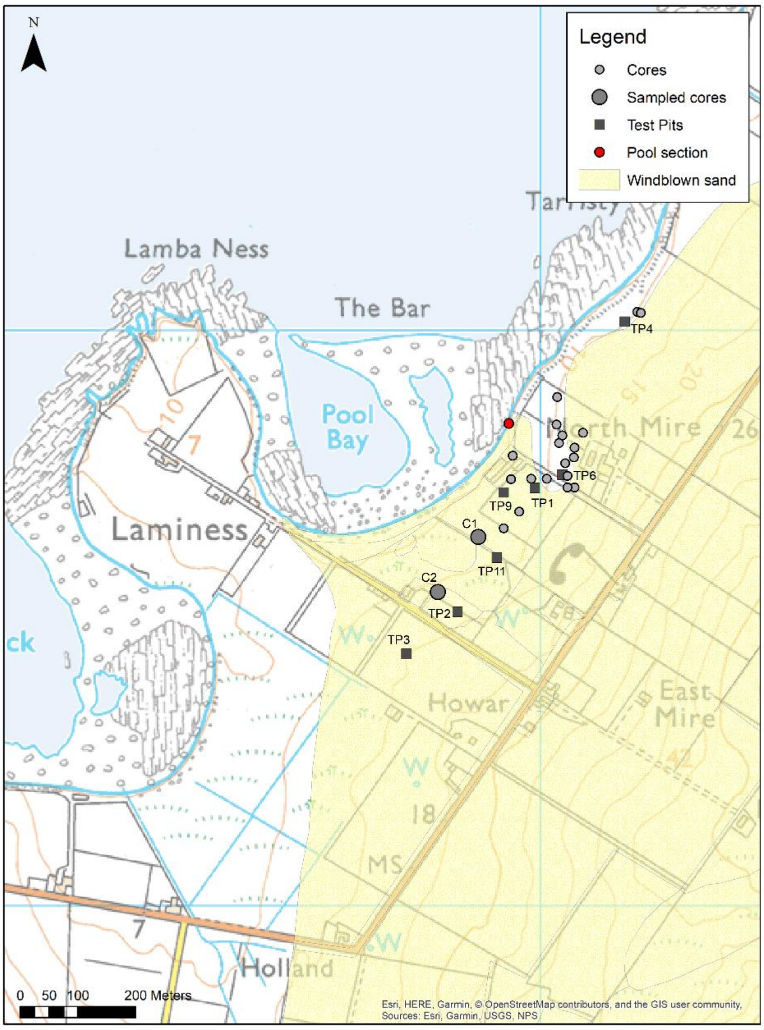

Figure 5.10. Map of sampling locations at Pool.

5.4. Test Pit and Core logs

5.4.1. Test Pit 1

361991, 1037726

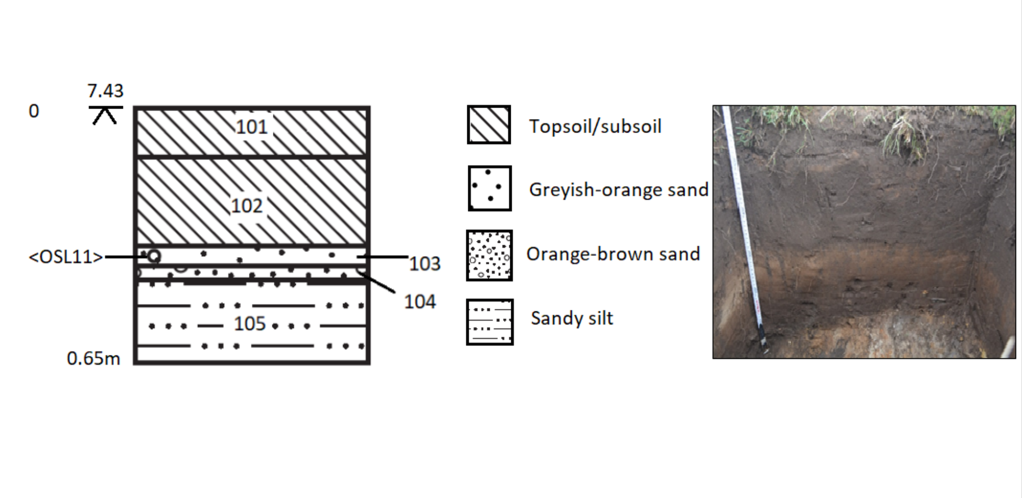

Figure 5.11. Pool Test Pit 1.

Context	Dimensions	Description
(101)	0-0.13	Topsoil
(102)	0.13-0.35	Dark brown silty subsoil
(103)	0.35-0.40	Mid yellowish-orange, medium-coarse windblown calcareous sand <OSL11> at 0.34m, close to the top boundary
		Mixed boundary
(104)	0.40-0.44	Coarse, dark orange-brown silty sand
		Mixed boundary
(105)	0.44-0.65	Dark brown fine sandy silt overlying till

Table 65. Pool Test Pit 1 stratigraphic sequence.

5.4.2. Test Pit 2

361857, 1037511

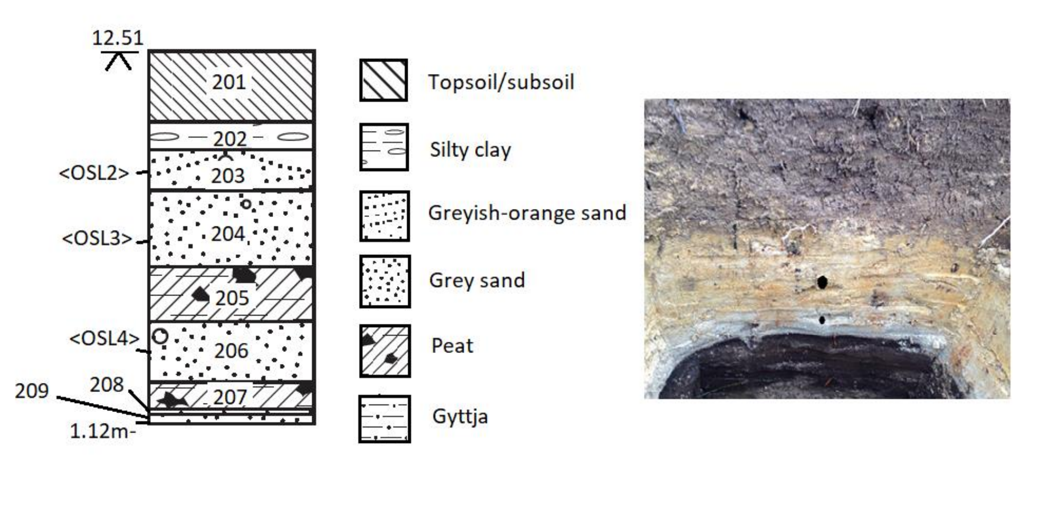

Figure 5.12. Pool Test Pit 2.

Context	Dimensions	Description
(201)	0-0.25	Topsoil
(202)	0.25-0.35	Fine-grained silty clay subsoil
(203)	0.35-0.50	Mid greyish-orange coarse-grained sand with grey mottling and some orange staining. <OSL2> at 0.40m
(204)	0.50-0.58	Pale grey medium-coarse calcareous sand <OSL3> at 0.56m
(205)	0.58-0.78	Dark, fibrous peat. Radiocarbon sample (Pool_205) (UBA-32508)
(206)	0.78-1.00	Dark grey, fine-medium calcareous sand <OSL 4> at 0.87m
(207)	1.00-1.10	Dark brown fibrous peat. Radiocarbon sample (Pool_207) (UBA-32509)
(208)	1.10-1.12	Light, whitish-grey Gyttja-like deposit
(209)	1.12-	Blue-grey medium calcareous sand with frequent shell fragments. Base not reached

Table 66. Pool Test Pit 2 stratigraphic sequence.

5.4.3. Test Pit 3

361768, 1037438.

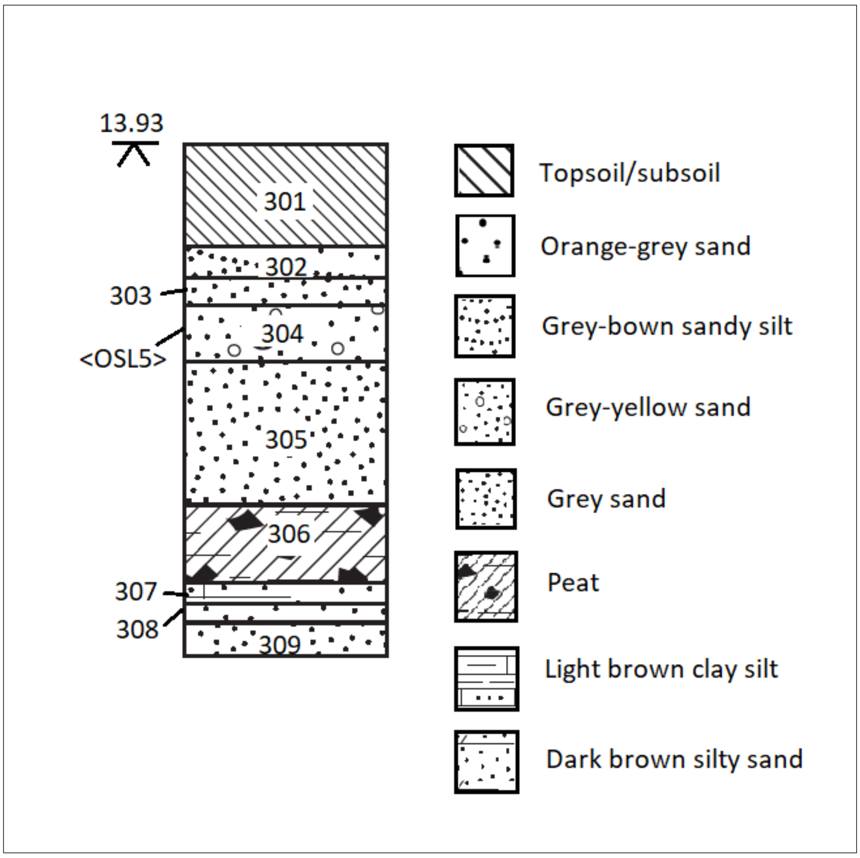

Figure 5.13. Pool Test Pit 3.

Context	Dimensions	Description
(301)	0-0.30	Topsoil and subsoil
(302)	0.30-0.40	Light grey medium-coarse sand with some orange staining, occasional organic inclusions and calcareous shell fragments
(303)	0.40-0.48	Mid greyish-brown sandy silt with some organic inclusions and bioturbation
(304)	0.48-0.66	Light grey calcareous sand with yellow staining <OSL5> at 0.56m
(305)	0.66-1.10	Mid-grey medium-coarse calcareous windblown sand
(306)	1.10-1.33	Dark fibrous peat. Radiocarbon sample (Pool_306) (UBA-32510)

(307)	1.33-1.39	Light brown medium sandy fibrous clayey silt, becoming less fibrous
(308)	1.39-1.44	Darker, fine brownish-grey silty sand
(309)	1.44-1.56	Dark grey coarse windblown sand with frequent shell fragments

Table 67. Pool Test Pit 3 stratigraphic sequence.

5.4.4. Test Pit 4

362147, 1038015

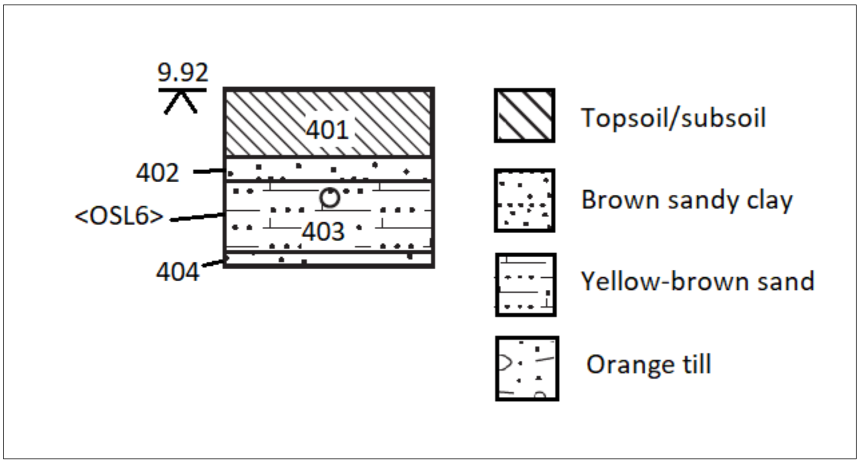

Figure 5.14. Pool Test Pit 4.

Context	Dimensions	Description
(401)	0-0.19	Topsoil and subsoil
(402)	0.19-0.26	Dark greyish-brown sandy clay. Frequent, medium-sorted sand grains
(403)	0.26-0.46	Mid yellowish-brown coarse calcareous sand. <OSL6> at 0.29m.
(404)	0.46-	Yellow sandy till

Table 68. Pool Test Pit 4 stratigraphic sequence

5.4.5. Test Pit 6

362039, 1037749.

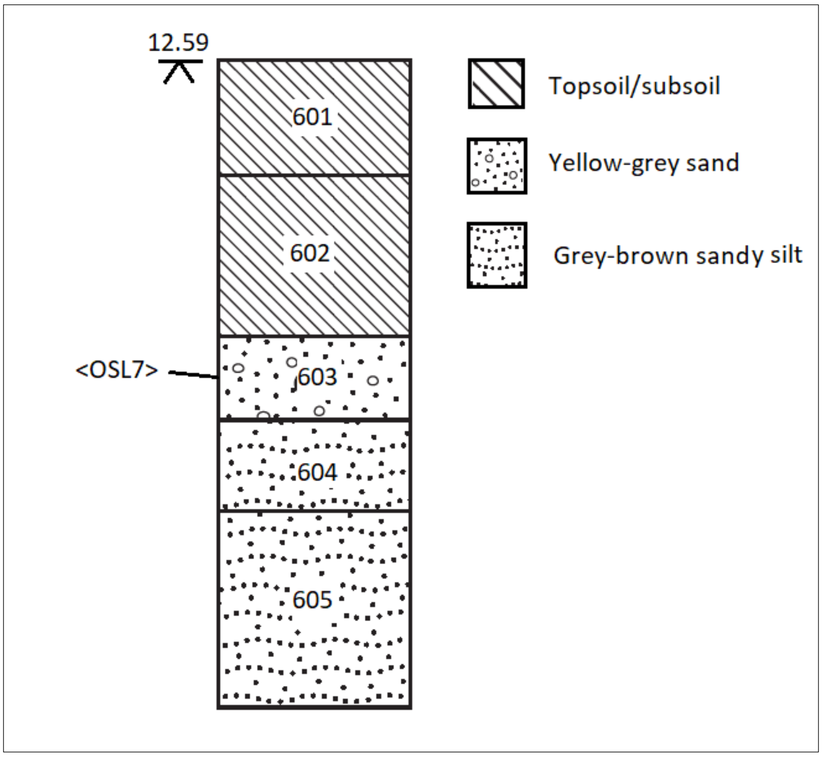

Figure 5.15. Pool Test Pit 6.

Context	Dimensions	Description
(601)	0-0.18	Topsoil
(602)	0.18-0.43	Subsoil
		Mixed boundary
(603)	0.43-0.56	Mid yellowish-grey medium-fine calcareous sand with some dark organic content. <OSL7> at 0.55m.
(604)	0.56-0.70	Dark greyish-brown sandy silt with shell fragments
(605)	0.70-0.98	Mid grey-brown sandy silt over glacial till

Table 69. Pool Test Pit 6 stratigraphic sequence

5.4.6. Test Pit 9

361937, 1037718

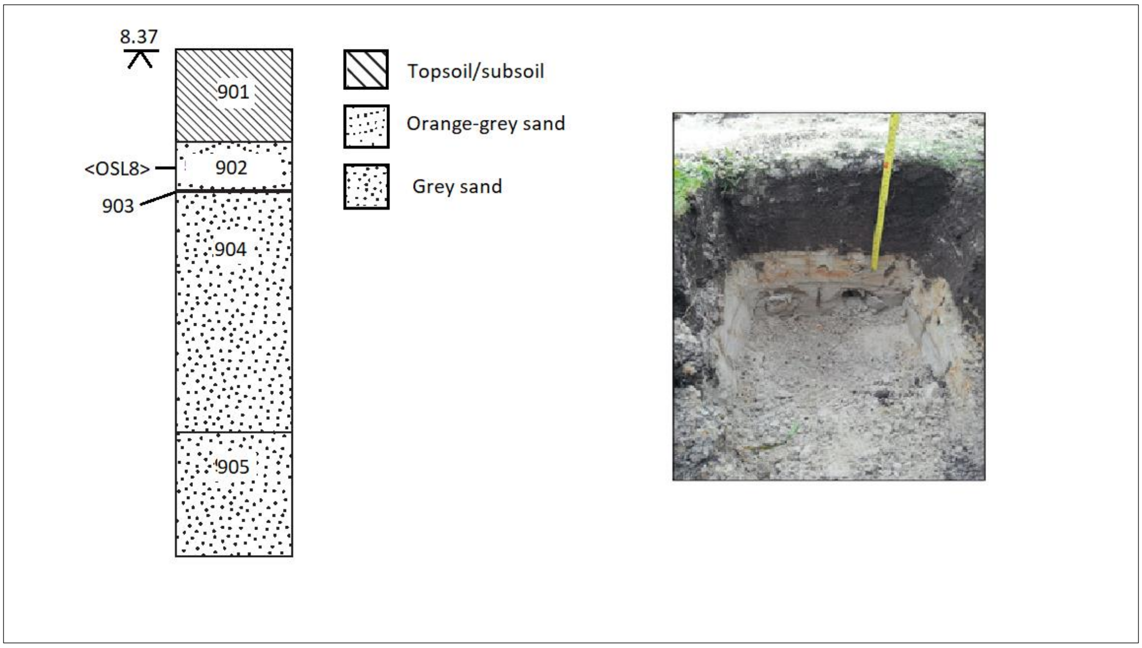

Figure 5.16. Pool Test Pit 9 section

Context	Dimensions	Description
(901)	0-0.24	Topsoil and subsoil
		Sharp boundary
(902)	0.24-0.36	Light orange-grey calcareous sand, medium-coarse with orange mottling. <OSL8> at 0.35m
(903)	0.37-0.38	Thin, dark lens (c.4mm thick) of sandy silt with some organics
(904)	0.38-1.00	Mid grey calcareous, finer-grained sand. <OSL9> at 0.47m
(905)	1.00-1.40	Mid-grey sandy clay, very sterile.

Table 70. Pool Test Pit 9 stratigraphic sequence

5.4.7. Test Pit 11

361925, 1037605

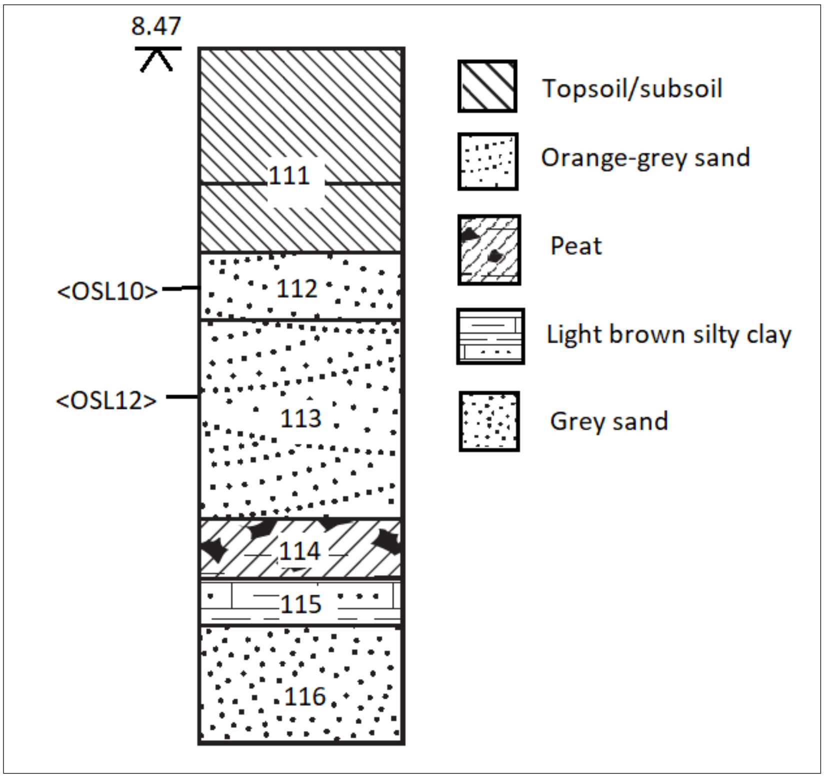

Figure 5.17. Pool Test Pit 11

Context	Dimensions	Description
(111)	0-0.30	Topsoil and subsoil
(112)	0.30-0.40	Mid grey, fine-medium grained clayey calcareous sand with some orange mottling <OSL10> at c. 0.35m
(113)	0.40-0.70	Mid grey calcareous sand with orange mottling <OSL12> at c. 0.55m
(114)	0.70-0.79	Fibrous peat. Radiocarbon sample (Pool_114) (UBA-32511)
(115)	0.79-0.86	Light brown silty clay
(116)	0.86-1.13	Mid grey calcareous sand, fine-medium grained and waterlogged. Base not reached

Table 71. Pool Test Pit 11 stratigraphic sequence

5.4.8. Core 1

361893, 1037641

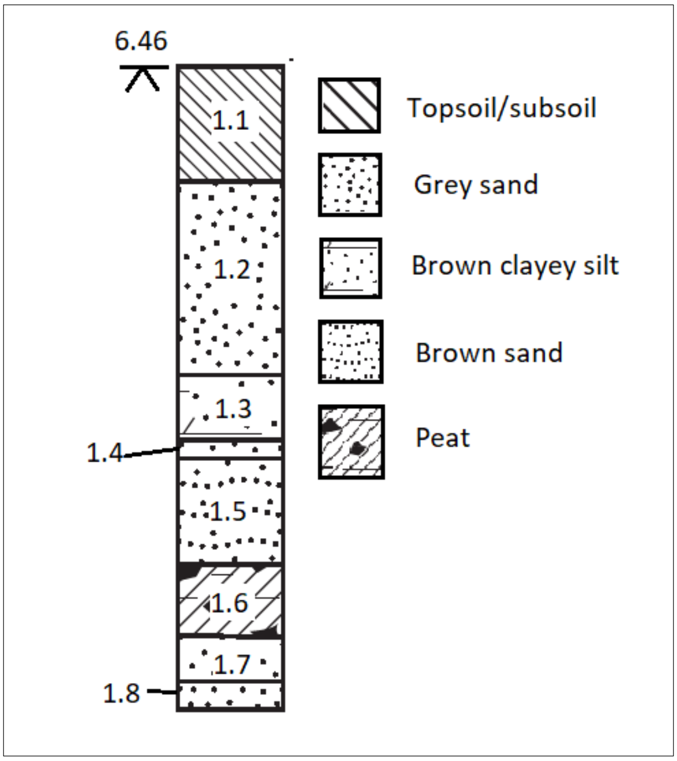

Figure 5.18. Pool Core 1

Context	Dimensions	Description
(1.1)	0-0.32	Topsoil/subsoil
(1.2)	0.32-0.87	Medium grained, mid grey windblown sand with some darker mottling
(1.3)	0.87-1.05	Dark brown organic clayey silt with calcareous shell fragments, occasional fibrous inclusions
(1.4)	1.05-1.09	Lighter brown organic medium clayey silt with shell fragments
(1.5)	1.09-1.40	Light grey-brown shelly sand
(1.6)	1.40-1.55	Fibrous peat with occasional sand grains. Radiocarbon sample (Pool_160) (UBA-32512)
(1.7)	1.55-1.62	Mid brownish-grey shell sand, medium-grained
(1.8)	1.62-1.74	Light grey shell sand, medium-grained overlying glacial till

Table 72. Pool Core 1 stratigraphic sequence

5.4.9. Core 2

361823, 1037545

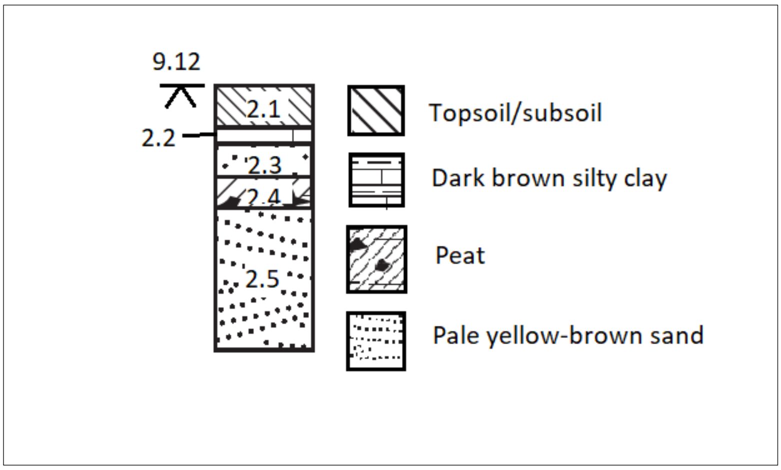

Figure 5.19. Pool Core 2

Context	Dimensions	Description
2.1	0-0.12	Topsoil
2.2	0.12-0.17	Dark brown silty clay with frequent rooting, slightly organic with occasional sand grains
2.3	0.17-0.27	Medium-coarse light grey calcareous sand
2.4	0.27-0.37	Dark, fibrous peat. Radiocarbon sample (Pool_240) (UBA-32513)
2.5	0.37-0.78	Pale yellow-brown flowing sand over glacial till

Table 73. Pool Core 2 stratigraphic sequence

5.4.10. Pool eroding section

361946, 1037838.

The sand that was visible in the Pool coastal section is presumed to be the upper sand layer due to its height in the section (5.32m) and on comparison with Hunter's digitised section (Section NS1, opp. 168). During fieldwork it was not possible to identify the lower sand layer in this area of the eroded face, which could either lend support to Macsween *et al.*'s suggestion that Hunter's sand layers should be conflated, or may simply be a visibility issue. A possible location for the lower sand layer has been offered in Figure 5.20. The sand which was sampled was a mid orange-brown, medium-coarse mineral sand, c. 0.06m thick. It lay between two orange-brown sandy layers comprising midden material and dumps of ashy hearth material. It lies in the lower stratigraphic, Neolithic band identified by the excavators and later researchers (e.g. Macsween *et al.* 2015).

Figure 5.20. Pool section OSL sample location and suggested location of the lower sand layer

5.5. Sampling and dating

5.5.1. Radiocarbon sampling and dating

Six samples for Rangefinder radiocarbon dating were recovered from Cores 1 and 2, and Test Pits 2, 3 and 11. Radiocarbon dates were sought to test, improve and constrain the luminescence chronologies being developed (Duller 2008, 22). As this project was speculative in nature, evaluative Rangefinder radiocarbon dates were selected to determine directions for future work. Rangefinder dates for the peat deposits were required to test the hypothesis that more than one of the sand mobilisations noted in the site's environs during fieldwork was later prehistoric in date (e.g. Bronze Age-Iron Age), and potentially contemporary with the later use of this important site and others. The timing of peat development and inundating of the former loch could then be tied and compared with changes in focus and socio-economic activity thereby improving chronological understanding. The development of the peat sampled by Hunter, J. *et al.* 2007 may be contemporary with the Iron Age occupation of the site and provides a *terminus post quem* for one additional episode of sand movement.

The identification and recovery of multiple sand deposits indicates that additional, previously-unrecorded sand movements also took place within this landscape. There is no direct archaeological evidence for this sand in the excavated portions of the site although plant species from later prehistoric phases are indicative of sandier soils in later phases (Bond, J. in Hunter, J. *et al.* 2007). This discovery is at odds with previously-accepted interpretations of environmental change at Pool which only accounted for prehistoric sand movement. It was envisaged that dating selected peat deposits would allow for the testing of the hypothesis that although there was environmental fluctuation during the site's later prehistoric occupation, there was no significant physical impact on the site itself. The testing of this hypothesis would have direct significance for understanding prehistoric perceptions of environmental change impacts beyond a purely causal approach grounded in catastrophism and abandonment. The bulk samples were analysed by the 14CHRONO lab, at Queen's University Belfast. All dates were calibrated using IntCal13 (Reimer *et al*. 2013) and are rounded to the nearest decade. They are reported in Table 74, and discussed in 5.6.

Lab ID	Sample ID	Uncalibrated 14C Age (BP)	±	F14C	±	Calibrated date range (cal. AD/BC), at 95% probability
UBA-32508	POOL_205 (TP2)	1268	30	0.8540	0.0032	cal. AD660-780
UBA-32509	POOL_207 (TP2)	2841	30	0.7343	0.0027	1090-920 cal. BC
UBA-32510	POOL_306 (TP3)	1116	35	0.8703	0.0038	cal. AD860-1020
UBA-32511	POOL_114 (TP11)	1158	27	0.8657	0.0029	cal. AD780-900
UBA-32512	POOL_160 (C1)	2572	28	0.7260	0.0026	810-750 cal. BC
UBA-32513	POOL_240 (C2)	1350	30	0.8453	0.0031	cal. AD640-710

Table 74. Radiocarbon determinations for peat deposits at Pool.

5.5.2. OSL sampling and dating

Fifteen samples were retrieved for a programme of OSL dating (Table 75), fourteen of which were retrieved from the test pits with the final sample taken from the eroding section of the settlement itself. When the time arrived to date the samples, not all were chosen for the final dating procedure. All 15 were measured for radionuclide concentrations (Appendix 2). Twelve of these samples were then selected for full dating preparation. Of these, only 9 were taken through to the dating process itself. Both calcareous and mineral sands were observed during the recording and sampling process. Samples were taken horizontally with light tight tubes from within the section, under black plastic sheeting. Tubes were then sealed with PTFE tape, labelled and bagged. The high water content of many of the sediments during sampling did not allow for easy visual identification of samples which may be related or equal to one another, and as such further visual descriptions were undertaken during the sample preparation process. Duplicate, bulk samples were also taken from each sampled deposit. Following the preparation of Samples 1-15 (Appendix 2), only samples 1-3, 5-8, 11 and 12 were selected for the full SAR protocol (Murray and Wintle 2000). Table 75 lists the total number of luminescence samples, while Table 76 lists the dating results. In order to calculate age, the following basic calculation was used:

$$\textbf{Age (ka years)} = \frac{\boldsymbol{Equivalent\ dose\ (De)(Gy)}}{\boldsymbol{Dose\ rate\ (Gy\ per\ year)}}$$

Sample	Test Pit	Context	Height (m)	Grid ref.	Lat.	Long.	Description
1	Pool section	Pool section	5.32	361946/1037838	59.22443	2.66846	Mid-orange, coarse mineral sand
2	2	203	12.5	361857/1037511	59.22249	2.66996	Mid greyish-orange sand with grey mottling and some orange staining
3	2	204	12.5	361857/1037511	59.22249	2.66996	Pale grey, coarse calcareous windblown sand
4	2	212	12.5	361857/1037511	59.22249	2.66996	Dark grey, fine-medium calcareous windblown sand
5	3	304	13.9	361768/1037438	59.22183	2.67151	Light grey calcareous windblown sand with yellow staining
6	4	403	9.9	362147/1038015	59.22704	2.66497	Mid yellowish-brown windblown calcareous sand.
7	6	603	12.6	362039/1037749	59.22464	2.66681	Mid yellowish-grey medium calcareous sand with shell fragments and some dark organic content
8	9	902	8.4	361937/1037718	59.22435	2.66859	Light orange-grey calcareous windblown sand, medium-coarse with orange mottling
9	9	904	8.4	361937/1037718	59.22435	2.66859	Mid grey calcareous, finer-grained windblown sand
10	11	112	8.5	361925/1037605	59.22334	2.66879	Mid grey, fine-medium grained clayey shelly sand with orange mottling
11	1	103	7.4	361991/1037726	59.22443	2.66765	Mid yellowish-orange windblown calcareous sand, medium-coarse
12	11	113	8.5	361925/1037605	59.22334	2.66879	Mid grey, fine-medium calcareous sand with orange mottling

Table 75. OSL dating samples with their context numbers, heights in m (OD), locations and descriptions.

Sample	Context	Number of accepted discs	Dose Rate (mGy a-1)	Stored Dose (Gy)	Age	Years BP	Calendar years	Period
1	Pool section	9	1.860	7.716	4.15 ± 1.20	4150±1204	2130±1204 BC	Spans Early Neolithic-Late Bronze Age
2	203	4	1.311	0.839	0.64 ± 0.34	640±341	AD 1377±341	Medieval
3	204	4	1.304	2.971	2.28±0.12	2280±108	261±108 BC	Middle Iron Age
5	304	2	1.272	2.812	2.90±2.55	2900±2553	886±2553 BC	Spans Neolithic-Medieval
6	403	8	0.969	1.464	0.99±0.41	990±408	AD 1021±408	Medieval
7	603	14	1.471	1.201	0.89±039	890±388	AD 1130±388	Medieval
8	902	2	1.354	2.584	2.59±1.16	2590±1162	572±1162 BC	Spans the Early Bronze Age-Late Iron Age
11	103	29	0.998	2.706	1.73±0.47	1730±468	AD 294±468	Middle-Late Iron Age
12	113	9	1.089	3.309	4.07±0.45	4070±454	2057±454 BC	Late Neolithic/Early Bronze Age

Table 76. Pool samples, context numbers, accepted discs, total dose rates, stored dose and age estimates.

5.6. Age determinations

5.6.1. Sample 1 (Eroding section)

During the statistical analysis of Sample 1, a date of 2130±1204BC was generated based on the weighted mean. This date falls within a Late Neolithic range. However, this dataset is notable for its large error and significant chronological spread, with two data populations lying in both the Late Neolithic and Bronze Age. One well-measured data point with low error margins in the Bronze Age range ensured that the hypothesised earlier Neolithic date (based on radiocarbon dates yielded for samples from the middens under-and overlying the sand) (Macsween *et al.* 2015) could not be immediately accepted. Three scenarios which may have affected the homogeneity and precision of this data and its chronological date may be considered;

1. Insufficient bleaching during transportation and/or deposition of the sand led to a younger age bias

2. As has already been noted, Sample 1 was retrieved using a tube inserted horizontally into an exposed sand horizon within an eroding coastal section. Although during opening under laboratory conditions the sample was observed to be fully contained in the sample tube (e.g. no surrounding, non-sand deposits were captured in the sample tube), it is possible that accidental exposure to light during sampling, or sample movement during transport and storage processes, may have taken place, thus affecting the validity of the date.

3. A third consideration is that this horizon was originally deposited in the late Neolithic, and then reworked during the Bronze Age. This seems unlikely but the problematic stratigraphy of the site (with the master site matrix not being available – see Macsween *et al.* 2015) ensures that this must be considered.

On consideration, and weighing up of;

a). the radiocarbon dates yielded for the contexts which bracket the sand deposited over the site at Pool (Macsween *et al.* 2015), and the TL dates produced by Hunter, J. *et al.* (2007) and by Spencer and Sanderson (2012) (see Chapter 5 introduction and discussion);

b). the OSL date yielded for the sand itself (2130±1204 BC, produced by the author);

the author has chosen to err on the side of the radiocarbon date produced by Macsween *et al.* (2015) in this instance. Several justifications can be given for this decision. Firstly, the over 1000-year error on the OSL date ensures that any interpretations of this date should be made with caution. Secondly, when the '-' error is taken into account and the date is adjusted accordingly (by *subtracting* the error), a date of 3334BC is produced, which is more in line with the age for the bracketing context by Macsween *et al.* (although this should not be taken as a reliable method). There was also some disagreement with the dates yielded from Spencer and Sanderson's TL dating.

5.6.2. Test Pit 2

Test Pit 2 contained two OSL samples <OSL-2, OSL-3> and two radiocarbon dates (Samples 205 (UBA-32508) and 207 (UBA-32509) (Figure 5.21).

OSL Sample 2

OSL Sample 2 returned a date of AD1377±341, placing the deposition of the sand, or its last exposure to light through reworking, to the Medieval period. This date also falls within the Little Ice Age. 5 aliquots were accepted from an original total of 32, with other discs rejected for low sensitivity. The comparatively high water content of the sample (23.5%) and its close proximity to Sample 3 may have negatively affected its dosimetry. As can be seen in Appendix 2, these aliquots fall into a significant peak at 0.5-2 Gy, allowing the date of AD1377 to be calculated.

OSL Sample 3

A date of 261±108BC was returned from Sample 3. Of the 34-disc run, 11 discs were accepted and on plotting fall in the range of 2-4Gy, with a weighted mean of 2.82Gy. This places the deposition of the sand, or its last exposure to light, in the Middle Iron Age. A water content of 20.7% lies in a similar range to that of Sample 2, which lay directly above Sample 3. A stark contrast in colour between the two sands is notable and indicates that they do indeed represent two distinct episodes of sand movement. Their proximity, and contrast in date (over a millennium) may indicate that a period (or periods) of erosion took place following the deposition of the Sample 3 sand in the Middle Iron Age) which removed any trace of stabilising soil deposits which may have developed over the sand. Likewise, such erosion and vegetation degradation may have also removed any sands deposited after the Middle Iron Age sand, and before the Little Ice Age sand.

The situation becomes problematic when the radiocarbon data is taken into consideration. The peat deposit sampled from Test Pit 2 (205), which directly underlay the Sample 3 sand, yielded a Late Iron Age-Pictish radiocarbon date range of cal. AD660-780 (UBA-32508). Even considering the fact that the radiocarbon date was yielded from a bulk sample - thus providing only a rangefinder date – the overlying sand (261±108BC) still predates the peat by over a millennium.

Test Pit 2 also contained another, lower sand deposit (OSL Sample 4, context (206)) which was not dated by OSL due to time constraints. The radiocarbon dates of cal. AD660-780 (UBA-32508), and of 1090-920 cal. BC (UBA-32509) for the peat immediately underlying it, ensures that the deposition of this lower sand layer can be slightly constrained to the later prehistoric period, between 1090-920 cal. BC (UBA-

32509) and cal. AD660-780 (UBA-32508). UBA-32509 also provides a *terminus ante quem* for lowest sand (209), which must have deposited before this date.

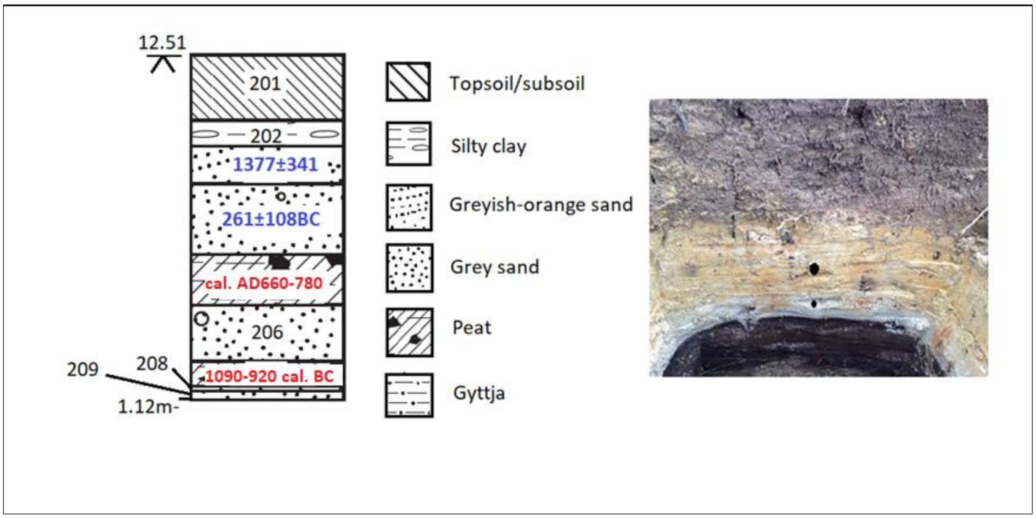

Figure 5.21. Test Pit 2 with radiocarbon (red) and OSL (blue) dates

5.6.3. Test Pit 3

Test Pit 3 contained one OSL sample <OSL-5>, sand (304) and one radiocarbon date (Sample 306, (UBA-32510) (Figure 5.22).

OSL Sample 5

Only two aliquots were accepted from a total of 32, ensuring that the date of 886±2553BC could be treated only as a rangefinder date for sand (304 <OSL-5>). Again, a significant error is present, ensuring that the deposition date could lie in either the Early Neolithic or the Medieval period. The low sensitivity of the samples may be explained by incomplete bleaching or significant reworking through erosion, scouring or later sand deposition. If the significant positive error of over two millennia is considered (e.g. 886BC+2553), the OSL date is brought to AD1667, which is within a chronostratigraphic order. However, without more precise statistical modelling of the OSL date, it would be unwise to accept this date unquestioningly. The high error and uncertainty around this date is ameliorated slightly by the radiocarbon date yielded by peat (306), located below OSL-5. This peat yielded a Norse age range of cal. AD860-1020 (UBA-32510), providing a *terminus post quem* for the deposition of the overlying sand (304) as well as (305). It also offers a *terminus ante quem* for the deposition of underlying sand (309).

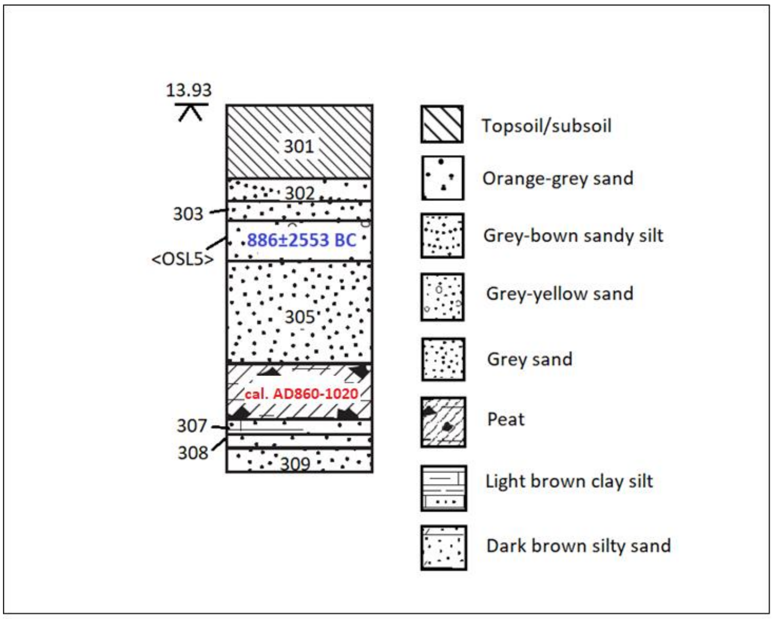

Figure 5.22. Pool Test Pit 3 with radiocarbon (red) and OSL (blue) dates

5.6.4. Test Pit 4

Test Pit 4 contained one OSL sample <OSL-6> (Figure 5.23).

OSL Sample 6

After initial plotting of eight aliquots and an age model applied, a Late Medieval OSL date of AD1509 was produced for sand (403). A cluster of data at the 1-2Gy mark was noted in the KDE and Abanico plots, as well as significantly spread outliers with notable errors at 3-5Gy and a single outlier at 0 Gy. After the subsequent removal of Aliquot 31 - which displayed a comparatively low sensitivity and was the outlier at 0 Gy - from the accepted data, a tight data distribution with low errors was seen to be clustered at 1-2 Gy. This produced a Norse-Early Medieval date of AD1021±408 (with the weighted mean moving from 0.746 to 1.464 Gy), bringing it in line with the data and weighted means displayed for Sample 7 (see below), a sand which is suggested to be of the same origin and depositional date. Given the similarity in data populations between Samples 6 and 7, as well as similarities in height and morphology, it is argued that these two samples represent the same sand deposit. In situ, Sample 6 sat above a glacial till and below sand (402) (not dated). No radiocarbon samples were retrieved from this Test Pit.

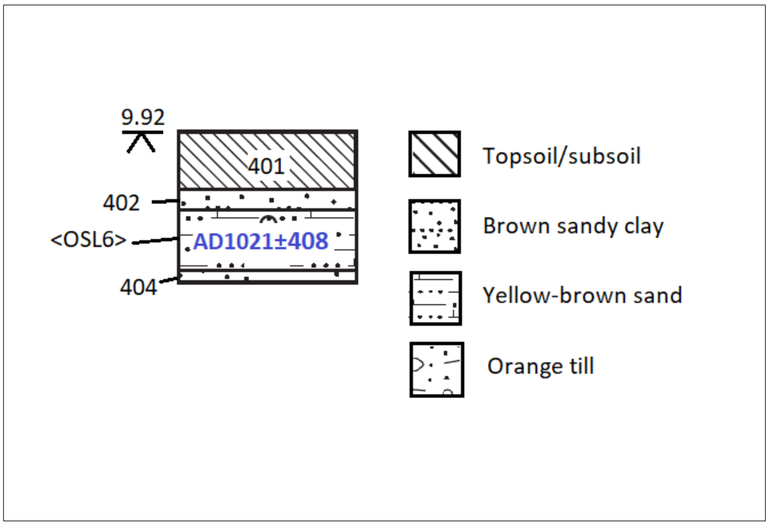

Figure 5.23. Test Pit 4 with OSL date (blue)

5.6.5. Test Pit 6

Test Pit 6 contained one OSL sample, <OSL-7> (Figure 5.24).

OSL Sample 7

Another Norse-Early Medieval date of AD1130±388 was returned for Sample 7, context (603), which is likely to correspond to the sand in Sample 6, (403). Both Samples 6 and 7 had 13 accepted discs out of 32. On plotting, Sample 7 was found to have a very tight distribution at c. 1-2 Gy with few significant outliers and low errors. Sample 7 has been interpreted as having been deposited during the same period as Sample 6 (above) and given their noted homogeneity during the sample preparation and processing stages, they are here interpreted as representing the same sand mobilisation event.

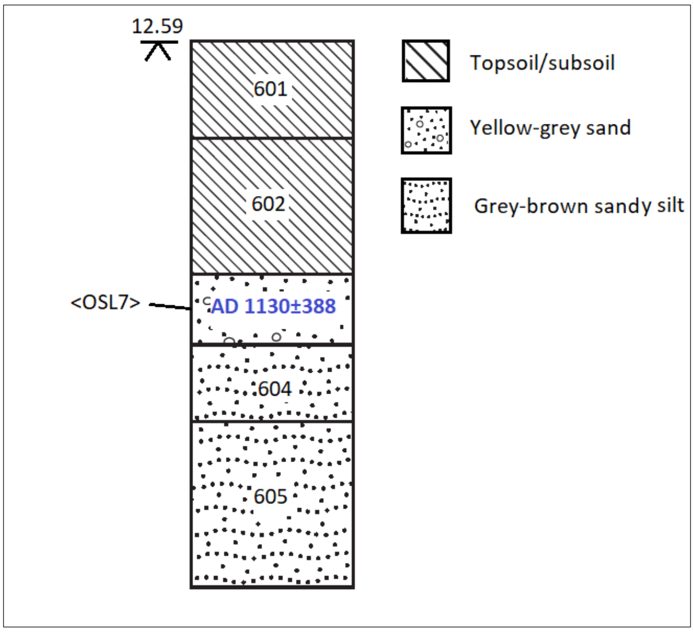

Figure 5.24. Pool Test Pit 6 with OSL date (blue)

5.6.6. Test Pit 9

Test Pit 9 contained one OSL sample, <OSL-8> (Figure 5.25).

OSL Sample 8

As was also the case with Sample 5 (sand (902)), only two aliquots were accepted from a run of 32 low-sensitivity aliquots, yielding a rangefinder age of 572±1162BC, again with significant error spanning the Early Bronze Age-Late Iron Age. It is one of three sand samples which yield a range encompassing an Iron Age date (alongside 3 and 11). Sample 8 (902) lies above OSL Sample 9 (904), which was not taken to data processing stage due to its extremely low sensitivity and poor response to radiation doses. This determination offers a terminus ante quem for the deposition of the underlying sands (904) and (905).

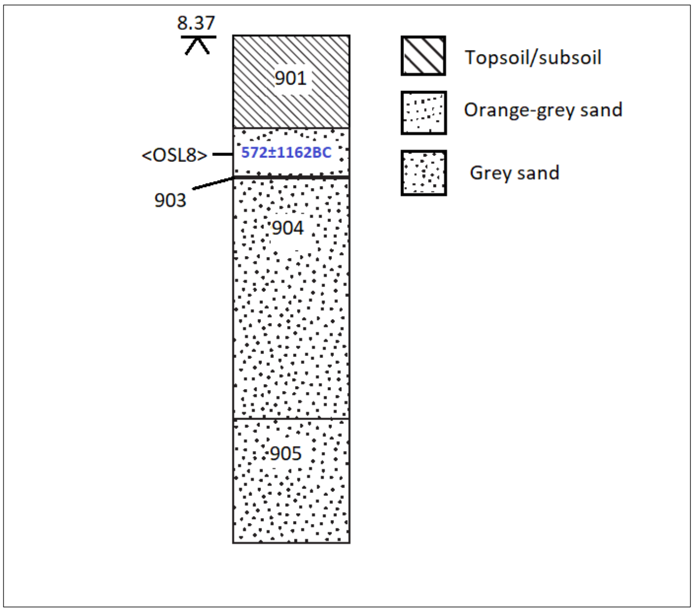

Figure 5.25. Pool Test Pit 9 with OSL date (blue)

5.6.7. Test Pit 1

Test Pit 1 contained one OSL sample, <OSL-11> on sand (103) (Figure 5.26).

OSL Sample 11

Sample 11 returned a Middle to Late Iron Age date of AD294±468 on 64 aliquots (comprising two runs of 32). On the first stage of processing, 26 discs were accepted with 12, 3 and 13 having been removed. This brought the weighted mean of the aliquot measurements from 2.136 to 2.679.

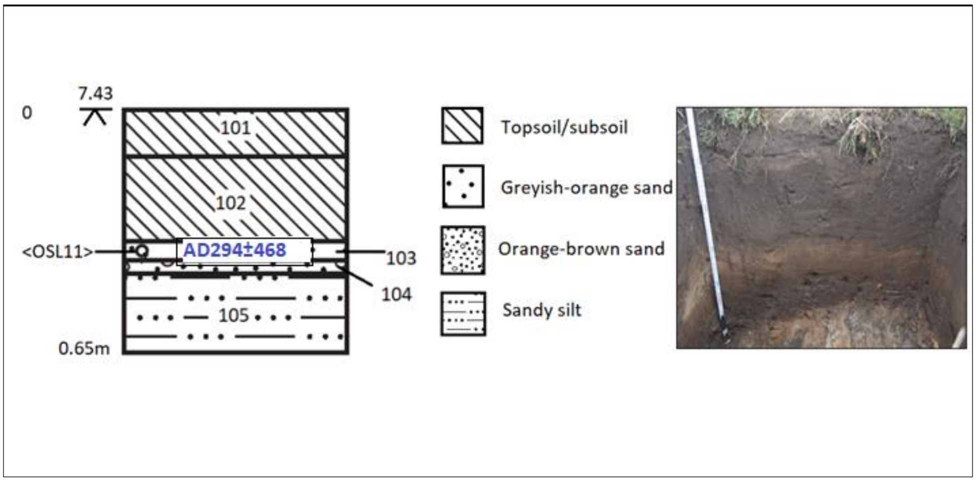

Figure 5.26. Pool Test Pit 1 with OSL date (blue).

5.6.8. Test Pit 11

Test Pit 11 contained one OSL date <OSL-12>, on sand (113) and one radiocarbon date (UBA-32511) on peat (114) (Figure 5.27).

OSL Sample 12

Six aliquots were accepted for Sample 12, giving a date of 2057±454BC. This places the deposition or reworking of this sand as spanning the Late Neolithic-Middle Bronze Age. A radiocarbon sample from peat (114) which directly underlay Sample 12, yielded a Pictish-Norse determination of cal. AD780-900 (UBA-32511). This is another example of a reversed stratigraphy in the sequence, whereby the sand overlying peat (114) predates it by nearly three millennia. Even if the positive error in the OSL date is added, the resulting date (1603BC) is still too early for the date of cal. AD780-900 for the peat. The peat does, however, provide a *terminus ante quem* for the deposition of sand (116), which must have been deposited prior to the formation of the peat.

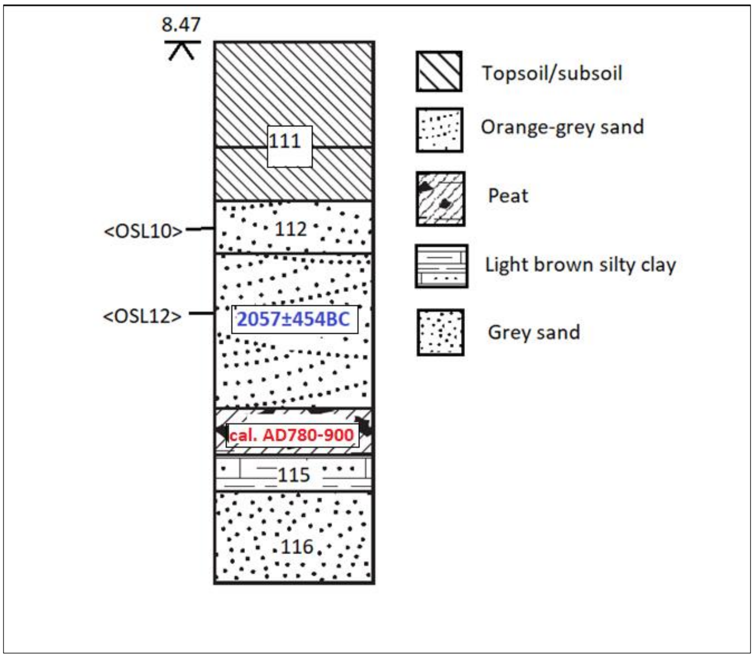

Figure 5.27. Pool Test Pit 11 with radiocarbon (red) and OSL (blue) dates

5.6.9. Core 1

Core 1 contained one radiocarbon sample, (UBA-32512) on peat (160/1.6) (Figure 5.28)

No sand samples were taken for OSL dating from Core 1, as the sand was exposed to light during sampling (which was undertaken with a gouge augur). The radiocarbon date from Core 1, however, ensure that some constraint for the sands observed in this core can be offered. The sample from (160/1.6) yielded a Late Bronze Age-Early Iron Age determination of 810-750 cal. BC (UBA-32512), offering a *terminus ante quem* for sands 1.7 and 1.8, and a terminus post quem for sands 1.2 and 1.5. It is notable that this determination is significantly older than that retrieved from the peat in Test Pit 11 (cal. AD780-900) which lay under 50m away. This demonstrates the highly discrete nature of deposits over a relatively small area.

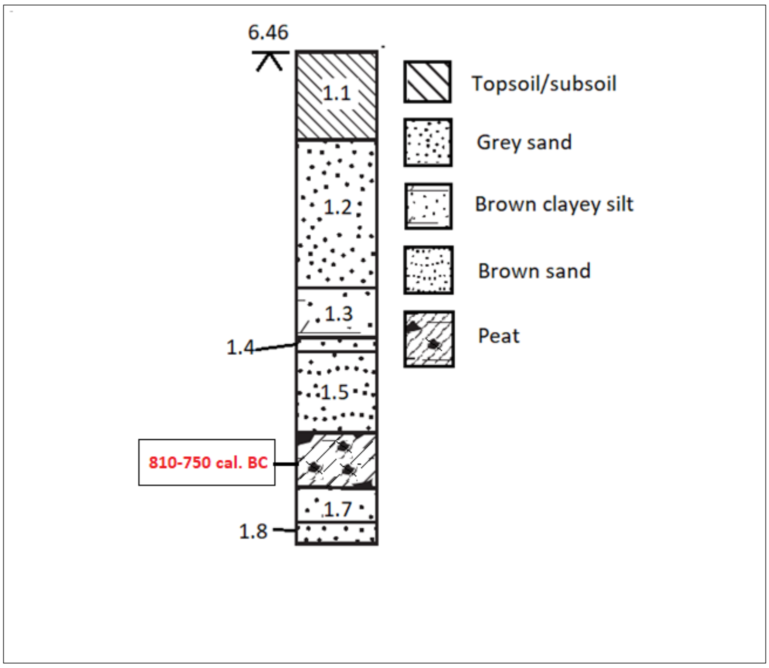

Figure 5.28. Pool Core 1 with radiocarbon date (red).

5.6.10. Core 2

Core 2 contained one radiocarbon sample, (UBA-3251) on peat (240/2.4) (Figure 5.29).

As with Core 1, no sand samples were taken for OSL dating from Core 2. Peat (240) yielded a Late Iron Age determination of cal. AD640-710 (UBA-32513), fitting particularly well with UBA-32508 from Test Pit 2 c. 40m away Some constraint for the sands in Core 1 can be offered. The underlying sand (205/2.5) must have been deposited before cal. AD640-710, while sand (203/2.3) must have been deposited after this date.

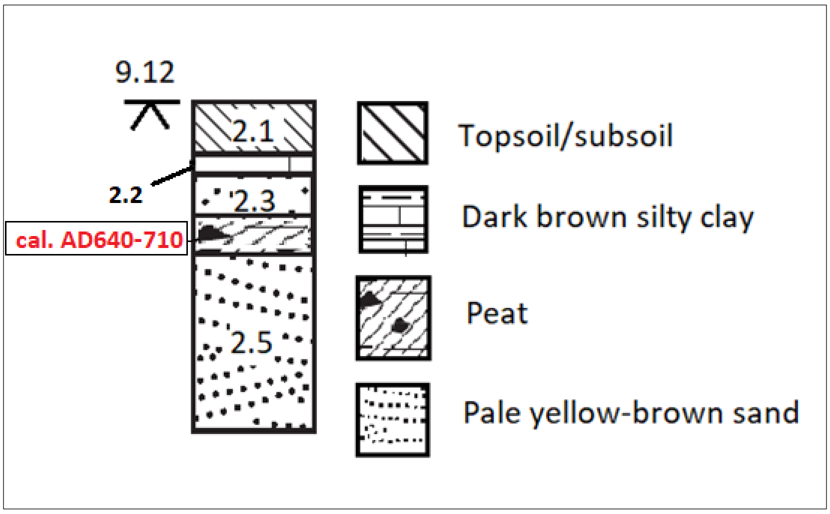

Figure 5.29. Pool Core 2 with radiocarbon date (in red).

5.6.11. OSL dates: discussion

Generally, the emission of bright luminescence signals from the deposits was fairly low, an occurrence which has been noted frequently in the Northern Isles context although this sensitivity varies by site (T. Kinnaird *pers. comm.*). Levels of sensitivity are governed by a number of factors, including the bleaching process during sediment transportation, water content of the sample, and the nature of the deposits surrounding the sample (Duller 2008). Many of the samples (1, 5, 8, and 12) displayed considerable errors ranging from a few centuries to over two millennia. In all of these cases, it is suggested that more credence is given to the associated radiocarbon dates which display low errors of <40 years. Nevertheless, there seem to be some broad patterns in the data with periods of sand movement during the earlier prehistoric period (possibly Neolithic-Early Bronze Age; samples 1 and 12), in later prehistory (samples 3 and 11), and the Early Medieval period (samples 2, 6, and 7). The total test pits and cores are shown together in Figure 5.32, with possible correlations shown in Figure 5.32.

5.6.12. Radiocarbon dates: discussion

Rangefinder radiocarbon dates only yield an 'average date' for the accumulation of a deposit. As such, they do not display more precise dates for the beginning and end of peat accumulation at this site. However, they do demonstrate and confirm that there were two phases of peat development in the landscape surrounding Pool (Figure 5.30); one in the Late Bronze Age-Early Iron Age, dated from samples in Test Pit 2 and Core 1 (1090-920 cal. BC (UBA-32509); 810-750 cal. BC (UBA-32512)), and one in the Late Iron Age-early Historic period dated from samples in Test Pits 2, 3, and 11, and Core 2 (cal. AD640-710 (UBA-32513); cal. AD660-780 (UBA-32513); cal. AD780-900 (UBA-32511) cal. AD860-1020 (UBA-32510)). Possible stratigraphic links are displayed in Figure 5.32. The early historic peat development and Early Medieval sand movement fit within a wider context of environmental deterioration in this chronological period, and confirm findings by Sommerville (2003; 2007) at other sites and landscapes across the northern island chain. More discussion on the significance of these results is presented in 5.7.

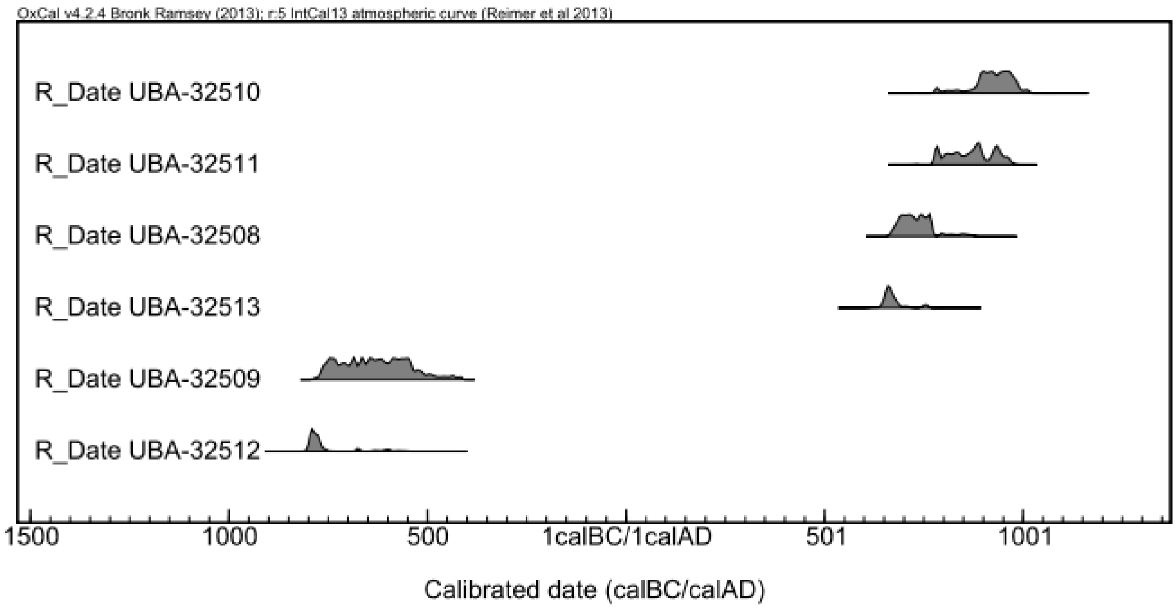

Figure 5.30. Calibrated date ranges for peat development at Pool

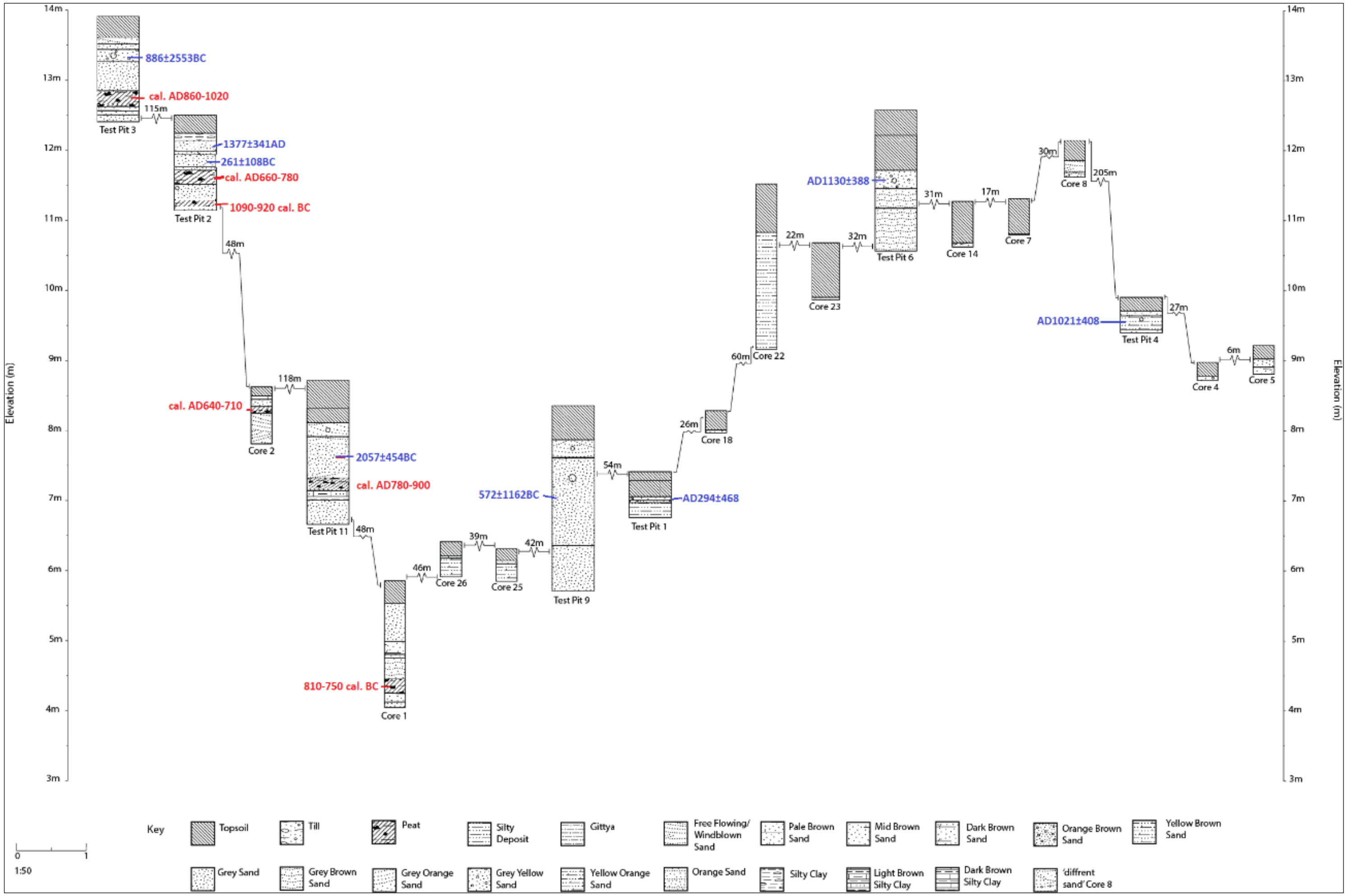

Figure 5.31. Schematic diagram of sampled test pits and core transects with radiocarbon dates in red, and OSL dates in blue.

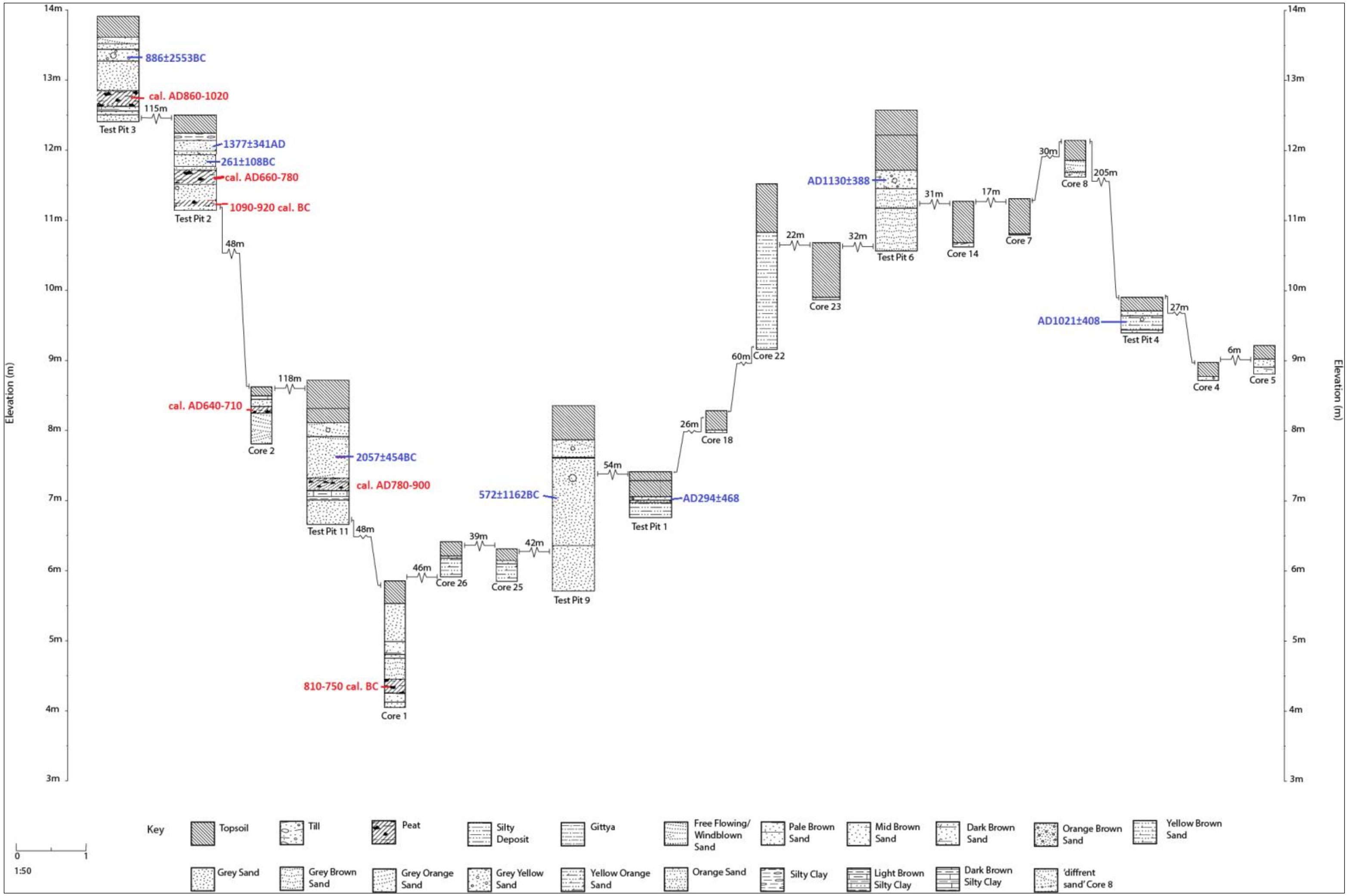

Figure 5.32. Schematic diagram suggesting possible relationships between dated deposits at Pool

5.7. Findings

5.7.1. Environmental change and settlement at Pool

The fieldwork at Pool reveals that the landscape was environmentally dynamic and prone to change both in the deeper and more recent past, and has raised interesting points for discussion. Stratified sequences of interbedded peats, organic silts and sands of over 3.5m in depth characterise Pool's immediate landscape context, indicative of changing local and regional palaeoenvironments. These deposits dominated the lower-lying boggy southern area, part of which is likely to have contained a freshwater loch covered by sand in the Late Iron Age (cal. AD530-670 (GU-2545)) (Bond, J. in Hunter, J. *et al.* 2007, 170-171).

Geophysical survey data auguring demonstrate that this stratigraphic sequence varies across the landscape, indicative of a complex environmental history with frequent episodes of sand mobilisation and subsequent erosion, redeposition and remodelling. This is evidenced by the piecemeal nature of the deposits, some of which survived only as pockets of material in sediment traps. These deposits often disappeared or faded out within a few metres. The development of peat between the sand layers may be indicative of a period of increasing wetness during which these organic deposits were rapidly formed. Sand grains recorded in some of the peat and clay-silt deposits (peat (106) in Core 1, and silt (604) in Test Pit 6) are indicative of an increase in sand mobilisation in a wetter, otherwise 'stable' environment prior to larger ingresses.

The dates for windblown sand and peat accumulation are discussed here, and their correlations with settlement periods at the site considered. From the available dating evidence (including the radiocarbon date yielded from the peat sampled by Hunter, J. *et al.* 2007), a case can be made for three episodes of increased windblown sand movement;

a). The Neolithic, over the archaeological site between Phases 2.1 and 2.2 (between 3889±303BC <SUTL-75a, 78a, 79, 82, 83> and 3606±282BC <SUTL-26, 27, 30, 35> (Spencer and Sanderson 2012, 3548-9), and between 2.2 and 2.3 (c. 3210-2935 cal. BC to 2815-2650 cal. BC (*start Phase 2.2-2.3; end Phase 2*) (Macsween et al. 2015, 15; Figure 9).

b). The Late Bronze Age-Late Iron Age, in the site's environs (Late Bronze Age-Late Iron Age; between 1090-920 cal. BC (UBA-32509) and AD660-780 (UBA-32508) (TP2)

c). The Late Iron Age-Norse period, in the site's environs between cal. AD660-780 (UBA-32508) and AD1377±341 <OSL-2> (TP2)

The problematic nature of the OSL dating results and their errors ensures that the Norse and Early Medieval dates are the only OSL dates which can be accepted with any confidence; any other dates are purely relative, provided by radiocarbon. As mentioned above, on consideration and weighing up of a). the radiocarbon dates for the contexts which bracket the sand deposited over the site at Pool and b). the OSL date yielded for the sand itself (2130±1204 BC, produced by the author), the author has chosen to err on the side of the radiocarbon date produced by Macsween *et al.* (2015) in this instance. The dates produced by various authors is again summarised in Table 77, with the author's OSL date added.

Two periods of peat accumulation were also identified;

a). In the Late Bronze Age-Early Iron Age, between c.1090-920 cal. BC (UBA-32509) and 810-750 cal. BC (UBA-32512);

b). In the Late Iron Age-early Historic period, between c. cal. AD640-710 (UBA-32513) and c. AD780-900 (UBA-32511) and likely to correspond with the peat identified by J. Bond during the original excavations.

The rangefinder dates can only give a broad chronological span for peat accumulation, but nevertheless they additionally offer some broad constraint to the deposition of sands above and below them; for example, sands in Test Pit 3 must have been deposited before and after cal. AD860-1020 (UBA-32510), while those in Test Pit 11 were deposited before and after cal. AD780-900 (UBA-32511). Those in Core 1 were deposited before and after 810-750 cal. BC (UBA-32512), and in Core 2 before and after cal. AD640-710 (UBA-32513)

Phase	**Activity**	**Hunter, J. *et al.* 2007 TL**	**Spencer and Sanderson 2012 TL**	**Macsween *et al.* 2015 radiocarbon, at 95% probability**	**Author 2018 (OSL)**
3.2.	Structures			2510–2395 cal. BC (*end 3.1/start 3.2*) to 2460–2280 cal. BC (*end Phase 3*)	
3.1.	Dark tips, structures	2235±262		2680–2515 cal. BC (*start Phase 3*) to 2510-2395 cal. BC (*end 3.1/start 3.2*)	
2.3.	Reddish-brown tips and structures	2255±140-2192±65	2162±133 <SUTL-11-13, 15-17, 20>	3210–2935 cal. BC (*start Phase 2.2-2.3*) to 2815–2650 cal. BC (93% probability; *end Phase 2*)	
	Sand (upper, later)				2130±1204BC <OSL-1>
2.2.	Reddish-brown tips	3544±157	3606±282 <SUTL-26, 27, 30, 35>		

Sand (lower, earlier)					
2.1.	Reddish-brown tips	3710±165	3889±303 <SUTL-75a, 78a, 79, 82, 83>		
1.2	Structures				
1.1	Dark tips	3643±145			

Table 77. Dates for the Neolithic phases of sand movement at Pool with new date produced by author included in the final column.

The Neolithic (Phases 1-3)

The date for the deposition of sand over the site at Pool is surrounded by some confusion, but it can at least be placed within the middle-later Neolithic. It has been suggested already that the sand dated by the author relates to the upper, later, sand deposit recorded by Hunter, J. *et al.* (2007). Even so, it is evident that this direct date does not fit particularly well with those already generated by other researchers for bracketing deposits. For example, the sand was dated indirectly by Macsween *et al.* to between c. 3210-2935 cal. BC and 2815-2650 cal. BC (*start Phase 2.2-2.3; end Phase 2*) (2015, 15). During the augur survey and subsequent test pit excavation and sampling in the landscape, the minerogenic sand encountered by Hunter, J. *et al.* (2007) over the site was not identified *around* the site. This may be the case for three reasons;

a). Test pits and augurs were not excavated to a level deep enough to identify the minerogenic sand in the surrounding landscape. Excavation through sand deposits was challenging, and the walls of many test pits collapsed after the removal of c. 1 metre's-worth of environmental deposits. An additional problem was the water table; excavation of test pits and auguring were undertaken in August when water tables are higher, and therefore flooding of the pits and augur holes was a frequent problem once a depth of c. 1.5m was reached. Unsurprisingly, this was particularly notable in the boggy area to the south of the site, which was unfortunately the area with the deepest environmental deposits and therefore holding potentially the most valuable information.

b). The Neolithic sand over the site was deposited by the occupants at the site, and not by wind. It may be that this sand was moved from elsewhere in the site or landscape (at a deeper level not reached by test pitting) and dumped in the excavated areas, perhaps as a levelling deposit. Given the sterile nature of the sand and its uniformity this seems unlikely, but is worth considering.

c). The Neolithic sands were once present in the landscape, but were eroded or subsumed by later sand deposits known to have been deposited in the Late Iron Age, Norse, and Early Medieval periods. They were therefore only preserved on the site itself as the tipping deposits of occupation material which characterised the Neolithic phases of activity at Pool were deposited directly above them soon after their deposition. In this case, the occupation deposits may have been laid down as stabilising deposits (see Chapter 6). This seems to be the most likely explanation, and attests to the frequent taphonomic problems encountered when dealing with windblown sediments.

The only evidence for some existence of windblown sand deposition in the landscape at Pool during the Neolithic is the high sand content of some of the greyish lenses within the burnt red tipping deposits characteristic of the Neolithic occupation phases at Pool. The red colour of these deposits appears to derive from the slow burning and smouldering of materials such as turf, which was presumably sourced within the landscape (Hunter, J. *et al.* 2007, 22). This was only visually identified during excavation, and further micromorphological study would elucidate the nature of these sand inclusions.

Following the second, later, sandblow (using Macsween *et al.*'s dates, this occurred between c. 2815–2650 cal. BC and 2680–2515 cal. BC, settlement focus seems to have shifted, and a change is evident in crop type from naked to hulled barley and a wider exploitation of the landscape (Hunter, J. *et al.* 2007, 73). The use of a new fuel source during Phase 3 was suggested following the identification of darker, greasier deposits with comparatively lower iron content above the reddish-brown tips. Although there is a visual and material distinction between the deposits, the components of this alternative fuel source are unknown (Hunter, J. *et al.* 2007, 38; 73).

This change in fuel source also appears to be reflected in the ceramic record. Studies of the thermoluminescent properties of the ceramics at Pool has suggested that there was a decline in the availability of higher temperature fuel (e.g. scrub, woodland sources and driftwood) after the Early Neolithic, and that there may have been more reliance on dung or peat from the Middle to Late Neolithic (Spencer and Sanderson 2012, 3548). Use of peat as fuel has also been observed at Meur, Sanday (Gardner 2017a; 2017b), and Links of Noltland, Westray (Hamlet 2014). This shift may have been due to the decline of woodland driven in part by over-exploitation and by strong winds and salt spray (e.g. stormy conditions), which inhibit tree growth (Caseldine and Whittington 1976; (Keatinge and Dickson 1979).

Focus of settlement activity appears to have changed following the sandblow; however, given their relatively small dimensions in thickness (in comparison, for instance, with the 1m sand horizon observed during the Tofts Ness excavations), it appears unlikely that the apparent hiatus in activity posited by the excavators was driven by a catastrophic event, despite Pool described as being "twice…completely subsumed under major sandblow events" (Hunter, J. *et al.* 2007, 516).

Rather, it illustrates the importance of recognising different spheres of activity within one site. It is likely that this sand deposit falls within a category representing evidence of *absence*. The perceived 'hiatus' in settlement at Pool, then, is more likely to represent a continuity of settlement elsewhere in the landscape or perhaps on part of the site itself which remains unexcavated, or which has since been eroded away by coastal processes. Macsween *et al.* have suggested that such a hiatus rather represents the "comings and goings" of settlement life at Pool, and therefore its continuing life cycle with a number of different trajectories (2015, 23).

This highlights the partial nature of excavation and therefore just how fragmentary our understanding might be, and the vagaries of sand deposition and the challenges in pinpointing chronologies. Some of the fundamental questions surrounding sand movement and why it may have driven abandonment can be re-explored from an alternative point of view; if numerous communities moved to other areas of the landscape during the same period, prior to sandblow, (therefore leaving an open, potentially robbed-out space in which sand could accumulate), *why* did the inhabitants leave, and where did they move to? Such patterns require further exploration as it is difficult to distinguish between settlement shift allowing sand accumulation, as opposed to sand accumulation forcing abandonment.

Pool's Neolithic phases are at least partially contemporary with a number of other important sites on Sanday and across the archipelago, with the changes at the settlement taking place within a wider context of social change, for example at Late Neolithic Barnhouse and Skara Brae (Mainland), Tofts Ness (North Sanday), and Links of Noltland (Westray) when settlements became much larger and aggregated (e.g. Jones 2005), and saw increasing sand mobilisation. Pool's Phases 1-3 developed alongside Tofts Ness Phase 1 (Figure 5.33) (3330–2910 cal. BC (*start Tofts Ness 1)* to 2880–2695 cal. BC (*end Tofts Ness 1*), and early Phase 2 (2855–2610 (*start Tofts Ness* 2), before Neolithic occupation ending in Phase 3 in 2460-2280 cal. BC (*end Phase 3*). Phase 2 occupation at Tofts Ness continued after Pool's had ended, with Tofts Ness Phase 2 modelled to 2120–545 (*end Tofts Ness 2*). This broad determination includes a Bronze Age 'hiatus' (see 4.8.1) (Dockrill *et al.* 2007; Bayliss *et al.* 2017 [Supplementary Material], 94). The contemporaneity with Tofts Ness is particularly significant as a possible Neolithic sand deposition episode took place at 2260±100BC <SUTL-602-3, 612-3, 616-7> (Sommerville 2003), although this determination is later than those for the sands at Pool.

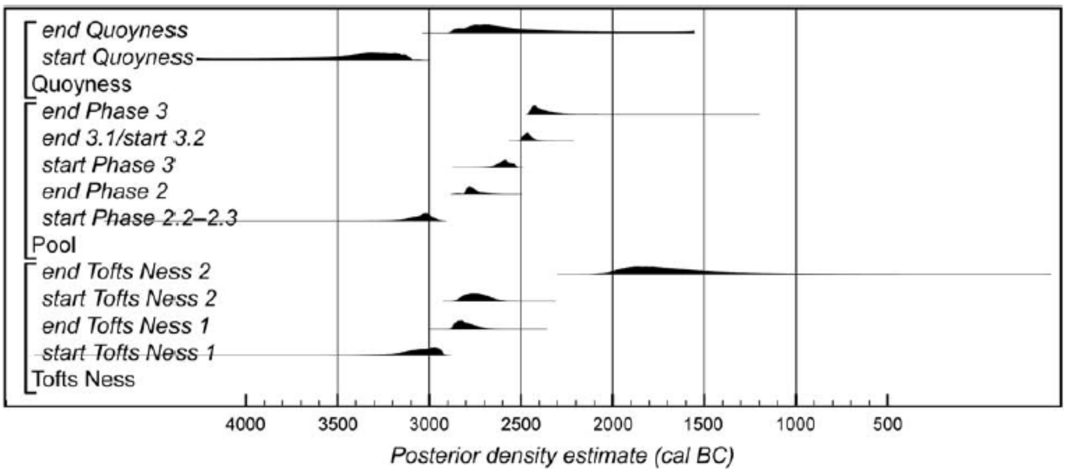

Figure 5.33. Key chronological parameters for the chronology of Neolithic Sanday devised by the Times of Their Lives project. Macsween et al. 2015, 22

The Bronze Age 'hiatus' (Phase 4)

During the Bronze Age, there was a cessation of activity in excavated areas of the Pool, perhaps for as long as two-three millennia (covering the latest Neolithic, Bronze Age, and earlier Iron Age) (Phase 4). No dates are available for this phase. Macsween *et al.* date the end of the Neolithic Phase 3 at Pool to 2460–2280 cal. BC (*end Phase 3*) (2015, 15). This phase can be further separated into 4.1 and 4.2. 4.1 is represented by turf horizons which were largely devoid of any anthropogenically-derived material including charcoal flecks, with any material almost certainly being residual in nature and related to a previous phase of activity. This is indicative of a natural formation process for the turf horizon following the ceasing of activity in the later 3rd millennium BC. Phase 4.2 has evidence for some activity during the abandonment, comprising a series of features constructed following the development of the abandonment horizon to the south of the site (two lengths of walling, interpreted as boundary in nature) (Hunter, J. *et al.* 2007, 60). This again indicates that settlement trajectories may have simply shifted to another area of the site or landscape.

None of the windblown sand deposits sampled in the landscape at Pool could be reliably dated to the Bronze Age by OSL. There was, however, development of peat around the site during the Late Bronze Age-Early Iron Age, around c.1090-920 cal. BC (UBA-32509). In Test Pit 2 this dated peat was overlain by sand, which was in turn overlain by a peat dated to AD660-780 (UBA-32508), suggesting that sand mobilisation did take place within this broad gap. There is therefore a 'gap' in terms of dated environmental material between the deposition of the Neolithic sand at the site, and the development of Bronze Age-Iron Age peat in the landscape, during which the environmental context is unclear. As seen in Chapter 4, buildings which had ceased to be occupied were 'prime candidates' for sand deposition, with sand free to infiltrate deroofed and robbed-out buildings. This does not seem to have been the case with the Neolithic remains at Pool.

*The Iron Age (Phases 5 and 6***)**

Activity resumed at Pool in the Late Iron Age, with the advent of Phase 5 dated by five thermoluminescence dates to c. 240±70AD. Phase 6 has been dated to the 3rd-8/9th centuries cal. AD (spanning at least cal. AD200-800 (GU-2244) to cal. AD610-870 (GU-2001), with contraction and decline of Iron Age settlement in the 8th-9th centuries. Phase 5 saw the occupation of three new structures over the Neolithic remains and the turf horizon, which were remodelled as part of settlement intensification and expansion in Phase 6. There is peat development in the landscape which spans the occupation of Phases 6 and 7, between c. cal. AD640-710 (UBA-32513) and c. AD780-900 (UBA-32511) and likely to correspond with the peat identified by J. Bond during the original excavations (cal. AD AD530-670 (GU-2545)), which appeared to have accumulating with the deposition of calcareous sand late in the site's Iron Age occupation. Evidence of this sand was not identified by the excavators on the site itself.

While no bioarchaeological evidence is offered for the Phase 5 occupation (Bond, J. in Hunter, J. *et al.* 2007, 186-9), the Phase 6 bioarchaeological data demonstrates some diversity in economic activity from the Neolithic. New weeds indicative of sandy soils and summer grain fields were identified, whereas the Neolithic period weeds characteristic of acidic and damp soil appear to have declined. However, it is also in this period that we get the accumulation of a peat deposit (generally recognised as representing wetter conditions). This presents an interesting conflict. Overall it appears that soils did become sandier either due to increased sandblow through climatic/environmental factors or increased disturbance from ard ploughing. This is at odds with the excavated archaeological evidence at the site itself, which only accounts for episodes of increased sand mobilisation in the Neolithic period. It begs the question; if sand was deposited across the landscape during occupation of the site, why was it not identified at the site? This could be explained in a number of ways;

a). The site was protected from the worst of the sand mobilisation and deposition by banks or walling not identified during the excavation. Alternatively, a true absence of banks or walls may have meant that any sand was blown off the exposed mound.

b). In a related vein, sand was deposited at the site, but occurred in very small quantities which were not visually identified by the excavators. Micromorphology would help to clarify this.

The increase in sandy soil-based plants may also be indicative of diversification in geographical terms, with sandier land being taken into cultivation as opposed to existing soil qualities changing. Such soils would have required manuring if they were to support barley cultivation (Bond, J. in Hunter, J. *et al.* 2007, 190), but currently there is no direct evidence for this due to the partial nature of the excavation.

Archaeological investigations at Tofts Ness revealed that this site was also covered with coastal sands during its later prehistoric occupation, albeit at a later date, when Pool appears to have been uninhabited. Phase 5 at Tofts Ness (later Bronze Age) is represented by a layer of white wind-blown sand across Settlement Mound 11, reaching over 1m in depth (see 4.8.1). This sand layer sealed the surrounding arable fields, thus appearing to represent an extensive, singular event. TL dates from the last use of a Phase 4 hearth provide a *terminus post quem* for this sand deposition, which should have taken place after the 11^{th}-9^{th} centuries BC. Settlement phases 4 (Late Bronze Age) and 6 (Early Iron Age) are stratigraphically separated by this event (Sommerville 2003; Dockrill *et al.* 2007). This demonstrates the variable nature of sand deposition across a single island.

The interface period (Late Iron Age-Norse, Phase 7).

The period has been described as the interface between native and Scandinavian cultures (Hunter, J. *et al.* 2007, 122), lasting from c. the 5^{th}-9^{th}/10^{th} centuries cal. AD with radiocarbon determinations spanning cal. AD430-650 (GU-1998) (7.1), and 810-1030 (GU-2005) (7.2). A tension between Iron Age/Pictish and Scandinavian traditions was observed in architecture and material culture, with extensive remodelling of the Iron Age settlement (and the construction of the long, sub-rectangular Structure 25) and the appearance of steatite (2007, 122-3).

The stratigraphy in Test Pit 2 suggests that a period of increased windblown sand movement took place between cal. AD660-780 (UBA-32508) and into the Norse period (see below, 'Phase 8'). This is a view enhanced by the environmental evidence, as a distinctive crop-based change also occurred in Phase 7 with the introduction of flax. There appears to have been an increase on nitrogen-dependent plants and those which thrived in lighter, sandier soils. Again, it may be that poorer land was taken into cultivation as opposed to the changing of original soils. Oats are capable of growing in poorer-quality soils whereas flax and barley require better-quality soils (Bond, J. in Hunter, J. *et al.* 2007, 190). Overall, cereal cultivation appears to have increased and intensified into the Norse period, likely because of changing soil quality. This may suggest that the inhabitants at this site and others like it chose to diversify and alter their economic practices over time while making use of existing structures and occupation deposits, rather than leave a settlement or landscape which had been occupied and invested in by their long-standing, perhaps also ancestral, community.

Phase 8. Early 10th-late 12th/early 13th century.

Phase 8 saw the expansion and full height of Norse activity at the site, concentrated on the Structure 29 longhouse. During 8.2 diagnostic material culture became almost entirely Scandinavian in character with the exception of the pottery assemblages which continued to include Iron Age pottery which Hunter argues were not residual (Hunter, J. *et al.* 2007, 148). Structure 29 lay at the apex of the Neolithic mound, and perhaps a deliberate decision by the Norse inhabitants (see Harrison 2016 for discussion of Norse 'mound' architecture). Only two radiocarbon determinations, both on bulk mixed animal bone, are available for this phase. As previously discussed, bulk bone samples can yield problematic dates; nevertheless, these determinations appear to be quite useful. Bone from the foundations of Structure 29 yielded a determination for Phase 8.2.2. of cal. AD970-1190 (GU-1806) for its construction, while bone from a midden sealing the wall of Structure 29 yielded a determination of 1020-1220 cal. BC (GU-1808) for Phase 8.2.3, marking the final occupation of the excavated area which indeed appears to have ceased around the later 12th-early 13th centuries cal. AD.

Two OSL determinations for sand movement offer a range fitting with the end of Phase 8 occupation; AD1020±408 <OSL6, TP4>, and AD1377±341 <OSL2, TP2>, and as discussed in 5.6, are likely to represent the same event Again, a lack of evidence for this sand at the site itself makes it impossible to correlate the deposition of this sand with the cessation of activity at the site. However, a continuation of environmental trends observed in Phase 7 are seen in Phase 8, and may support the dating evidence for increased sand mobilisation in this period. Further increases in plants which thrived in sandy and well fertilised soils were identified, perhaps attesting to the existence of managed infields outwith the excavated area. Production of barley as well as flax intensified, and by all accounts, contributed to a successful and productive economic basis for the site. It has already been noted that Structure 29 lay at the apex of the Neolithic mound, which was perhaps a deliberate decision by the Norse inhabitants to display prestige and the fertility of this location which had been inhabited over deep timescales (see Harrison 2016 for discussion of Norse ‘mound’ architecture and accumulation histories).

Given its size and the depth of deposits, the site at Pool could be compared to other large, deeply-stratified settlement mounds on Sanday. Some of these sites, many of which would appear to be later in date (e.g. Early Medieval/Historic-c. 7th-13th centuries) have been identified as a particular monument type – the ‘farm mound’, characterised primarily by deep accumulations of midden and agricultural waste material. This settlement phenomenon is particularly visible on Sanday, which holds at least 15 such sites including Langskaill, Westbrough and Skelbrae (Lamb, R. G. 1980, 7; Davidson *et al.* 1986, 45) (Figure 5.34). Given that comparatively few of these sites have been subject to sustained archaeological investigation, it seems likely that some will not fit into a ‘farm mound’ category as there are clearly some significant differences between the sites. On the broad scale, however, their significant depth of occupation in a specific location could indeed distinguish them from other site types on the island. It is important to consider these deep accumulations of settlement material in any discussion of settlement on the island, where there is a particularly high concentration. Although they cannot be directly linked as a site type given the chronological disparity, prehistoric/Norse sites like Pool can be compared with the farm mounds thematically and geographically. Longterm occupation and the persistent use of coastal landscapes often dominated by widespread shell sand deposits are features characteristic of both site types, and attests to the cultural significance of these environments.

Sommerville argued for a lack of sand movement in Orkney during the Norse period, suggesting that this was the case due to an amelioration in climate between the 10th-12th centuries AD, and into the Medieval period (c. AD1100-1500) prior to the Little Ice Age (Sommerville 2003, 350). However, alongside those at Pool this thesis has identified numerous examples of extensive sand mobilisation in the Norse-Viking periods, particularly in Mainland Orkney in the bays of Skaill and Birsay, and at Deerness (Chapter 4). If there was indeed a broad-scale amelioration in climate during these periods, this is yet another thread of support for the notion that increased sand movement cannot be solely attributed to increases in storminess, but more likely was driven by periods of colonisation and intensification of agriculture and other activities in sand landscapes.

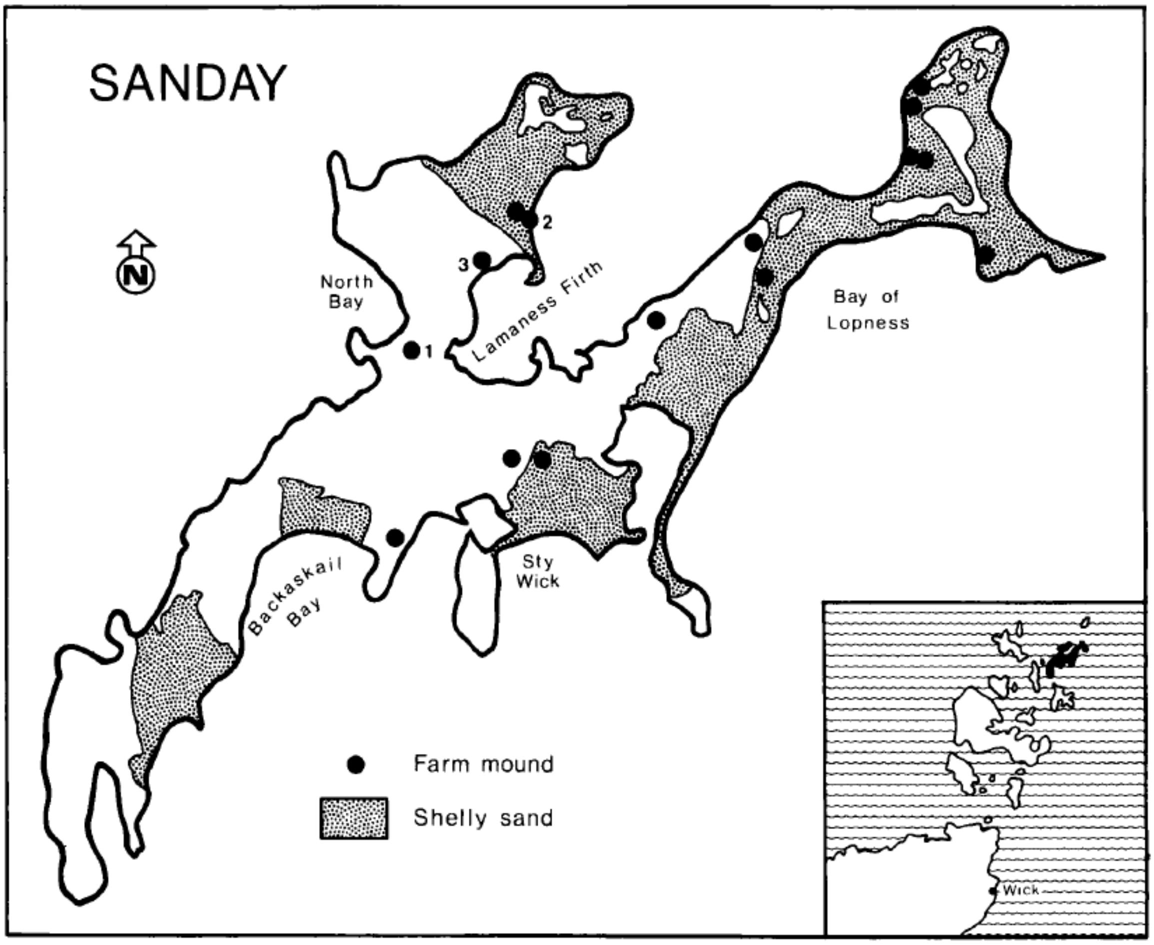

Figure 5.34. Distribution of farm mound sites and large shell sand deposits on Sanday, notably Westbrough (1), Langskaill (2) and Skelbrae (3). After Davidson et al. 1986, 46.

5.7.2. Outcomes

Multiperiod sites like Pool are ideally-situated for approaching increasingly pertinent and challenging questions surrounding human-environment interactions. The fieldwork was undertaken in order to further explore some of the interpretational issues currently faced by excavators when windblown sand is encountered at archaeological sites and landscapes. The Pool fieldwork project also fits within the wider thesis by contributing to the answering of Research Question 4 ('Did coastal sand movement have a notable impact on contemporary prehistoric settlements?'). The answer to this question ultimately varies on a site-by-site basis, but some broad conclusions can be drawn here in relation to the site at Pool.

As the fieldwork project and post-processing developed, the complexity of human interactions with sand and the difficulty of interpreting the taphonomy of windblown sand were realised. The first recorded episode of windblown sand deposition at Pool is dated to the Neolithic period, comprising two layers of minerogenic sand encountered across the site's Neolithic phases during John Hunter's excavations. Confusion arose when the author of this thesis was unable to locate this sand in the wider landscape. The possible reasons for this are discussed above, in 5.7.1. Broadly contemporary ceasing of Neolithic activity at Tofts Ness, Skara Brae, and a host of other Grooved Ware settlements have been identified – with the original excavators of Skara Brae, and Tofts Ness, for instance, suggesting that windblown sand ingresses may have been responsible for these perceived hiatuses or ending of activity. This does not appear to be the case for Pool, and suggests that a different driver behind the cultural changes at the end of the Neolithic must be explored. As noted at the end of Chapter 4, the Neolithic occupation of the Sanday sites of Pool, Tofts Ness and Stove (located at the far south of Sanday, and contained no sand deposits (Bond, J. *et al.* 1995)) is interesting in that unlike Skara Brae, Links of Noltland, and Green (as well as Cata Sand, North Sanday), the settlements were founded directly over till as opposed to extensive earlier sand deposits. The landscape would have looked distinctly different to the earlier settlers, and conceived of in a different way.

No sand deposits were identified in the landscape which could be convincingly dated to the Bronze Age (when there was a hiatus at Pool (Phase 4)) – a period traditionally associated with significant climatic deterioration (e.g. Farrell 2009). However, occupation at Pool was wholly or partially contemporary with other sites (such as Links of Noltland, Westray, and Tofts Ness, Sanday), which experienced *multiple* episodes of sand deposition across the Neolithic-Bronze Age periods. This suggests that the driver behind this hiatus in activity at Pool was not climatically driven, and that the landscape was still habitable and profitable – this was a cultural choice.

The landscape surrounding the site at Pool does, however, contain palaeoenvironmental evidence for a number of *later* episodes of windblown sand deposition, with deposits measuring from c. 0.10 to >0.40m in depth. The deposition of the Late Iron Age and Norse sands was contemporary with the Phase 6-8 occupation at the site, although there was no evidence for these sands on the excavated areas of the site. The bioarchaeological evidence for these phases appears to be in line with the evidence for Iron Age and Norse episodes of sand movement, with higher percentages of plants which thrived in sandy soils being noted for these phases. The results of this study raised two significant interpretative issues alluded to at the beginning of the thesis; firstly, that the deposition of windblown sand is highly locally-variable, changing varies across relatively small stretches of coastline. This makes any attempts at correlation with broader proxy evidence for environmental change very difficult to sustain. This is discussed further in Chapter 6. Secondly, that these episodes of sand deposition, the bioarchaeological and archaeological material more generally suggests that agricultural production was both productive and sustainable, and although no direct evidence for this was identified, it is likely that similar manuring and soil improvement practices were taking place at Pool. This adds to the growing evidence that sand deposition was a well-recognised – and remembered - occurrence which could be mitigated against. It was part of dwelling at the coast, and formed a key facet daily life and interactions in coastal spheres of activity.

The presence of calcareous and mineral sands is indicative of multiple sand sources, raising interesting questions about provenance which are unfortunately difficult to answer. It is likely that the source for the Neolithic minerogenic sand deposited at the site <OSL-1> is now located offshore (T. Kinnaird *pers. comm.*) and that the remaining calcareous sands derive from reworked dune deposits, which were frequently mobilised and established as a key onshore sediment source after sea levels reached their current height in the Neolithic. Consideration of Pool's wider landscape context (Figure 5.4) suggests that these calcareous sands were probably originally mobilised from the extensive sand dunes to the rear of the bays at Quoyness (where the site at Quoy Ness is located – see Appendix 1) and Dounhelzie, from a northeasterly direction with smaller-scale mobilisation then taking place within the landscape once the sand had colonised.

Another key outcome of the field project was an enhanced recognition of the problematic nature of OSL dating, first alluded to in Chapter 4. The OSL dates for the sands at Pool were generally unreliable and inaccurate, with error ranges so large that they encompassed multiple periods. It is pertinent to reflect on whether OSL dating is the best technique to employ on windblown sand. While it can offer a means of dating sediments in the absence of organic material for radiocarbon dating, it relies on key assumptions which are problematic when the nuances of weather are considered. The technique dates a sediment's last exposure to light, and relies on its 'clock' having been totally reset following extensive bleaching – the event which is being dated. If these sediments are not fully bleached (e.g. exposed to light), large error ranges occur. Uncertainty arises here, as many storms and winds strong enough to mobilise sand take place in reduced light conditions, which might affect the level of bleaching which is able to take place. The comparative success of the radiocarbon dating portion of the project advocates for its use alongside, or instead of, OSL dating wherever possible.

The landscape at Pool was inhabited for around five millennia, during which time numerous environmental changes took place. It is interesting to note that on two occasions (in the Decembers of 1921 and 1939), exceptionally high tides rose up to the farmstead and burst through the interior, forcing the inhabitants to temporarily evacuate (Hunter, J. *et al.* 2007, 523). It is tempting to consider whether similar events may have occurred in the earlier occupation periods at Pool, and is a reminder that responses are diverse, and their minutiae not always archaeologically visible.

Chapter 6. Windblown sand deposition in prehistoric Orkney.

6.1. Comparison with environmental proxies

A key facet of this project was the development of a database which gathered all known archaeological sites in Orkney which contained stratified windblown sand deposits. This was undertaken in order to answer Research Questions 1 and 2, which asked;

1. What is our current state of understanding of the nature and geographical extent of blown sand deposits?
2. Can regional or chronological variation in patterns of sand movement be detected, and how does this fit within proxy evidence for northwest European storminess?

These questions are addressed here and in Chapter 7. These sites are summarised in Chapter 4. Fifty-three sites (across all periods) now make up the previously-limited dataset. Whereas the summaries of the sites in Chapter 4 were presented island-by-island, here discussion will take the form of a chronological summary of Neolithic-Iron Age incidents of windblown sand deposition included in the database (Table 78; Table 79; Table 80). Some incidents of windblown sand accumulation are more tightly-constrained chronologically than others, and dates or rationale behind dating periods given Chapter 4. Multiperiod sites which display evidence for more than one period of windblown sand deposition feature more than once; the chronology of the site (for example, single period, multiperiod) is specified in the tables below. The schematic diagrams (Figure 6.1; Figure 6.2; Figure 6.3) show a selection of dated sites and their correlation with key environmental proxies.

6.1.1. The Neolithic (c. 4000-c. 1900 BC)

Site	Island	Site type	Period	Period of human activity	Sandblow date	Dating method	Reference
Links of Noltland	Westray	Settlement	Neolithic-Bronze Age	Late Neolithic (from c. 3160–2870 to 2170–1840 cal. BC (start_LoN; end_LoN); Bronze Age (from c. 2170–1840 cal. BC (end_LoN)) – until c. 1000 BC.	Late Neolithic. Trench D: from at least 3160–2870 cal. BC until 2850–2640 cal. BC ((*last_Phase_II*); between 2230-2130 cal. BC (*Red_deer*), and 2200-1930 cal. BC (*last_Trench_D*) (Clarke *et al*. 2017, 72; Illustration 11); Trench A: after 2470-2140 cal. BC (GU-1433) and 2480-2135 cal. BC (GU-1692), perhaps until 2470–2005 cal. BC (GU-1695) (Marshall *et al.* 2016, 29; Table 4).	Radiocarbon	Clarke *et al*. 2017; Marshall *et al.* 2016; Moore and Wilson 2009; 2015; 2017
Pool	Sanday	Settlement	Neolithic; Late Iron Age-Norse	Neolithic-Norse (with Late Bronze Age-Early Iron Age hiatus in Phase 4) (from at least 3210–2935 cal. BC (*start Phase 2.2-2.3*) to 2460-2280 cal. BC (*end Phase 3*); from at least cal. AD 200-	Between 3889±303BC <SUTL-75a, 78a, 79, 82, 83> and 3606±282BC <SUTL-26, 27, 30, 35>, and between c. 3210-2935 cal. BC to 2815-2650 cal. BC (*start Phase 2.2-2.3; end Phase 2*)	Radiocarbon OSL TL	Hunter *et al.* 2007; Macsween *et al.* 2015; Spencer and Sanderson 2012

				800 (GU-2244) to c. 1020-1220 (GU-1808)			
St Boniface	Papa Westray	Settlement	Neolithic-Norse/Medieval	Middle Neolithic (c. 3020-2700 cal. BC(AA-9561) to Norse/Medieval (c. cal. AD1010-1280 (GU-3069c)	Early-Middle Neolithic (3020-2700 cal. BC(AA-9561)	Radiocarbon	Lowe 1988
Knap of Howar	Papa Westray	Settlement	Early Neolithic	Early Neolithic (From c. 3635-3370 cal. BC (*start_knap_of_howar*) to c. 3305-2835 cal. BC (*end_knap_of_howar*).	Early Neolithic (Between c. 3635-3370 cal. BC (*start_knap_of_howar*) and 3345-3020 cal. BC (OxA-16476) (Bayliss et al. 2017 [Supplementary Material], 14; 19); after c. 3500-2850 cal. BC.	Radiocarbon	Ritchie 1983; Bayliss *et al.* 2017
Meur	Sanday	Well, pre-burnt mound	Neolithic-Iron Age	Early-Late Neolithic (from at least 3336-3023 cal. BC (GU-41721)	Neolithic (c. 2475-2299 cal. BC (GU-36668))	Radiocarbon	Gardner 2017a; 2017b
Skara Brae	Mainland	Settlement	Late Neolithic	Late Neolithic; 2920-2885 cal. BC - 2545-2440 cal. BC (*central_phase_1_start; central_phase_2_end*)	Early-Middle Neolithic (before 3350-3020 cal. BC (SUERC-12717 (GU14731)); Late Neolithic (at c. 2920-2690 cal. BC (SUERC-12733 (GU14741)); from c. 2870–2815 cal. BC to c. 2840-2685 cal. BC (*central_phase_1_end; central_phase_2_start*); at c. 2620-2460 cal. BC (SUERC-12470 (GU14686)); after	Radiocarbon	Clarke, D. V. 1976a and b; Simpson *et al.* 2006; Bayliss *et al.* 2017

					2545-2440 cal. BC (*central_phase_2_end*).		
Point of Buckquoy Area 6	Mainland	Settlement	Neolithic-Late Bronze Age; Pictish-Modern	Late Neolithic-Early Bronze Age (from at least 2630-2180 cal. BC (GU-1557)); Pictish-Modern (c. 9^{th}-10^{th} centuries AD to 18^{th}-19^{th} centuries AD)	Late Neolithic-Early Bronze Age (around 2630-1690 cal. BC (GU-1557; GU-1640)	Radiocarbon	Morris *et al.* 1989
Point of Buckquoy Cuttings 5 and 6	Mainland	Midden, structures	Neolithic-Late Bronze Age; Pictish-Modern	Late Neolithic-Early Bronze Age (from at least c. 2150-2000 cal. BC (*Boundary start_cutting_6*)); unknown historic	Late Neolithic-Early Bronze Age (before c. 2150-2000 cal. BC (*Boundary start_cutting_6*) to c. 1600-1400 cal. BC (*Boundary end_cutting_6*; Marshall *et al.* 2016, 14).	Radiocarbon	Morris *et al.* 1989 Marshall *et al.* 2016
Tofts Ness	Sanday	Settlement	Neolithic; Iron Age	3330–2910 cal. BC (*start Tofts Ness 1*) to 2120–545 cal. BC (*end Tofts Ness 2*) with Bronze Age 'hiatus' (Bayliss *et al.* 2017 [Supplementary Material], 94).	2260±100BC <SUTL-602-3, 612-3, 616-7>	OSL	Sommerville 2003; Dockrill *et al.* 2007
Cata Sand	Sanday	Settlement	Early Neolithic	Early Neolithic	Early Neolithic	No scientific dates published	Cummings *et al.* 2016; 2017; 2018
Ring of Brodgar	Mainland	Monument	Late Neolithic-Bronze Age	Late Neolithic (completed at c. 2750-2210 cal. BC)	2191±200 BC <SUTL-2281>	OSL	D. Sanderson *pers. comm.*;

							Bayliss et al. 2017
Ness of Brodgar	Mainland	Settlement	Late Neolithic	Late Neolithic (From c. 3065-2950 cal. BC to c. 2285-2100 cal. BC	?Late Neolithic	-	Card *et al.* 2017; D. Sanderson *pers. comm.*
Green	Eday	Settlement	Neolithic	Early-Middle Neolithic (Before 3340-3020 cal. BC (OxA-28864))	Early Neolithic-Late Neolithic (From c. 4045-3365 cal. BC to c. 3320–2520 cal. BC)	Radiocarbon	Miles 2008a; Griffiths, S. 2016.

Table 78. Episodes of Neolithic sand deposition

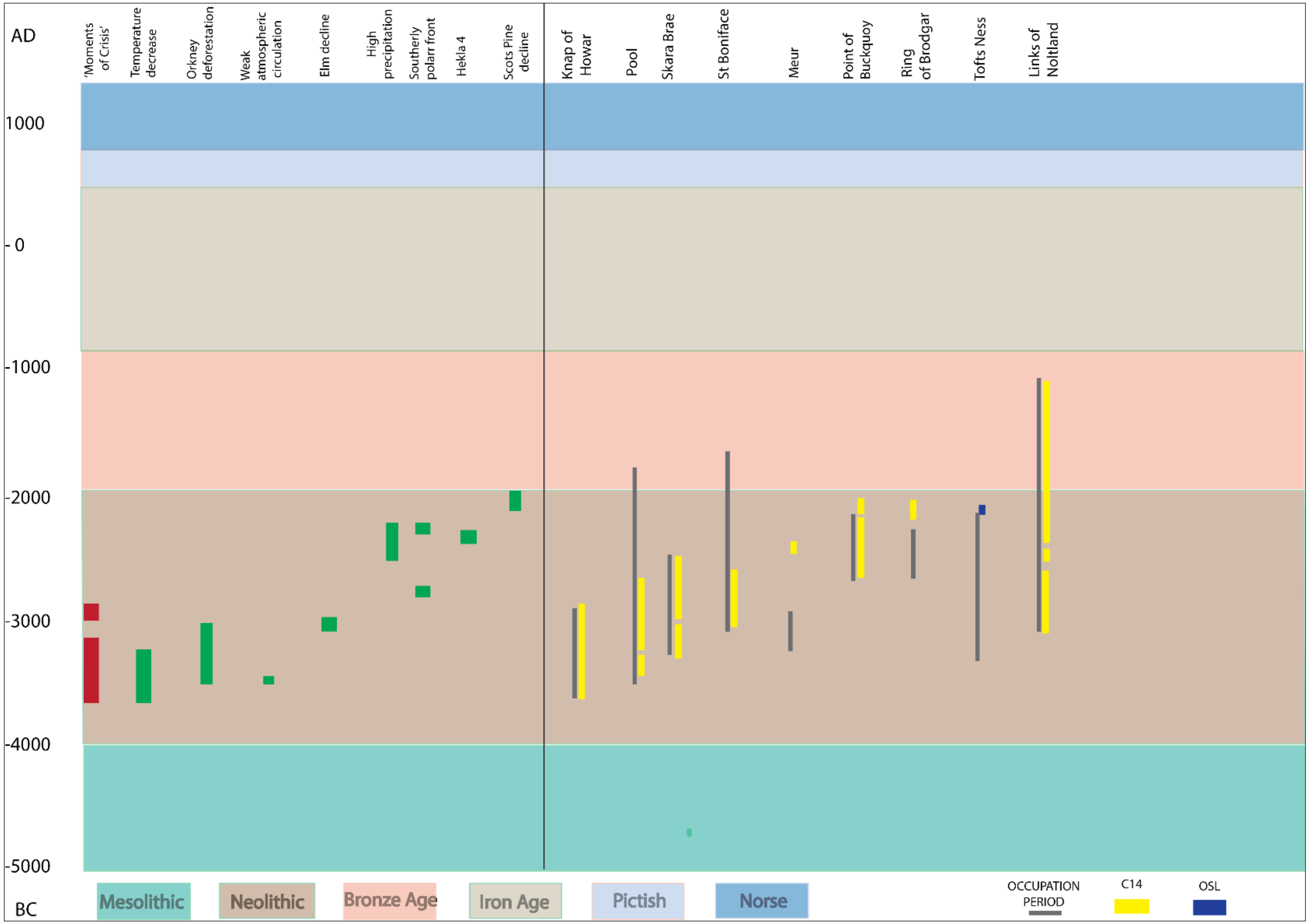

Figure 6.1. Schematic Neolithic timeline diagram. Selected climate proxies mentioned in text to left and episodes of Neolithic occupation and dated windblown sand deposition to right.

Notably, Sommerville's thesis states that there was a lack of evidence for Neolithic episodes of sand deposition (2003, 245). More recent excavations since this work - and a closer analysis of the existing evidence - have changed this picture. Indeed, the list of windblown sand horizons dating to the Neolithic period is now one of the most extensive (Table 78). A total of thirteen sites across five islands hold datable evidence for windblown sand deposition during the Neolithic period (Table 78). All but two (Meur, Sanday and Ring of Brodgar, Mainland Orkney) are settlement sites. This may reflect a wider bias towards the excavation of settlement sites in particular.

The earliest identified sand incursions took place across the northern Orkney Islands, on Westray, Papa Westray, and Sanday. The earliest known incidence of windblown sand deposition on a Neolithic site occurred at the Knap of Howar, where regular incursions took place from c. 3635-3370 cal. BC (*start_knap_of_howar*). The latest identified is that at Links of Noltland Trench D, between 2230-2130 cal. BC (*Red_deer*), and 2200-1930 cal. BC (*last_Trench_D*) (Marshall *et al*. 2016). Three of the Neolithic category sites contain windblown sand deposits which are not securely dated, although it is suggested that they can be broadly assigned to the Neolithic period based on stratigraphic position: Ness of Brodgar (Mainland Orkney), Green (Eday), Cata Sand (Sanday). The majority of identified sand mobilisation clusters in the later Neolithic, although notable incursions also took place towards the latest phases of the Neolithic (Figure 6.1). In most cases, these sand deposits appear to represent cumulative processes as opposed to the result of a single event, with some sites (such as the Links of Noltland and Skara Brae) being exposed to regular sand movements as evidenced by multiple thin lenses identified in extensive midden deposits.

Climatic context

Early Neolithic (c. 4000-3000 cal. BC)

Although the Neolithic is generally recognised as being fairly temperate (e.g. Karlen and Larsson 2007), a number of climate proxy studies have been cited which appear to demonstrate some downturn throughout the period at varying temporal and geographical scales (Figure 6.1). Most of these studies are at the northwest European scale. From c. 4000BC, proxy studies suggest that climatic conditions in north-west Europe appear to have noticeably deteriorated (Tipping 1994). Temperatures fell, gradually at first followed by a steeper fall at c. 3650-3200 cal. BC (Lu2577) (Stuiver and Becker 1993) in Scandinavia (Grudd *et al.* 2002; Helama *et al.* 2002), with a weakening in atmospheric circulation at c. 3400 cal. BC (see Bond, G. C. *et al.* 2001 for full suite of determinations). Storm-derived dune-building events on Irish coasts and elsewhere were noted at c. 3200-3100 cal. BC (WK-11687; Beta-175939) (Caseldine *et al.* 2005; Holmes *et al.* 2007), with tree-ring sequences from in situ bog pine macrofossils suggesting that drier soils allowing pine growth on Northern Scottish blanket peat c. 3200-3000 BC (Moir *et al.* 2010).

Climatic fluctuations during the Neolithic are generally identified in woodland cover fluctuations (Tipping 1994), and as such this remains a key strand of palaeoecological evidence. The earlier Neolithic environmental record in Scotland is most widely characterised and framed by the mid-Holocene elm decline, which began fairly rapidly in the British Isles and Europe from c. 3000BC and stretched across northern Europe, although its synchronicity is variable (see Tipping 1994, 18-21; Parker *et al.* 2002, 3). Although the exact causes behind the decline have been debated, it seems likely that it was the interplay of climatic impacts and human activity which caused the decline, as is likely the case with other incidences of woodland cover fluctuation (Bell and Walker 1992, 162-3; Barclay 2003, 141; Parker *et al.* 2002).

The interplay between human and climate impacts is fairly well-documented in Orkney's palaeoecological record for the Neolithic period, and pollen data remains as one of the most detailed sources for this period. The majority of field data comes from Mainland Orkney, although data from other islands is increasing (e.g. Farrell 2009). Increases in vegetation clearance and other activities linked to increases in reliance on an agricultural economy appear to be the drivers behind a number of declines in pollen count. On Mainland, the landscape appears to have been devoid of tree cover by the middle of the Neolithic (Farrell 2009, 123). Woodland appears to have started declining at c. 3950 cal. BC in some areas, with further decline of birch-hazel scrub woodland at c.3500-3000 cal. BC (see publications below for various lab codes), being replaced by more open vegetation. This pattern has been observed at Glims Moss, Loch of Skaill and Pow (Keatinge and Dickson 1979, 604-5), at Quoyloo Meadow (Bunting 1994; 787-90), Scapa Bay (de la Vega-Leinert *et al.* 2007, 767) and later at Crudale Meadow (4300-3700 cal. BC (no lab code given) although there are some issues with the chronologies of the sequences at Loch of Skaill and Quoyloo meadow (Farrell 2009, 122-3).

Late Neolithic: c. 3000-2000 cal. BC.

At c. 3000/2900-c.2700 cal. BC (Keatinge and Dickson 1979), the climate became wetter and stormier with significant levels of aeolian transport (Tipping *et al.* 2012). From c. 3000 cal. BC, higher water content in soils appears to have resulted in slowed and stunted pine growth in northern Scotland. Further increases in dune-building are noted at c. 2800-2400 cal. BC (LuS 6451) in southwest Scandinavia (de Jong *et al.* 2009), after c. 2300 BC with a peak at c. 2200-2100 BC in Denmark (Bjork and Clemmensen 2004; Karlen and Larsson 2007; Tipping *et al.* 2012, 12). 2500-2200 is marked by a far wetter general climate (Barber, K. E. *et al.* 1994; Anderson, D. E. *et al.* 1998; Charman *et al.* 2006). In terms of woodland cover and available resources, traditional perspectives have presented Orkney as having been largely deforested as a result of agricultural development by c. 3500 BC. However, it is now clear that woodland decline was not synchronous across the islands, with some woodland stretching into the Bronze Age (Farrell 2009; Farrell *et al.* 2012, 8-10).

The decline of Scots pine (*Pinus sylvestris*) in northern Scotland (c.2000 BC) stands as a significant palaeoecological change on a relatively local scale, and provides a record of a northern Europe-wide climatic deterioration. The decline has been attributed in part to the Hekla 4 eruption in Iceland (Blackford *et al.* 1992), where either acidic ash fallout affected pine pollen counts, or as a negative climatic result of eruption more generally, leading to cooler and wetter conditions.

Correlations

Citing many of the above proxy records, it is during the period c.3600-c.3300 cal. BC that Tipping *et al.* identify their first climatic ‘moment of crisis’ for northwest European climate and Scottish prehistory. Given the imprecise nature of many of the dates for sand deposition on Neolithic sites, few significant correlations with key climate proxies can be noted above and in Table 28. Woodland decline in Orkney from c. 3500 BC and the elm decline in Scotland at c. 3000 BC correlate broadly with sand deposition at Pool (c. 3100-2800 cal. BC), Links of Noltland (c. 3160-2870 cal. BC; 2850-2640 cal. BC) and St Boniface (3020-2700 cal. BC (AA-9561)).

In a study of radiocarbon-dated diatom records, increases in cyclonic activity in the North Atlantic have been linked to a more southerly Polar Front (causing temperature decreases and storminess) at 3550-3530 cal. BC (AAR-6569) and 3360-2910 cal. BC (UtC-9659) (Witak *et al.* 2005). The earlier of these dates also correlates with phases of sand movement at the Knap of Howar, Skara Brae, Links of Noltland, Pool and St Boniface, but poor agreement can be seen with the second of these dates.

The Hekla 4 eruption date (~2395-2279BC) and an increase in salinity levels observed in Greenland ice cores (Sommerville 2003) appears to correlate with the possible Neolithic periods of sand movement identified at by OSL Tofts Ness (2260±100 BC <SUTL-602-3, 612-3, 616-7>) (Sommerville 2003; Grattan 2006), and Ring of Brodgar (2191±200 BC <SUTL-2281>). A key theory proposed by Sommerville suggests that the eruption of Hekla 4 exacerbated an already-deteriorating climate, and was a key driver behind Late Neolithic sand movements. It led to cooler temperatures, wetter weather, and increased storminess (Sommerville 2003, 345). Weak atmospheric circulation (an important proxy indicator for storminess), high precipitation, and the Scots Pine decline do not appear to correlate with any of the dated episodes of sand movement in Orkney.

6.1.2. The Bronze Age (c. 1900-c. 800 BC)

Site	Island	Site type	Multiperiod?	Period of human activity	Sandblow period	Dating method	Reference
Point of Buckquoy; Area 6	Mainland	Settlement	Late Neolithic-Early Bronze Age; Pictish; Modern	Late Neolithic-Early Bronze Age (from at least 2630-2180 cal. BC (GU-1557)); Pictish-Modern (c. 9th-10th centuries AD to 18th-19th centuries AD)	Late Neolithic-Early Bronze Age (around 2630-1690 cal. BC (GU-1557; GU-1640)	Radiocarbon	Morris *et al*. 1989
Point of Buckquoy; Cuttings 5 and 6	Mainland	Settlement	Late Neolithic-Early Bronze Age; Pictish; Modern	Late Neolithic-Early Bronze Age (from at least c. 2150-2000 cal. BC (*Boundary start_cutting_6*)); unknown historic	Late Neolithic-Early Bronze Age (before c. 2150-2000 cal. BC (*Boundary start_cutting_6*) to c. 1600-1400 cal. BC (*Boundary end_cutting_6*; Marshall *et al*. 2016, 14).	Radiocarbon	Morris *et al*. 1989 Marshall *et al*. 2016
Skaill, Deerness	Mainland	Settlement	Early Bronze Age-Medieval	Early Bronze Age-Middle Iron Age (Site 5) (Between 1949-1752 cal. BC (OxA-1716) and 370-1 cal. BC (Birm-413)); Early Iron Age-Pictish (Site 6) (from at least c. 700-200BC (no scientific dating) to c.	Later Prehistoric (Sites 5 and 6) (between 1513-1392 cal. BC (OxA-1437)	Radiocarbon	Buteux 1997

				AD600-770 (Birm-765) Pictish-Norse (Site 2) (9th-11th centuries AD – no scientific dating) Norse-Medieval (Sites 1-4) (c. AD900-1600 – no scientific dating).			
St Boniface	Papa Westray	Settlement	Middle Neolithic-Norse/Medieval	Middle Neolithic (c. 3020-2700 cal. BC(AA-9561) to Norse/Medieval (c. cal. AD1010-1280 (GU-3069c)	Early Bronze Age (between 1610-1320 cal. BC (AA-9560) and 1535–1115 cal. BC (AA-9562))	Radiocarbon	Lowe 1998
Mill Bay	Stronsay	Palaeoenvironmental section	n/a	n/a	Early Bronze Age (c. 1450-1150 cal. BC); Late Bronze Age-Early Iron Age (from 850-310 cal. BC)	OSL, radiocarbon	Kinnaird *et al.* 2012; Tisdall *et al.* 2013
Pool	Sanday	Settlement	Neolithic-Norse	Neolithic-Norse (with Late Bronze Age-Early Iron Age hiatus in Phase 4) (from at least 3210–2935 cal. BC (*start Phase 2.2-2.3*) to 2460-2280 cal. BC (*end Phase 3*); from at least cal. AD 200-800 (GU-2244) to c. 1020-1220 (GU-1808)	Late Bronze Age-Late Iron Age (between 1090-920 cal. BC (UBA-32509)	Radiocarbon TL OSL	Hunter *et al.* 2007; Macsween *et al.* 2015;

Lopness	Sanday	Palaeoenvironmental section; cist	n/a	n/a	Middle Bronze Age (1015±140BC)	OSL	Sommerville 2003
Links of Noltland	Westray	Settlement	Neolithic-Bronze Age	Late Neolithic (from c. 3160–2870 to 2170–1840 cal. BC (*start_LoN; end_LoN*); Bronze Age (from c. 2170–1840 cal. BC (*end_LoN*)) – until c. 1000 BC.	Middle-Late Bronze Age (c. 1000BC).	-	Clarke *et al*. 2017; Marshall *et al*. 2016; Moore and Wilson 2015
Pierowall Quarry	Westray	Chambered cairn, settlement	Neolithic; Early Iron Age	Neolithic (from at least 3040-2605 cal. BC (*start_pierowall_quarry*) to 2860-2600 cal. BC (*cairn_levelled*) (Bayliss *et al*. 2016, 38); Early Iron Age (from at least 800-410 cal. BC (GU-1580) (Sharples 1984, 89).	Bronze Age (between 2860-2600 cal. BC (*cairn_levelled*) and 800-410 cal. BC (GU-1580)	Radiocarbon	Sharples 1984; Bayliss *et al*. 2017
Meur	Sanday	Burnt mound	Bronze Age	Early-Late Neolithic; Bronze Age-Early Iron Age (from at least 3336-3023 cal. BC until at least 40 cal. BC-cal. AD87)	Middle Bronze Age (1297-1115 cal. BC; Late Bronze Age-Early Iron Age (c. 810-540 cal. BC).	Radiocarbon	Gardner 2017a; 2017b
Tofts Ness	Sanday	Settlement	Neolithic-Iron Age with Bronze Age ‘hiatus’	3330–2910 cal. BC (*start Tofts Ness 1*) to 2120–545 cal. BC (*end Tofts Ness 2*) with Bronze Age ‘hiatus’ (Bayliss *et al*. 2017	Early-Late Bronze Age (between 1880-1600 cal. BC to 1680-1440 cal. BC (*span 3*) and c. 11^{th}-9^{th} centuries BC <SUTL-95,	TL, OSL, radiocarbon	Sommerville 2003; Dockrill *et al*. 2007; Bayliss *et al*. 2017

				[Supplementary Material], 94).	103-6>), possibly before c. 1740-1520 cal. BC (SRR-5249) Late Bronze Age (after 11^{th}-9^{th} centuries BC <SUTL-95, 103-6>) and before 1450-900 cal. BC (GU-2183) to 770-410 cal. BC (GU-2208) only Late Bronze Age-Early Iron Age (After c. 1000-200 cal. BC (GU-2207), possibly 625±185BC <SUTL-608-9, 611, 614-5, 618>		
Bay of Skaill	Mainland	Cist inhumation, palaeoenvironmental section	Early Bronze Age-Late Iron Age	Late Iron Age-Pictish (Skeleton dated to cal. AD550-680 (GU-7245) (James *et al.* 1999, 773).	Between 765±620 BC <SUTL-621> and cal. AD550-680 (GU-7245)	OSL, radiocarbon	Sommerville 2003; James *et al.* 1999

Table 79. Episodes of Bronze Age sand deposition

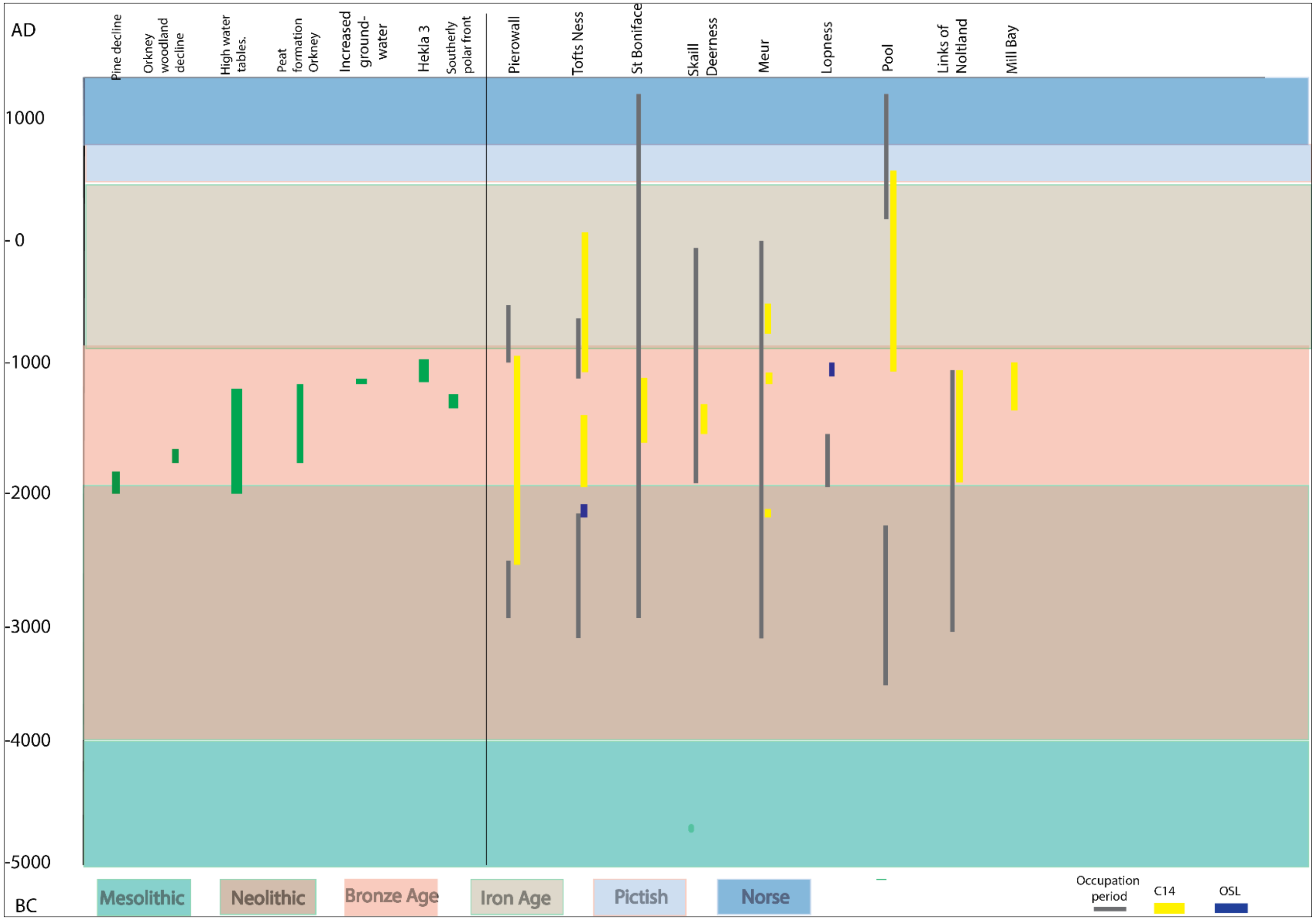

Figure 6.2. Schematic Bronze Age timeline diagram. Selected climate proxies mentioned in text to left and episodes of Bronze Age occupation and dated windblown sand deposition to right.

Twelve periods of windblown sand deposition across five islands can be identified for the Bronze Age in Orkney (Table 79), with the earliest occurring at Tofts Ness (from at least c. 1880-1600 cal. BC (*span_3*) and the latest at Pool (between 1090-920 cal. BC (UBA-32509) and AD660-780 (UBA-32508)). A wider range of site types is represented in the Bronze Age dataset. Three are settlement sites (Point of Buckquoy, St Boniface, Links of Noltland, palaeoenvironmental sections (Mill Bay and Bay of Skaill), a burnt mound (Meur), and a cist burial (Lopness). The dates for windblown sand deposition are scattered across the period, although it must be noted that some episodes of sand deposition can only be assigned very broad date ranges (see Chapter 4).

Climatic context

Peatland radiocarbon dating indicate that water tables in central, southern, and parts of northern Scotland dropped and became notably drier by c. 1150-800BC (BETA-208725, using OxCal 400) (Bronk Ramsey 2001; Swindles *et al.* 2010). Significant machair mobilisation dated by OSL occurred across the Outer Hebrides from c. 1800-1300BC (Gilbertson *et al.* 1999, 439), along the Northern Irish coast from c. 1400-1200BC and elsewhere in Scotland, northern England and Denmark from c.1100-450BC (Wilson *et al.* 2004; Bjork and Clemmensen 2004). Western Irish records have identified mean annual temperatures as being colder than the Holocene average through the Bronze Age, although these temperatures were still warmer than the Iron Age (McDermott *et al.* 2001). The expansion of peat and heather moorland on Orkney during the earlier Bronze Age has been linked to a period of cooler and wetter conditions (Bunting 1994), and fits with the broader record of European environmental change (e.g. Tipping 1994). Periods of woodland decline on Mainland Orkney took place from c. 1750 cal. BC, with episodes of widespread peat formation from c. 1750-1530 cal. BC (SRR-981-2) (Keatinge and Dickson 1979, 590). Another Hekla eruption (Hekla 3) took place during the Bronze Age, at c. 1400-1260 cal. BC (AAR-3699) (Eiríksson *et al.* 2000).

Correlations

Imprecise dating again proves challenging for any meaningful correlation with northwest European and Scottish climate change proxies. Increases in cyclonic activity in the North Atlantic have been linked to a more southerly Polar Front at 1250 cal. BC (Witak *et al.* 2005). This correlates with the episodes of sand movement at Point of Buckquoy. The eruption of Hekla 3 at c. 1400-1260 cal. BC (AAR-3699) may be broadly correlated with windblown sand deposition at Lopness at c. 1015±140BC <SUTL-890-891>, and again is used by Sommerville to support the key hypothesis that the Hekla eruptions in the Neolithic and Bronze Age increased agricultural marginality, leading to the destabilisation of sandy areas which increased their susceptibility to windblown sand movement (Sommerville 2003, 345) as agricultural pursuits in these areas increased. The eruption also was central to Burgess' upland abandonment hypothesis (Burgess 1985) and was linked to an increased growth in speleothem rings in northwest Scotland (caused by an increase in groundwater levels) dated to 1135±130 BC using uranium-thorium concentrations (Baker *et al.* 1995), and increases in windblown sand mobilisation in northwest Ireland (Wilson and Braley 1997) and Denmark (Clemmensen *et al.* 1996). Sand deposition at Point of Buckquoy may correlate with the spread of peat formation in Orkney, but again, the broad date range for sand deposition at the site means that this should be approached with caution. The Bronze Age more widely is traditionally seen as a period of 'decline' but it is notable that this period does not feature in Tipping *et al.* 's climatic 'moments of crisis'. More recent research has suggested that the Bronze Age climate decline hypothesis for northern Scotland is more complex than originally thought, with this period in fact heralding a great deal of agricultural expansion (Farrell 2009).

6.1.3. The Iron Age (c. 800BC-c. AD 500)

Site	Island	Site type	Multiperiod?	Period of human activity	Sandblow period	Dating method	Reference
Skaill (Deerness)	Mainland	Settlement	Early Bronze Age-Medieval	Early Bronze Age-Middle Iron Age (Site 5) (Between 1949-1752 cal. BC (OxA-1716) and 370-1 cal. BC (Birm-413)); Early Iron Age-Pictish (Site 6) (from at least c. 700-200BC (no scientific dating) to c. AD600-770 (Birm-765) Pictish-Norse (Site 2) (9th-11th centuries AD-no scientific dating) Norse-Medieval (Sites 1-4) (c. AD900-1600 – no scientific dating).	Later Prehistoric (Sites 5 and 6) (between 1513-1392 cal. BC (OxA-1437) and the 8th-10th centuries AD) Late Iron Age-Pictish (Site 6) (c. cal. AD420-775 (Birm-592, 763, 765) Norse (Site 2) (c. AD800-900) Norse-Medieval (Site 4) (c. AD900-AD1600) Medieval (Site 1) (c. AD1100-1200)	Radiocarbon	Buteux 1997
Point of Buckquoy	Mainland	Settlement	Late Neolithic-Early Bronze Age; Pictish-Modern	Late Neolithic-Early Bronze Age (from at least 2630-2180 cal. BC (GU-1557)); Pictish-Modern (c. 9th-10th centuries AD to 18th-19th centuries AD)	Before Pictish period (c. 8th/9th century AD)	Radiocarbon	Morris *et al.* 1989 Marshall *et al.* 2016
South of Red Craig Area 1	Mainland	Settlement	Late Iron Age-Pictish; Norse	Late Iron Age-Norse (from at least AD550-570 (GU-	Iron Age-Norse (between c. cal. AD55-585 (GU-1554, 1551) and c. cal. AD620-	Radiocarbon	Morris *et al.* 1989

				1554) to at least c. cal. AD880-1140 (GU-1552).	1035 (GU-1956, 1957) (Morris *et al*. 1989)		
Meur	Sanday	Burnt mound	Neolithic; Bronze Age-Iron Age	Early-Late Neolithic; Bronze Age-Early Iron Age (from at least 3336-3023 cal. BC until at least 40 cal. BC-cal. AD87.	Late Bronze Age-Early Iron Age (c. 810-540 cal. BC (GU-15746))	Radiocarbon	Gardner 2017a; Gardner 2017b
Tofts Ness	Sanday	Settlement	Neolithic-Iron Age (with Bronze Age 'hiatus')	3330–2910 cal. BC (*start Tofts Ness 1*) to 2120–545 cal. BC (*end Tofts Ness 2*) with Bronze Age 'hiatus' (Bayliss *et al*. 2017 [Supplementary Material], 94).	Late Bronze Age-Early Iron Age (After c. 1000-200 cal. BC (GU-2207), possibly 625±185BC <SUTL-608-9, 611, 614-5, 618>	OSL, radiocarbon	Sommerville 2003; Dockrill et al. 2007; Bayliss et al. 2017
Pierowall Lady Kirk	Westray	Palaeoenvironmental study	n/a	n/a	Early Iron Age (340±200BC <SUTL-879>)	OSL	Sommerville 2003
Mill Bay	Stronsay	Palaeoenvironmental section	n/a	n/a	Late Bronze Age-Early Iron Age (from 850-310 cal. BC (BETA 300342; SUERC-26654)	OSL, radiocarbon	Kinnaird *et al*. 2012; Tisdall *et al*. 2013
Evertaft	Westray	Midden	Iron Age; Norse	Iron Age (from at least cal. AD130-420 (AA-39134)).	Middle Iron Age (240±165AD)	OSL	Sommerville 2003
St Boniface	Papa Westray	Settlement	Middle Neolithic-Norse/Medieval	Middle Neolithic (c. 3020-2700 cal. BC(AA-9561) to Norse/Medieval (c. cal. AD1010-1280 (GU-3069c)	Early-Middle Iron Age (625-190 cal. BC (GU-3268c)) Middle Iron Age (c. 340 cal. BC-cal. AD115 (GU-3275c; GU-3061c))	Radiocarbon	Lowe 1998
Scar	Sanday	Walled structures, boat burial	Late Iron Age/Pictish; Norse	Late Iron Age/Pictish (cal. AD430-640); Norse (remains interred at c. AD895-1030).	Late Iron Age/Pictish-Norse (between cal. AD435-650 and c. AD895-1030).	Radiocarbon	Owen and Dalland 1999

Pool	Sanday	Settlement	Neolithic-Norse	Neolithic-Norse (with Late Bronze Age-Early Iron Age hiatus in Phase 4) (from at least 3210–2935 cal. BC (*start Phase 2.2-2.3*) to 2460-2280 cal. BC (*end Phase 3*); from at least cal. AD 200-800 (GU-2244) to c. 1020-1220 (GU-1808)	Late Bronze Age-Late Iron Age (between 1090-920 cal. BC (UBA-32509) and AD660-780 (UBA-32508))	Radiocarbon TL OSL	Hunter, J. *et al*. 2007; Macsween *et al*. 2015

Table 80. Episodes of Iron Age sand deposition

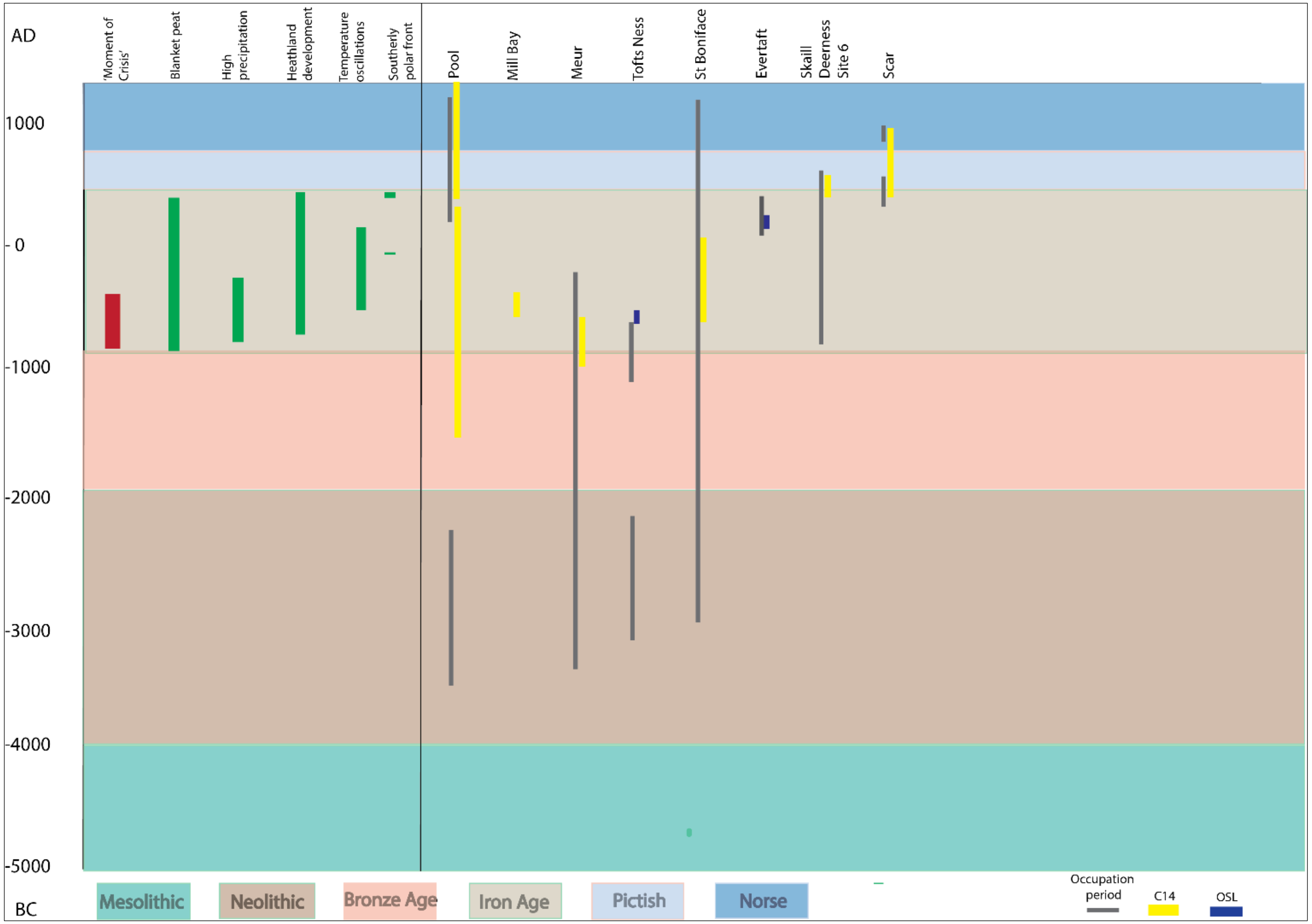

Figure 6.3. Schematic Iron Age timeline diagram. Selected climate proxies mentioned in text to left and episodes of Iron Age occupation and dated windblown sand deposition to right.

Eleven incidences of windblown sand deposition have been identified for the Iron Age, most of which took place in the northerly islands of the archipelago (Table 80). The earliest took place at Pool after 1090-920 cal. BC (UBA-32509) and before AD660-780 (UBA-32508)), and the latest at Scar between cal. AD435-650 (GU-3825)) and c. cal. AD895-1030 (AA-12595-97)). The majority of sand deposition episodes took place in the earlier Iron Age, with two (Evertaft and Scar) sitting at the cusp of the Late Iron Age-Pictish period.

Climatic context

According to annual band counting of stalactites, warmer and drier conditions appear to have lasted from c. 900-700BC in and around Ireland and Scotland (Proctor *et al.* 2002; Davis, B. *et al.* 2003), although a sudden shift to wetter conditions and higher precipitation across northern Britain according to stacked peatland records was also noted by Charman *et al*. (2006) at c. 810 cal. BC (see publication for full suite of dates). An increase in stormy conditions was noted at around 770-400 cal. BC (SRR-6555) in northern Scotland (Wilson *et al.* 2002), and in the Outer Hebrides from c. AD200-650 (Gilbertson *et al.* 1999, dated by OSL). In Orkney, heathland expansion begins from c. 650 cal. BC. The drivers behind heath formation are unclear, but are probably a combination of climatic and anthropological factors (wetter weather, and increased agricultural activity leading to soil degradation respectively (Farrell 2009).

Correlations

The episodes of sand deposition dating to the earlier Iron Age appear to correlate with Tipping *et al.* 's third 'moment of crisis' at c. 850 BC-c. cal. AD500 (Figure 6.3). The end of Phase 2 settlement at Tofts Ness (with Phase 2 modelled to 2120–545 cal. BC (*end Tofts Ness 2*) (Bayliss *et al.* 2017 [Supplementary Material], 94) correlates with deposition of sand across the site, dated by OSL to c. 625±185 BC <SUTL-608-9, 611, 614-5, 618> (Sommerville 2003, 347).

The proposed deterioration of climate with wetter weather reflected in the spread of heathland and blanket peat from the Iron Age is cited by Armit as a key driver behind the development of brochs, in an increasingly competition-based society (Armit 1990). Most of the blown sand deposits appear to correlate with this proxy. It is notable that the extensive periods of increased precipitation, peat and heathland expansion do not correlate particularly well with the dated episodes of windblown sand movement. This may suggest that episodes of wetter weather and peat development do in fact represent periods of relative 'stability' when sandy landscapes were less likely to become destabilised. Increases in cyclonic activity in the North Atlantic have been linked to a more southerly Polar Front, radiocarbon dated to c. cal. AD 330-650 (UZ-2369) (Stötter *et al*. 1999; Witak *et al.* 2005).

6.1.4. Discussion

What emerges from any presentation of windblown sand depositional episodes alongside key climatic deterioration proxies is the difficulty in attempting meaningful correlations. This is not helped by broad, millennial-scale chronological spans for many of the sites, where sand deposition is not directly dated and is rather indirectly dated through the use of radiocarbon. Similarly, many of the OSL dates possess significant errors (see Chapter 5 and Appendix 1). It is clear that a complex relationship exists between episodes of windblown sand deposition and climatic deterioration proxies. During many periods of increased precipitation (typically represented by peat and heathland expansion) do not correlate particularly well with the dated episodes of windblown sand movement. In fact, a *cessation* of peat development at Mill Bay (Stronsay) corresponded with a period of greater aeolian activity, with sands inundating the peat surface increasingly frequently from c. to c. 1450-1150 cal. BC (BETA-300344) (Tisdall et al. 2013). This may indicate that episodes of wetter weather and peat development do in fact represent periods of relative 'stability' when sandy landscapes were less likely to become destabilised.

A classic proxy dataset typically used to suggest increased storminess for the Medieval period/Little Ice Age is the GISP2 ice core, which presents a 4000-year long Na+ (sea salt) concentration time series although only the most recent 1400 years receiving in-depth analysis at high resolution (Meeker and Mayewski 2002; Sommerville *et al.* 2007). Although it has been suggested that the full 4000-year record may offer a good proxy for prehistoric storminess too, it is noted that this relationship is complicated and requires further interrogation (Sommerville *et al.* 2007). In the GISP2 record, *reduced* North Atlantic storminess is noted from 2250-1750 cal. BC, a period spanning the Late Neolithic-Early Bronze Age, and which also correlates with many episodes of increased sand mobilisation in Orkney. This demonstrates the complicated relationship between a widely-accepted storminess proxy and local-scale environmental investigations. Conflation of millennial scale, northwest European proxies and localised events is highly problematic, and only becomes more confusing as more proxies are added to the scenario – with many conflicting relationships evident.

This is not to say that climate is unimportant – but rather that proxies used to visualise climate are complicated and not straightforward. It is important that data is not "sucked in and smeared" (Baillie 1991) in order to produce correlations with climate proxies. As such, caution is urged in any interpretation of the chronological data presented above. It is not the aim of this thesis to orchestrate a detailed debate on the existence or non-existence of climatic deterioration during the earlier Holocene. It is argued, though, is that correlative studies are not the most productive means of investigating complex human-environment relationships. As suggested in Chapter 1 – new means of exploring these relationships must be sought. In the following sections, this will be put into practice, through an exploration of human interactions with sandscapes through a range of activities at the coast.

6.2. Living with sand

Now that broad chronological and geographical patterns have been highlighted, discussion will focus on aspects rarely touched by previous studies of the archaeology of windblown sand. In the last section it was suggested that attempted correlation of dated episodes of windblown sand deposition with broad climatic proxies does not move us further towards an understanding of the significance of these deposits, which lies much closer to home. It will be argued that all too often the deposition of windblown sand is viewed through a lens of 'catastrophe' and abandonment (e.g. Childe 1931; Sommerville 2003), and suggest new ways to understand life in a dune landscape. Key themes will be drawn out which characterise the significance of dwelling in landscapes affected by windblown sand in various ways. Beginning with the decision to settle and to construct, life in sand landscapes will be considered. Perception of the weather in an exposed coastal zone will then be discussed, followed by mitigation strategies and concepts of resilient response to coastal change.

6.2.1. Construction and dwelling on the coast

The Northern Isles are comprised of a series of topographic contrasts. Precipitous cliffs and rock stacks coexist with gentle sloping shores, while further inland the landscape is dominated by large lochs, mountains and far-reaching horizons comprising sea and water tracts. Contrasts can be drawn between high and low, sky and sea, acidic peat 'blackland' and machair, and it is these contrasts - which were encountered and perceived in everyday life – that structured relationships and were paramount in constructions of identity (Tuan 1974; Jones 1998, 305). A distinct decision is made when settling in a landscape: whether to start afresh or to reinhabit an older, abandoned site or reuse its construction materials; to settle by the shore, or at the base of a hill; in river valleys or uplands. Many of these decisions were influenced by cosmological concerns, but also by the environment; the resources it provided, and the impacts of the weather on that environment. In turn, the choice of settlement location provided a clear message about the identity of its inhabitants. Settlements in a dune landscape may have looked markedly different to those located in the moor or upland landscapes. Wheelhouses constructed behind the coastal dune cordons of the Outer Hebrides, for example, were subterranean structures, dug into sands. Inhabitants of these respective settlements may have also had clear ideas about the identities of others.

A decision to settle in a specific landscape may be driven by multiple factors, and the coastal zone and its hinterland offered a distinctive location, which dominated perceptions of any island landscapes. Some distinctive coastal settlement patterns have been identified for the Outer Hebrides, where during the Neolithic and Early Bronze Age occupation appears to have been largely focussed upon the central zone, with increasing utilisation of the machair and avoidance of the rocky east coast in the later prehistoric period (Rennell 2008, 46). Exploitation of the coastline featured as a significant activity across the whole of the Atlantic Scottish taskscape, structuring social relations between individuals, households and communities and the artefacts they produced and used to a significant degree. The coast and the shoreline stand as important spheres of interaction, where ownership could be established, resources collected, and relationships developed (e.g. Sharples 2005a; 2012).

The coastline offers a great deal of resources, from shellfish, salt, wood, seaweed and sea mammals. Shellfish would also attract feeding sea birds, which would also gather in great numbers to make good use of this increase of resources - thereby proving easy pickings for any discerning hunter at the shoreline. Birds and eggs from cliff colonies, and their feathers, provided additional resources. As the Scottish islands became largely deforested from the Late Neolithic period (Farrell *et al.* 2014), the availability of driftwood became of major importance for the substantial constructions of the later prehistoric period. Much of the wood utilised in the construction of Dun Vulan was Tamarack larch, which is argued to have drifted from the east coast of North America (Parker Pearson and Sharples 1999, 347). Beach cobbles and other stones made useful tools and building materials, and sand and shells provided material for the tempering of pottery.

The movement of sand and low tides could provide a wealth of seafood which can be harvested with relative ease. Inhabiting sediments in the intertidal, estuarine and sublittoral zones, cockles (*cerastoderma edule*) are an abundant species which are easily dislodged by storms and winter gales (Marine Life Information Network (marlin.ac.uk). Kelp and other seaweed species were also gathered from rocky shorelines at low tide and after storms, for cooking, fertilising, or fuel (Armit 1990; Sharples 2005a, 161; Hunter, J. *et al.* 2007, 120). Access to these resources may have been controlled and divided between families and communities, according to settlement status, location or economic requirement, as it was in the recent past with peat-cutting and coastal bird exploitation (Harman 1997; Angus 2001 cited in Sharples 2005a).

The availability of coastal resources and the fertile qualities of the sandy plains – many of which also contained a fresh water source (as at Pool, Tofts Ness and Skara Brae) have proved attractive prospects during early phases of experimental agriculture and its subsequent development. Providing it was stable and a balance was drawn between sand and soil, sandy soil provides easy drainage and fertilisation, a prospect known to have been attractive in the historic periods. Across the Northern and Western Isles, sand was traditionally removed from beaches and dunes to lighten heavy clay soils or with shell sand, to be used as lime to counteract against acidic soils (Bird *et al.* 2003, 227). Here, a tension again emerges between the lack of straightforward correlations between sand movement and 'climate', when human action becomes intertwined with natural process (see Chapters 2 and 3).

The remains of these earlier settlements would have provided readily-available building materials for later settlers, and a link to a landscape to be claimed. Associated areas of dune sand or sandy pasture have proved attractive settlement locations for numerous reasons. Sand can be easy and relatively quick to dig at first, although it is prone to collapse. Dune vegetation provided a source of bedding, thatch and fuel. There are multiple examples of houses and settlements being constructed directly over windblown sand deposits across the Northern and Western Isles. This has already been noted for the

Norse period (Harrison 2013) across the Northern Isles, and a closer examination of the prehistoric evidence demonstrates that similar practices can be identified.

The Neolithic

The early Neolithic structure and hearths at Cata Sand, Sanday were found to be constructed directly over sand and stones at the Grithies dune (C. Richards *pers. comm.*). Similarly, the Phase I houses and midden deposits at Skara Brae were constructed over approximately 0.10-0.15m of undulating windblown sand, which in turn overlay a natural basal clay representing the original ground surface (Childe 1931, 88-9; Clarke, D. V. 1976a, 11). At the Links of Noltland (Westray), much of the Neolithic and Bronze Age settlement were founded on undulating sand deposits comprising the original dune landscape (Moore and Wilson 2010, 30). The complex Neolithic Grobust building (Structure 18) at Links of Noltland was constructed into a midden lined pit which had been dug into a sand dune lying close to the modern coast edge (Moore and Wilson 2011, 19; Clarke *et al.* 2017).

The dynamism of the Noltland landscape is attested to by the presence of thin turf lines between these sand deposits, indicative of a complex history of sand stabilisation and destabilisation. Excavation of sondages directly outside the structure (to the west and north west respectively) revealed that the construction pit cut through multiple layers of clean white sand, the number of which increased to the north west, closest to the modern coastline. Midden layers interspersed with windblown sand were added during or after construction (Moore and Wilson 2012, 70). Revetting walls lined the sides of the pit, developing the structure into a semi-subterranean building (Moore and Wilson 2012, 49) (Figure 6.5). The structure comprises two rooms connected by passages, as well as a number of smaller cells (Figure 6.4). Currently radiocarbon dating and modelling has only been applied to materials infilling the structure, which suggest that use of the structure ceased in the second half of the third millennium cal. BC (Marshall *et al.* 2016)

Figure 6.4. Outline plan of Structure 18 'Grobust building' at Links of Noltland. Moore and Wilson 2012, 50.

Figure 6.5. Structure 18, Links of Noltland, showing its construction within the sand dune. Moore and Wilson 2012, 65.

The Bronze Age

During the Bronze Age phases of occupation at the Links of Noltland, several structures were also found to have been constructed in and over deposits of windblown sand, many of which had been stabilised by cultivation soils prior to construction. These features included the complex burnt mound at the edge of the Scheduled Monument Area, which was constructed into a sand dune (Figure 6.6). Sondages excavated around the burnt mound demonstrate that it was constructed over a series of buried 'A' and 'B' horizon soils. In the north sondage, an 'A' horizon displaying a series of ard marks, filled with windblown sand, was recorded. A 'B' horizon covered a thin layer of windblown sand, which overlay natural clay deposits. In a sondage excavated to the west of the burnt mound, a field bank was also constructed over 0.05m of windblown sand. This overlay a soil containing burnt stones, which in turn overlay a buried 'A' horizon likely to equate to that observed in the north sondage (Moore and Wilson 2015, 5).

Upon excavation, the burnt mound was found to comprise three 'levels', the first of which comprised an early mound; although this contained no evidence for structures, it is possible that any structural remains were substantially remodelled, and no traces remain. A secondary 'core' mound was then constructed, which contained the structural complex. A tertiary mound then developed around the secondary mound, and comprised the material generated by the structural complex of the secondary mound (Moore and Wilson 2017, 13). It is notable that some areas of the secondary burnt mound were separated from the early mound by deep windblown sand deposits. These had been paved over at the entrance to the secondary burnt mound structure, and behind the south and southwest sides of the inner chamber (Moore and Wilson 2017, 13). The secondary core burnt mound was constructed over, and incorporated within, existing deep deposits of windblown sand (likely to represent a dune) and burnt stone. This suggests a desire to persist in the use of this area, and these remains – with the position and use of the burnt mound solidified and elaborated through the development of a more complex architectural form. Windblown sand continued to accumulate through the construction period of the complex secondary burnt mound (Figure 6.7), and after its construction – creating a subterranean complex entered via a passageway (Moore and Wilson 2017, 15) (Figure 6.8).

Figure 6.6. General view of Links of Noltland burnt mound looking east (Moore and Wilson 2015, 13).

After their construction, the roof slabs over both cells bracketing the complex secondary burnt mound chamber were covered with burnt stone in sand – interpreted as forming part of the construction process to hold the large roofing stones in place. This deposit was them covered with sand with lenses of ashy soil, and capped with compact black silty clay (Moore and Wilson 2017, 29). Burnt stone used in the heating process continued to be heaped on top of this structure, thus continuously constructing and developing the mound.

Figure 6.7. Deposits of windblown sand and burnt stone at the entrance to the burnt mound structure. Moore and Wilson 2017, 11.

Figure 6.8. View of passage entering cellular burnt mound structure. Collapsed roofing slabs are visible in the foreground, behind which the cut for the passage through the sand dune can be clearly seen. Moore and Wilson 2016b, 13.

Many of the Bronze Age domestic structures at the Links of Noltland were also constructed over deposits of windblown sand and cultivation soils. Following a bout of deflation, the excavations in early 2007 revealed the remains of three structures (Structures 1-3) within the PIC site, identified typologically as Bronze Age in date. Midden deposits, windblown sand layers and cultivation horizons pre-dating the settlement were also noted. All three structures were constructed over deposits of cultivation horizons interleaved with windblown sands. This confirmed that this area of settlement was situated in a previously-farmed landscape, with midden wall-core indicating the presence of earlier settlement also existing in the vicinity. Neolithic midden deposits identified as those excavated by Clarke (West Midden) were also noted (Moore and Wilson 2006, 7).

All three structures were partially robbed in antiquity, with later windblown sand deposits filling the robbed-out construction pits. The three structures all displayed internal divisions and midden wall cores. Structures 1 and 3 were noted to be facing each other (Moore and Wilson 2007a, 6), reminiscent of the Bronze Age structures at Sumburgh Airport (Downes and Lamb 2000). Structure 12 comprises a curvilinear building with close parallels to Structures 3 and 5, which yielded a second millennium BC date. It was constructed over a deposit of windblown sand some c. 0.15m deep, which in turn overlay an earlier cultivation soil. The poorly-preserved Structure 2 overlay up to 1.4m of windblown sand interspersed by palaeosols and cultivation horizons, containing frequent fragments of pottery. The high level of sand weathering was noted on many of the construction slabs of Structure 2, indicative of a significant period of exposure to drifting sands in antiquity (Moore and Wilson 2007a, 10).

The earliest settlement activity at St Boniface (Phase 2) saw the construction of two structures (1a and 1b) over a thick deposit of windblown sand during the Late Neolithic-Early Bronze Age (from between c. 3020-2700 cal. BC (AA-9561) and 1610-1320 cal. BC) (AA-9560), into which funerary features had also been cut in Phase 1. One of these structures (1b) was later sealed by the windblown sand deposited in Phase 3 between 1610-1320 cal. BC (AA-9560) and 1535-1115 cal. BC (AA-9562) (Lowe 1998, 27-30). The Early Bronze Age midden and Pictish houses at Point of Buckquoy Area 6 were also constructed directly over sand.

The Iron Age

At Howmae Brae (North Ronaldsay), two Iron Age radially-divided roundhouses, rectangular byres and steadings, and a courtyard were constructed into a sand dune, with revetting walls (Traill, W. 1885; MacKie 2002) (Figure 6.9). At King's Craig (Papa Westray) the earliest prehistoric structural remains at the eroding site (comprising three structures, drains and flagged surfaces) were built directly over a c. 0.50m deposit of windblown sand (Moore and Wilson 1998). At Berst Ness/Knowe of Skea (Westray), the floor deposits and two hearths of a later prehistoric sub-rectangular house were found to have been constructed over a thick windblown sand deposit, which in turn overlay the remains of a Neolithic stone structure. The thick outer walls of the building were found to comprise four skins of outer wall facing which had been constructed in rapid succession (Moore and Wilson 2002, 89).

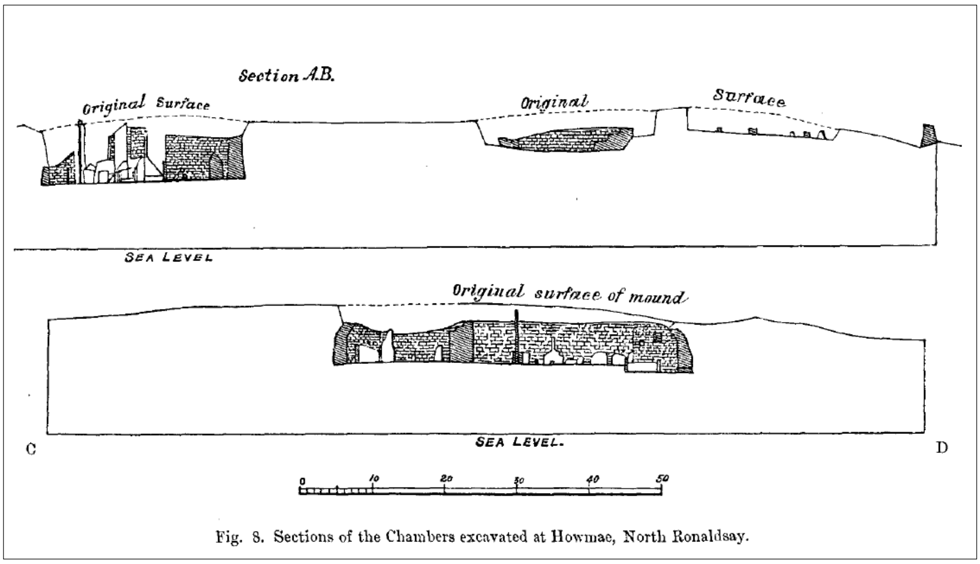

Figure 6.9. Section through the sand dune and settlement at Howmae Brae. Traill, W. 1885, 26.

After the Iron Age

Practices identified at prehistoric sites above can be seen to have continued into the historic period. At the Pictish-Norse Site 2 at Skaill, Deerness (Mainland Orkney), House 1 (dating the 8th-9th centuries AD), was constructed directly above sand dunes, which had already been cut into by a series of small pits. This house was later remodelled in the Norse period (Buteux *et al.* 1997, 71), becoming House 2. Following the abandonment and inundation of House 2 by sand, House 3 was constructed directly above it in the late 9th-early 10th century AD. During the construction of the new walls of House 3, the sand which had filled House 2 was cleared down to its original floor surface, onto which the House 3 inner walls were built. The outer wall face was built directly onto the sand (Buteux *et al.* 1997, 74). Likewise, at Mayback (Papa Westray), at the base of the section beneath the 14th-18th century farm mound, a structure was built on a deposit of windblown sand c. 3.5m in thickness (Moore and Wilson 1998, 303). Possible structures at Noup (Westray), which remain undated, were also constructed in windblown sand deposits. Measuring between 10m-30m in diameter, each of the three mounds appear to contain a separate structure (Moore and Wilson 1998, 237).

Burials in sand

There are several examples of areas of coastal windblown sand being utilised and selected for other activities apart from settlement. As well as being densely settled, Skaill Bay was utilised as a location for multiple cist burials, with graves being dug directly into the sand dunes and sandy pastures. This has also been observed at St Boniface, where the earliest activity at the site is the Phase 1 funerary activity, which predated both the Phase 2 settlement and the Phase 3 windblown sand inundation of the site. In phase 1, three cist-like structures were cut directly into the sand, with one containing a human skull and a small cairn. Radiocarbon samples from above and below the features yielded dates of 1610-1320 cal. BC (AA-9560) (Phase 3) and 3020-2700 cal. BC (AA-9561) (Phase 1) respectively (Lowe 1998, 23; 115).

Excavations within the SAM area at Links of Noltland revealed the remains of over 100 Bronze Age cremation and inhumation burials which had been dug into loose sands (Moore and Wilson 2012, 47) (Figure 6.10). Remains recovered from the 2009 excavations in this area have been dated to 1630-1460 cal. BC (GU-27901) and 1690-1510 cal. BC (GU-27908). (Moore and Wilson 2011, 28). It was difficult to identify relationships between the burial cuts, the old ground surface and the sequence of windblown sands encountered in this area due to the significant levels of deflation (Moore and Wilson 2011, 41-2; Moore and Wilson 2012, 46). However, the earliest deposits at the cemetery comprised a layer of clean white sand overlying the glacial till. The sand was overlain by a darker brown sand forming an old ground surface (Figure 6.11). This was sealed by another clean white windblown sand deposit, followed by another old ground surface. The burials all appear to post-date these deposits, and the sands must have been deposited before the Bronze Age dates yielded for the inhumations. The inhumations are likely to be broadly contemporary with the use of Bronze Age structures 4, 5, and 6 which lay approximately 50 metres away (Moore and Wilson 2011, 38).

Figure 6.10. Inhumation burials (F9358 above and F9373 below cut into windblown sand at the Links of Noltland Bronze Age cemetery. Moore and Wilson 2012, 43).

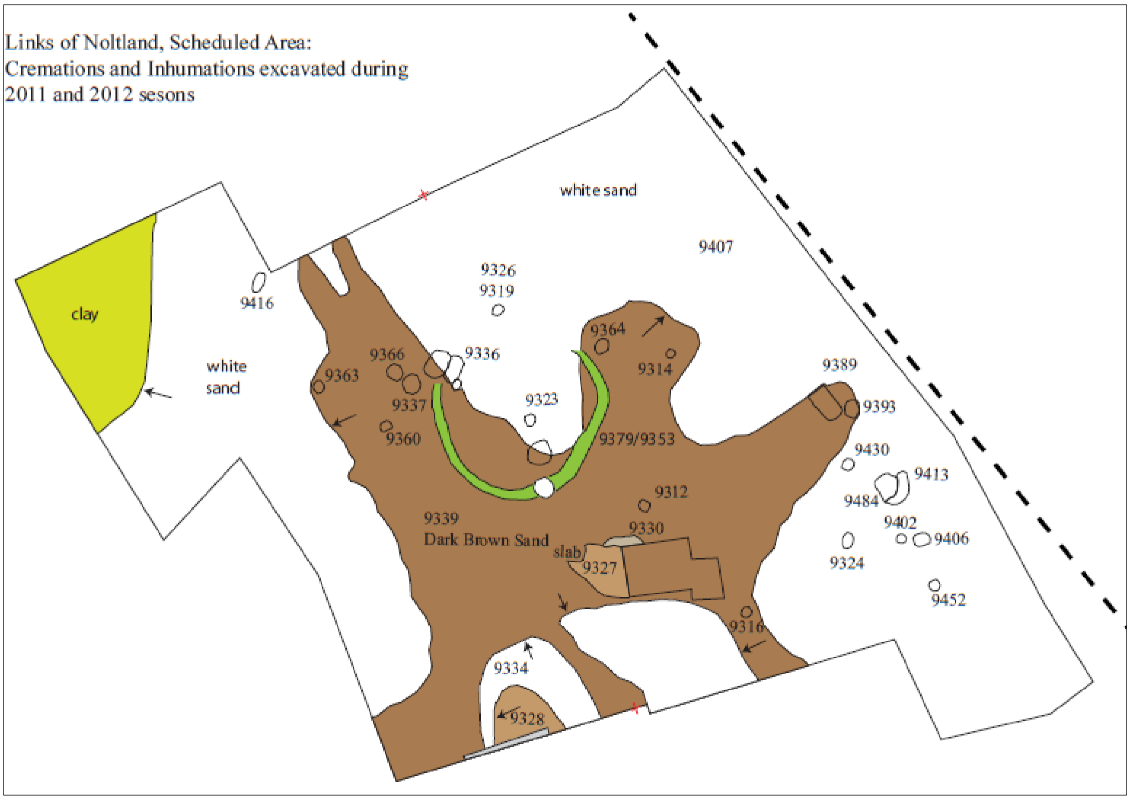

Figure 6.11. Plan of cremations and inhumations excavated at the Links of Noltland 2011-2012. The dark brown area represents a dark brown sand deposit, likely to comprise turbated and truncated windblown sand deposits disturbed by multiple burials. Moore and Wilson 2012, 40).

A series of Late Iron Age and Pictish cist inhumations were also cut into sand, and covered by cairns, at Red Craig Area 1, Birsay (Mainland Orkney) between c. AD55-AD585 (Morris *et al.* 1989, 123). Two cist burials, interpreted as being of Norse origin, were later inserted into the blown sand deposit at Skara Brae (Childe 1931). Later activity in the Norse period also demonstrates the selection of sandy locations for the digging of graves, as at Pierowall Links (Westray), Westness (Rousay) Scar (Sanday) and Skara Brae (Mainland).

The decision to build various structures and features directly into sand dunes and over deposits of sand may have been influenced by the relative ease of excavation of sand (in order to form a construction or burial pit). Alternatively, and rather paradoxically, sand dunes may have also been viewed as landforms which provided an opportunity for increased structural integrity - whereby a dwelling could be surrounded and encased. At Links of Noltland, perhaps the sand dune into which the Bronze Age burnt mound was constructed could have been viewed as a means of conserving heat. Sand could provide increased shelter from the wind and the cold, albeit heightening the risk of collapse. An understanding of the potential for dunes and other sandy landforms to become destabilised appears to have existed, however, with evidence for the stabilisation of sands on construction surfaces with midden.

At the Links of Noltland, sand continued to develop over the top of some structures, and alongside the accumulation of occupation material, ensured that many dwellings became completely enveloped within the sand dune. Here the boundaries between natural features and human dwellings become blurred. Themes of wrapping and encasing in construction of dwellings and other features have featured prominently in some aspects of the archaeological and anthropological literature. In Polynesian society, the act of wrapping within various 'skins' of material forms a metaphorical strategy for protection and containment, both hiding and obscuring an object or person while also drawing attention to its presence (Richards and Croucher 2014, 212). Similar themes have been explored in the Orcadian context (Richards et al 2016, 225), where the occurrence of construction inside – and envelopment by - materials was primarily a process characterised by occupation materials, or midden. The process of increasing nucleation of Late Neolithic settlements went hand in hand with the expansion and accumulation of large volumes of midden and occupation deposits. Where earlier settlements were cut into midden, later settlements became subsumed in midden. This can be observed on the Mainland, at Skara Brae, Muckquoy, Stonehall, and Crossiecrown, and the outer islands at Pool, Stove, Links of Noltland and Rinyo (Richards *et al.* 2016, 164). The cultural significance of midden is a theme which has permeated numerous discussions of prehistoric social life (e.g. Guttman 2001; Waddington 2008; Richards *et al.* 2016). Throughout the Orcadian Neolithic, midden (as well as clay) took on an important role in the structure and creation of the house and its fabric, both physically and symbolically. Midden became an important structural component of wall cores at Knap of Howar, Skara Brae, Stonehall, Links of Noltland, and Tofts Ness amongst others (A. Shepherd pers. comm., Richards *et al.* 2016, 192).

At many of these coastal sites, the accumulation and transformation of these important occupation deposits was also punctuated by the deposition of windblown sand. It can be demonstrated that sand and midden were important textures (see Evans, J. G. 2003, 45-7) in coastal settlements – with varying patterns and colours in these accumulations of cultural (midden) and natural (sand) deposits providing markers of time and change. To build in sand, to use it and dwell within it was ultimately to destabilise it, thereby making it ever more perceptible to communities, and pervading activities, in daily life.

6.2.2. Life in the sandscape and the perception of weather

After construction in or near the sand had taken place, so began life in this dynamic environment. At sites like the Links of Noltland and Skara Brae, regular windblown sand incursion and accumulation became a part of everyday life, with sand becoming interweaved into the very fabric of settlement. At Links of Noltland, the same can also be said for experiencing sand during the excavations (Figure 6.12). It has already been suggested that it is timely to move away from narratives dominated by correlations between northern European proxies towards a consideration of human-environment interactions on a settlement scale.

Figure 6.12. Links of Noltland barrows engulfed after sand storm during the excavations. Moore and Wilson 2010, 66.

Toby Pillatt's study of two 18th century weather diaries written by inhabitants of Mosser in the Lake District begins with an attempt to correlate weather recorded in said diaries with instrumental climate records. Although these records did not focus on this region, they are commonly regarded as highly accurate and long-running (The Central England Temperatures series, and the England and Wales Precipitation series) (Pillatt 2012, 35-6). On comparison between the data sources, few statistical correlations could be identified. Pillatt used this discovery to highlight a key point. Even with access to a well-recognised instrumental measurement series (a resource rarely available for archaeologists interested in climate patterns stretching beyond a few centuries), few meaningful correlations between scientific measurements and 'on the ground' experiences were able to be made. This demonstrates the difficulty faced by archaeologists when using proxy records to create accurate measures of past climate – a relationship which is sometimes barely tenuous using modern sources and trusted instrumental measures (Pillatt 2012, 37).

As raised in Chapter 3, there have been growing calls for a consideration of 'weather' as an interpretative framework through which to understand human-environment interactions. This has been summarised by Pillatt's (2012) *Archaeological Dialogues* paper, which called for a conceptual shift from climate and society to weather and landscape. Such broad, structuring processes as climate only become relevant in the "lived temporality of human lives" (Pillatt 2012, 41). Landscape here plays a central role, into which weather is embedded and experienced. This was certainly true for the more recent residents of the islands; Patrick Fea, a farmer living at the Bay of Stove, Sanday, wrote daily records of wind direction and impacts upon his crop (Hewison 1977). For the inhabitants of coastal settlements and arable landscapes, short bursts of bad weather (such as storms, wet summers, colder winters, and late springs) (Dodgshon 2005, 334) would have been considered more problematic than 'climate': a comparatively modern conception and means by which to understand the weather. Admirable though Pillatt's 'call to arms' may be, the challenge arises when prehistorians attempt to put these concepts into practice, with no access to weather diaries and instrumental records. Here, the material record becomes our weather diary.

It is possible to see and feel the weather coming on the coast, on the horizon and when the air and atmosphere change. Things might become calm and still before a storm, the skies grey and the air heavy. It could bring with it a sense of foreboding or helplessness, or a sense of relief, such as a heavy and much-needed rainfall after an extended dry spell. It is a wholly sensory occurrence, experienced and responded to daily. As such it is a vitally important state (a sphere which should be perceived *in* rather than forming a background for action (Ingold 2011b, 130-1) which was tied up in every action in some way. It was - and is - truly influential, and could be manipulated for political or practical means. Weather is a daily occurrence and therefore central to any discussions concerning the context of social action and change.

6.2.3. Perceptions of weather and wind

The primary focus now lies on the means by which sand was able to be mobilised: the wind. The wind has long held significance in the human imagination, featuring in various popular sayings including "throw caution to the wind" and "winds of change". That there are approximately 38 different words for 'wind' in Scottish Gaelic (A. MacLellan *pers. comm.*) is further indicative of the rich and varied role played by this manifestation of the weather. It holds numerous qualities which interact with the immediate environment. It fertilises (by carrying seeds and pollen), carries smoke, moves ships through the water and provides an exceptional sensory experience by moving smell, cooling, and allowing ventilation. Blowing sand is wind made material, and the weather made tangible. In Britain, the movement of sand by wind it is a process unique to the coast and its hinterland, unlike other manifestations of weather. It was visible and could be experienced on a human timescale.

In the 19th century and earlier, the wind was strongly influential on matters of health and medicine; while wind was frequently thought to spread disease and 'miasmas', the notorious 18th century physician James Graham also claimed his healthy constitution was achieved by keeping his window open to receive the maximum impact of the wind during storms in Scotland (Graham 1973, 3; cited in Jancovic 2007, 144). It is experienced both indoors and outdoors, as a breeze, gust or a draught. Its significance as a meteorological phenomenon and mode of perception has featured frequently in the critical anthropological literature; Ingold, for example, suggests that wind should be considered as an aspect of the landscape, which moves between various domains of the metaphorical and the physical (Ingold 2007, 2007). In the spiritual domain, the wind can create life (as believed by the Navajo), and was interlinked with the existence and movement of spirits (Hsu and Lowe 2007).

6.3. Impact and response to sand deposition in the archaeological record

The previous chapters of this thesis have focussed on the nature and chronology of windblown sand deposition, and the challenges associated with assigning drivers to deposition. This was achieved through the synthesis of all known archaeological sites with evidence for windblown sand deposition. This has provided a solid dataset for broader conceptual discussion of the impacts of windblown sand deposition on people, their sites and landscapes – and numerous responses to it. In the historic period, numerous historical sources attest to the widespread, and often rapid, abandonment of agricultural land and associated farmsteads, partially driven by the deposition of large quantities of windblown sand - particularly during the 'Little Ice Age'. A particularly stark example can be found in the abandonment of the Culbin Sands, mainland Scotland following one or more large storms in the autumn of AD1694. Located on the coast of Nairn and Moray, the dunes and their coast face north-west to the Moray Firth with an area of c. 3000ha with the sands deriving from eroding sandstones and granites (Edlin 1976, 2;7). The sand inundated sixteen fertile farms and an associated mansion house, remaining unstable for over two centuries until full afforestation was undertaken by the Forestry Commission in 1921 (Edlin 1976, 1).

In the Scottish Islands early records gathered by Henry Sinclair, who catalogued crofting rents in Orkney in AD1492 and AD1500, provide a historical context for abandonment. A proliferation of "blawin" sands in Orkney (namely Sanday, Westray and Papa Westray) appears to have led to the abandonment of a significant amount of agricultural land, either as a result of rent increases, decreases in soil fertility or a combination of both factors.

The drivers behind this sand movement appear to be numerous and difficult to disentangle but may have included an increase in stormy weather coupled with the introduction of rabbits and over cultivation. This demonstrates the difficulty even in the historic data of identifying a singular, climatic driver behind sand movement (Sinclair 1492; Peterkin 1820 cited in Sommerville 2003, 23-4).

Here the data collated in the sand site database and summarised in Chapter 4 is used to identify similar impacts of windblown sand movement and deposition, and possible responses to these processes. To begin, a summary of direct – and indirect – impacts of the deposition of windblown sand is presented in Table 81. These impacts are drawn from the archaeological, environmental, and historical record.

Direct	Indirect
Large inundations of agricultural land	Degradation of soils and ground surfaces, leading to poor harvests. This can lead to an inability to sustain community inhabitants, and animals. In the historic period, this was combatted by seeking rests and eases of rent after land went to waste.
Small inundations of agricultural land	Increased fertility of soils
Inundation of general landscape	Less aesthetically-pleasing landscape; Confusion and loss of recognition of a known landscape; former freshwater lochs and lagoons filled with sand; areas which were formerly non-sandy 'hinterland' now enveloped by the coast; increased availability of sand-burrowing shellfish such as razor clams
Inundation of settlement	Structural collapse; covering of walkways and public areas; covering of equipment and areas for specific tasks; covering of spiritually significant buildings
Uncovering of burials through deflation	Stress, increasing superstition

Table 81. Impacts of windblown sand movement and deposition.

Upon the initial exploration of the impacts of – and responses to – increasing sand mobilisation, a recurrent theme becomes apparent; that of marginality. This theme is frequently defined by downturns in socio-economic fortune at site level, the cause of which is frequently attributed to periods of climatic deterioration and its impact upon the wider landscape. Manifestations of marginality can be grouped into three distinctive types, which frequently overlap; environmental marginality, economic marginality, and social or political marginality (Coles and Mills 1998, vii). This variation in criteria has ensured that recognising marginality in the archaeological record is fraught with difficulty.

Environmental marginality is generally defined as being beyond the control of human populations (although this may have been driven by them). What was in their control, was their response to this marginality (Coles and Mills 1998). Economic marginality relates specifically to the subsistence economy, while social and political marginality refers to the political and/or cultural isolation of specific communities dwelling on the edge of larger communities. It is clear from the discussion to come that definitions of 'marginality' will vary on a site by site basis, and that the process of "becoming marginal" is driven by a great number of factors. Coles and Mills' definitions and discussions of social and political marginality may be compared with that of John Evans (2003, 111). Citing the apparent occurrence of poor harvests and deterioration in the Lammermuir Hills, Evans suggested that cooperation between settlements intensified:

"far from being poorly adapted to these upland areas and living at the edge of subsistence levels, these farmers were actively using the marginality of the land to engender cooperation, greater social intercourse, opportunities for expression and the emergence of new ideas". Evans, J. G. 2003, 111.

Here, despite a traditional picture of economic marginalisation, these landscapes lay at the heart of social interaction. In the face of perceived marginality, then, can come resilience as a key socio-economic survival strategy.

6.3.1. Resilience and buffering strategies: addressing risk and uncertainty

The next step is to consider how communities responded to larger-scale sand mobilisations – or an accumulation of multiple small-scale events - which required a response. An important facet of the relationship between climate, environment and social change is the understanding of cultural responses to risk and uncertainty – where the *successes* of communities are just as interesting as narratives of social devolution (Wilkinson 2012, 61). The variability and unpredictability of the local environment are key themes by which concepts of risk and vulnerability may be structured. The changeable nature of the weather and environment can exert considerable influence on human activities and behaviour, although to avoid deterministic outcomes it is important to consider these on a local scale (Halstead and O'Shea 1989, 3). A number of cultural responses to environmental variability have been identified and discussed by Halstead and O'Shea in their treatment of 'bad year economics' and how this can be identified in the prehistoric and early historic context – namely diversification, storage, exchange, and mobility.

Halstead and O'Shea's model is based on the centrality of food to cultural behaviour and social life. While economic and dietary concerns are an important consideration in any discussion, they were arguably not the only facet of prehistoric life to be threatened by climatic and environmental shifts. Halstead and O'Shea's suggested responses will therefore be considered alongside other, broader themes of direct relevance to the Orkney Islands, including the possible significance of house construction practices, soil improvement and sand stabilisation. Campbell, J.'s (2009) studies of disaster reduction utilised by Pacific islanders reveal similar practices, but goes a step further by considering the origins of many of these strategies, which were transmitted through generations and across settlements and communities by social memory (see also McIntosh 2000).

The concept of social memory, whereby communities hold and pass between them information about past weather and successful responses to change, can inform understandings of environmental perception and response. Such transmitted information on response and success rates would be immediately accessible in times of need. This theoretical model and approach emphasises that reactions to and perceptions of changing climate and weather are "culturally conditioned" and can be transmitted through ancestral lines (McIntosh 2000; Pillatt 2012, 32). This approach is also intrinsically linked with that of Traditional Ecological Knowledge (see Chapter 1). Just as extensive knowledge of weather conditions, tidal times and seasonal activity (for example, bird migration) could be learned and understood, so too could successful responses and strategies, when the environment did not behave as predicted (McIntosh 2000). The well-fertilised infields of many sites (see below, 'Soil Improvement' and 'Stabilisation of sand deposits') may here be viewed through a lens of social memory and traditional ecological knowledge. At Skara Brae and Tofts Ness, the application of numerous layers of occupation debris over sand deposits of varying thicknesses implies a deep-time understanding of the practice and its success. Inherited landscapes and resources were therefore developed.

6.3.2. House construction

The way weather is experienced within the house, and climate history in relation to domestic architecture, remains relatively unexplored in both archaeological and anthropological literature (Eriksdotter 2013, 24). An attempt to reconcile considerations of weather conditions with cosmological concerns (as popularised in the 1990's by the works of, Carsten and Hugh-Jones (1995), Parker Pearson and Richards (1994), Oswald (1997), and Parker Pearson and Sharples (1999), among others), can be problematic given the reluctance of some academics over the past three decades to revisit and engage with weather and environmental context as a driving force, which many consider to be rather deterministic and prosaic. As such, weather conditions have played a "subordinate role" in discussions of this nature (Eriksdotter 2013, 25).

It is challenging to consider 'weather proofing' practices in the prehistoric record within a literature which is dominated by less-prosaic interpretations of the house. Nevertheless, aspects of construction in the prehistoric record, and it is point worth considering. It can be argued that the house and the way it is used and conceived of in the imagination can also structure, and be structured by, the weather and the way in which humans interact with it. The lighting of the house, craft activities and doorway orientation can all be influenced by weather conditions, as can building materials, techniques and furnishings (e.g. Parker Pearson and Sharples 1999; Pope 2007; Eriksdotter 2013, 32).

In the Pacific Islands of Samoa, Fiji, and Tonga, the construction of precolonial domestic structures was influenced by a consideration of weather conditions. Houses were often constructed with no windows and few doors, as airtight structures reduced the development of high pressure inside dwellings, which was a common cause of dwelling collapse and shelter failure. Buildings also featured steep hipped roofs which were less susceptible to wind damage. Campbell also notes that many Fijian *bure* (traditional dwellings) were constructed on mounds, with the relative height reflecting the social status of the occupant (Campbell, J. 2009, 92). Across south-east Asia, too, weather proofing remained a key concern in construction of the house, as well as more spiritual concerns (Waterson 1996). Here, it was recognised that rounded house forms provided better protection from winds (Waterson 1996, 220).

Construction materials and techniques are also worth considering here with reference to the prehistoric record. The construction of dwellings into sand dunes, revetted with stone and midden, may also be viewed as a means of weather-proofing through an extra layer of protection. Additionally, at Pool (Structure 6), Skara Brae, and Rinyo, the wall 'skin' constructions typical of the Neolithic period were filled with a sand core (Hunter, J. *et al.* 2007, 38). Here, sand became interweaved with the very fabric of the structures; a material which ultimately, in many some cases, overwhelmed them. At Berst Ness (Knowe of Skea), the thick exterior walls of a later prehistoric house were in fact found to represent four skins of outer wall facing, constructed in rapid succession (Moore and Wilson 2002) – perhaps in response to either to structural failure, a desire to 'monumentalise' the house (e.g. Sharples 2006), *or* as a means of insulating the house. Underlying networks of drains at Tofts Ness (Structure 4) and Skara Brae (Dockrill *et al* 2007, 48; Shepherd 2016) show a clear concern for water management and removal.

During the Neolithic period, and especially the Bronze Age, the construction of paired structures with their entrances facing one other became a key feature of the settlement record in the Northern Isles (Downes and Lamb 2000; Richards *et al.* 2015). In the Neolithic context, this is exemplified by Structures 8 and 9 at Pool (Hunter, J. *et al.* 2007), Structures 12 and 14 at Links of Noltland, and the Grey House and Red House at Crossiecrown (Richards *et al.* 2016, 220-221). In the Bronze Age, Structures 1 and 3, and 5 and 6, at Links of Noltland (see Appendix 1, and Moore and Wilson 2015) and those at Sumburgh Airport (Figure 6.13) (Downes and Lamb 2000), are key examples. Paired structures were also observed in the Late Iron Age Phases 5 (Structures 15 and 16), and Phase 6 (Structures 18 and 19) at Pool (Hunter, J. *et al.* 2007, 75-145), as well as at Howe, where all structures in the Iron Age village displayed two separate rooms (Ballin Smith 1994).

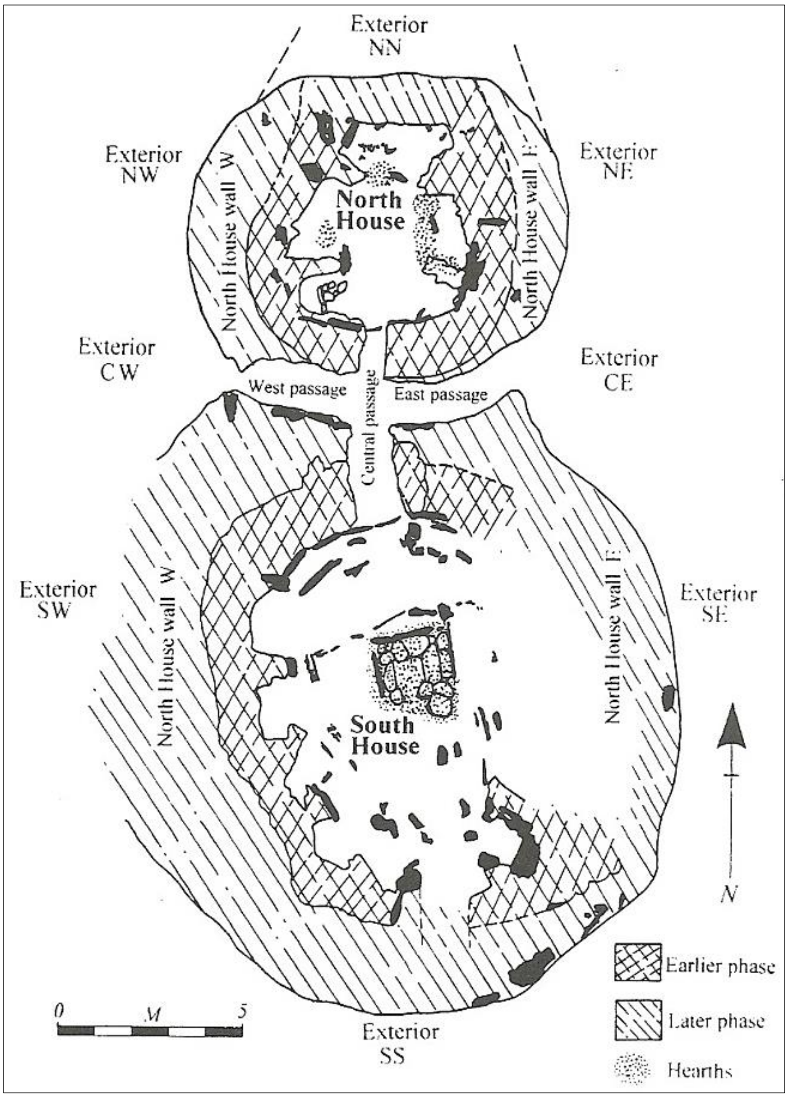

Figure 6.13. Houses at Sumburgh Airport. Downes and Lamb 2000, 73.

The Links of Noltland features a high concentration of paired houses, a domestic style which featured in both the Neolithic and Bronze Age phases at the site. It may be suggested that the construction of paired domestic structures was designed with more practical concerns in mind. Aside from conveniently functioning as a single, or related unit, this may have added an extra level of protection if the rear of one structure faced towards the prevailing wind, with the door facing away toward the opposite door. This could be posited for Neolithic Structures 12 and 14 (Moore and Wilson 2012, 18), where the rear of Structure 12 faced the west – the direction of the prevailing wind. A similar possibility could be suggested for Bronze Age structures 5 and 6 at the site. However, this pattern does not fit in all cases across the site (for example, with Bronze Age paired Structures 1 and 3).

A number of excavators seem to have been influenced by the nature of the weather in their interpretation of settlement form and function. Ritchie viewed the use of midden as a house wall core at Knap of Howar as a means of weather-proofing (Ritchie 1983, 48), while Hedges, J. W. (1987) interpreted a retaining wall to the west of the Pictish – Viking 'hall house' 1 at Saevar Howe as having functioned as a means of keeping the area to the west of the house free from drifting sand, where midden accumulated (Hedges, J. W. 1983, 82). In the vicinity of the Bronze Age cemetery at the Links of Noltland, the remains of a low wall (to the north of a structure which was reminiscent of a corn dying kiln), was interpreted as a windbreak (Moore and Wilson 2012, 51). At the Links of Noltland, the sand continues to inundate the landscape making it impossible for excavators not to realise the its important in the site formation process (Figure 6.12).

6.3.3. Diversification

In this context, diversification in the face of environmental change may include expanding the standard subsistence base, thereby reducing the risk of shortage should a resource which was heavily relied upon be compromised (Halstead and O'Shea 1989, 3). The bioarchaeological remains from Tofts Ness have frequently been interpreted through this perspective (Dockrill and Bond 2009). At least three known episodes of windblown sand deposition are recorded at Tofts Ness; two in the Bronze Age (during Phase 3/4 and Phase 5) and one in Phase 6 during the occupation of the Early Iron Age roundhouse (Structure 5) (Figure 6.14). Using the bioarchaeological and palaeoenvironmental evidence from Phases 4 and 6, the excavators of Tofts Ness argued that distinct shifts in economic practice at the site could be identified.

Figure 6.14. The Early Iron Age roundhouse at Tofts Ness. Dockrill and Bond 2009, 36.

Phase 4 (Late Bronze Age) palaeoeconomic evidence

Much of the barley recovered from the Late Bronze Age contexts appears to suggest immature harvesting by hand-pulling, perhaps as a response to a need for more straw for fodder, furnishing, or basketry (Dockrill and Bond 2009, 41). Environmental samples from this phase also appear to demonstrate a significant increase in fungal spores, which could be interpreted because of composting of byre material or of wetter climatic conditions. Additionally, it appears that a new podsolic source of heathland turf was being exploited, although its source is unknown. This period is characterised by the intensive management and improvement of the Late Bronze Age infields, the cultivation of which appears to have produced unusually long barley grains (Dockrill and Bond 2009, 37). This evidence as well as many stone tools has led to an interpretation of Phase 4 as the most productive of all site phases, which stands in disagreement with prevalent interpretations of a deteriorating climate at this time (e.g. Sommerville 2003). The animal bone assemblage appears to show that smaller cattle were farmed than in the Neolithic period, with a gradual increase in the relative proportion of sheep (Dockrill *et al.* 2007, 81-2).

Phase 6 (Early Iron Age) palaeoeconomic evidence

The primary difference between the palaeoeconomic strategies of Phases 4 and 6 is the decrease in evidence for barley production, although it still may have represented a significant part of the site's economy. The decrease in size of barley grains may have been linked to the poorer, drier sand-based soils cultivated during this phase following the sandblow event, when the main mineral component for the soil matrix became calcite sand. Enhancement of the calcite soils previously observed in Phase 4 appears to continue with similar intensity, with the addition of multiple materials to the soil including decomposing organics. Such additions to the soil would have helped to mitigate against the two main problems associated with the cultivation of sand-based soils – drying, and resultantly an increased susceptibility to wind erosion, and combatting decreases in organic nutrients. If such soils were used for grazing this may have also led to dietary deficiencies in animals (Dockrill *et al.* 2007; Dockrill and Bond 2009). Dental wear and an increase in juvenile butchery in the animal bone assemblage may indicate a more intensive dairying strategy in the Early Iron Age. The increase in relative numbers of sheep observed in Phase 4 appears to have continued in Phase 6, as well as the axial splitting of bone for marrow. The increase in numbers of split to chopped bone may suggest a shift in butchery practices, perhaps demonstrating that all aspects of meat resources were being used as much as possible. There is no significant evidence for a change in fishing strategy between the two phases (Dockrill *et al.* 2007, 82).

Similar diversification may also be manifested in the varying and shifting use of shellfish in quantity and type, although this point it must be stressed that differing sampling and collections between site excavations and varying soil qualities can have a significant effect on true shellfish assemblage sizes. However, this is a point worth considering. Marine molluscs were rare in the soils and middens of the Neolithic phases at Tofts Ness, with a steady increase in number through the Bronze Age and into the Early Iron Age. Overall, limpets were the most numerous, although other species were present including the cockle and rough periwinkle. No shell was recovered as part of the Pool excavation sampling strategy so unfortunately there is no directly comparable data (Hunter, J. *et al.* 2007, 272).

Similar patterns have been noted for the Outer Hebrides. At the wheelhouse at Cnip, limpet and periwinkle dominated during all phases, suggesting the exploitation of rocky shorelines and repeated use of seaweed, upon which periwinkles would have been carried into the settlement (Armit 1990, 180). An increase in the use of shellfish as a food resource and perhaps decorative items has been suggested for the Late Iron Age phases at Bornais Mound 1, where there is an increase in number and variety. In the Late Iron Age, there appears to have been a preference for limpets gathered from rocky shore environments, whereas in the Norse period of occupation there was a preference for winkles (Sharples 2012, 228).

The increasing presence of shellfish at Tofts Ness was suggested to be representative of an increasing reliance on fishing as an economic strategy at Tofts Ness. However, the role of limpets as a possible 'famine food' in the face of changing environmental conditions was also considered by the excavators (Dockrill *et al.* 2007, 228). Such a view is reminiscent of the interpretation of Childe, who viewed the presence of shellfish in the Skara Brae assemblages as a famine food that the survivors of his great 'sand inundation event' were forced to "rely on" (Childe 1931, 64).

These interpretations of shellfish as a famine food fail to capture the diverse and wide-ranging role of wild resources throughout prehistory (Noble *et al.* 2017, 2). Shellfish could be also used as bait and fertiliser, a common use for seaweed too. Historical ethnographic data for Lewis suggests that molluscs and seaweed were both favoured for their fertilising properties, and as such were used in the agricultural fields every seven years (Martin 1716, cited in Armit 1990, 180). It may be that the increasing use of shellfish resources over time does reflect a change in environment. However, these were changing environments that the inhabitants of the coastline chose to exploit to their advantage. For example, cockles are often found and harvested after a storm or bad weather, when they litter the beach (Figure 6.15).

Figure 6.15. Cockles and razor clams thrown up by storms in January 2016 at West Sands, St Andrews.

6.3.4. Soil amendment

Land degradation stands as one of the most significant impacts of windblown sand inundation, both in the prehistoric and more recent past. The mobilisation and erosion of various sediments by aeolian dynamics more broadly continues to stand as a problematic process in the agricultural sphere. In April 2013 an overnight storm inundated farmland across Moray, covering and degrading barley crops (Figure 6.16). In a related vein, the early 2018 adverse weather conditions experienced across the United Kingdom (termed the ‘beast from the east’ – a cold weather front which moved across the North Sea from Scandinavia) led to the erosion of large swathes of ploughed and destabilised agricultural topsoil, which were deposited onto the snow (Figure 6.17).

Figure 6.16. Forres (Moray) farmer Cameron MacIver examines one of his barley fields, which was inundated by windblown sand overnight during a storm in 2013. HE Media.

Figure 6.17. ‘Snoil’, a mixture of snow and soil at the side of fields in Boscastle, Cornwall. S. Stevens.

A frequently-noted feature of the archaeological record at sites and landscapes inundated by windblown sand across the Northern and Western Isles is the improvement of soil quality through the application of manure to sandy soils. The aggrading and improvement of agricultural soils, and the stabilisation of sands, is a strategy which has been noted at numerous sites in the Northern and Western Isles (e.g. Guttmann 2001; Dockrill and Bond 2009), for example at Jarlshof and Old Scatness (Shetland), Tofts Ness (Sanday), (Dockrill and Bond 2009), Skara Brae (Simpson *et al.* 2006), Links of Noltland (Westray) (Moore and Wilson 2011; Hamlet 2014), Cill Donnain (South Uist) and Eoligarry (Barra) (Gilbertson *et al.* 1999). The practice is not the preserve of a single period, with manuring noted at Neolithic Skara Brae and Links of Noltland (Orkney), Bronze Age Jarlshof (Shetland) and Iron Age Old Scatness (Shetland) in the Iron Age (Dockrill and Bond 2009). Such deposits have been compared to the rich 'plaggen' soils of the Middle Ages (Guttmann 2001).

Chronological patterns in the use of prehistoric manuring strategies in the Northern Isles have been identified by Guttman, though, who suggested that domestic waste and turves dominated as manuring materials from the Neolithic through to the Iron Age, after which domestic animal manure became more common (Guttman *et al.* 2006). Earlier use of animal manures has, however, recently been identified at the Links of Noltland (McKenna and Simpson in Moore and Wilson 2011). Findings will only be briefly described here, as significant work has already been undertaken on many of these themes, and the reader is encouraged to seek further information from the publications listed above.

In the Neolithic and Iron Age phases at Tofts Ness, domestic waste midden, human manure and grassy turf were applied to ard-cultivated soils which became increasingly sandy, in order to enhance their fertility (Guttman *et al.* 2006). Similar practices have been posited for the Neolithic site of Stove (Sanday) (Bond, J. M. *et al.* 1995). At Knap of Howar, the Period I midden deposits (dating to c. 2800-2400 cal. BC) which extended up to 20m south of the dwellings (Ritchie 1983; 1995) were suggested by the excavator to have functioned as a source of fertiliser and bedding for cultivation (Ritchie 1995, 23; Richards *et al.* 2016, 192). During the construction of the Grobust House (Structure 18) at the Links of Noltland, a sequence of three midden layers interspersed with windblown sand also appear to have functioned as consolidation deposits for the dune into which the structure was built (Moore and Wilson 2012, 70).

Midden deposits were also intermingled with the Neolithic ploughsoils adjacent to habitation areas at the Links of Noltland (Clarke, D. V. and Sharples 1985, 74; Richards *et al.* 2016, 192). Micromorphological analysis of thin section samples were taken from a sondage located beyond archaeological remains, near the Bronze Age Structure 1 at the Links of Noltland (Figure 6.18). The sondage comprised deposits of calcareous windblown sand and cultivation soils, which formed rapidly through accumulations of the sands and anthropogenic additions. The soils began to form with the application of imported turf and domestic waste, including pottery, charcoal and bone, while the upper portions of this soil context indicated reduced windblown sand movement and evidence for enhanced vegetation coverage (McKenna and Simpson in Moore and Wilson 2011, 79; Hamlet 2014). The sand inundations appear to have been rapid, and after their deposition were mixed and worked together with the soils to prepare and stabilise the land surface for cultivation. The soils which were formed above this comprised similar deposits of domestic waste alongside more turf, and animal manure to stabilise the sands (McKenna and Simpson in Moore and Wilson 2011, 78-9).

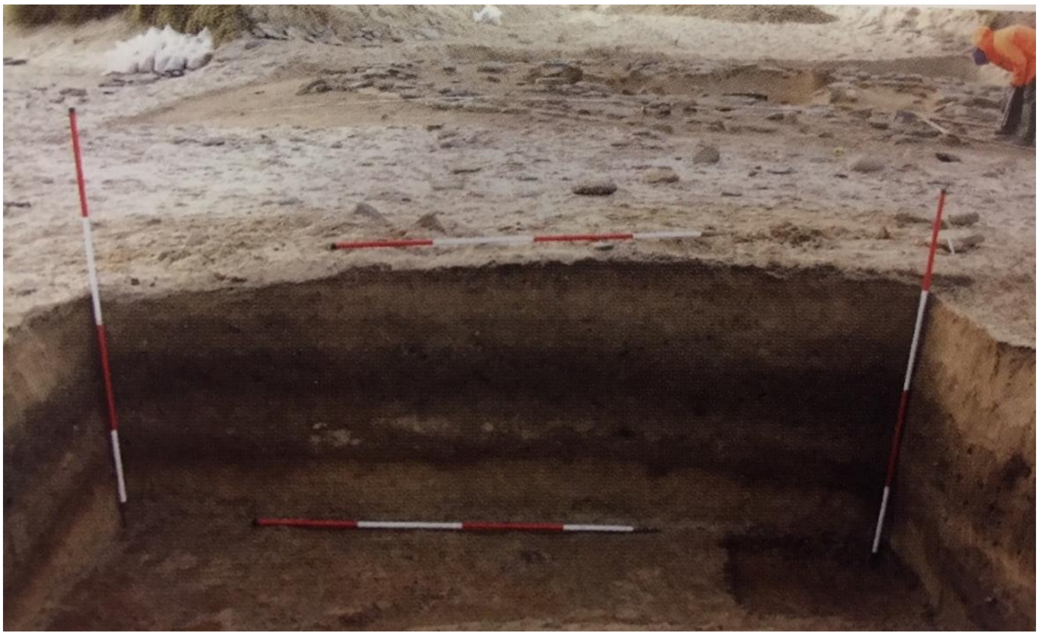

Figure 6.18. Area 1 East-facing sondage photograph showing interleaved windblown sands and humic soils. Moore and Wilson 2011, 23.

6.3.5. Stabilisation of sand deposits

Another related activity identified in the archaeological record is the stabilisation of sand horizons with midden or manure to inhibit sand movement and create stable surfaces. The use and curation of waste materials in construction, stabilisation and weather-proofing appears to have formed an important part of site development since the Neolithic (Simpson *et al.* 2006). Such practices have been identified in samples taken from the 1972-1973 excavations at Skara Brae. Micromorphological sections from both the earlier and later phases of occupation at Skara Brae (Phases I and II) revealed evidence for consistent episodes of windblown sand deposition (particularly in Phase II). This was stabilised and consolidated by anthropic soils and middens dominated by fuel residues (Simpson *et al.* 2006, 229). Whereas peats and turves dominated the middens remains from Phase I, Phase II midden comprised a wider range of household waste materials (Simpson *et al.* 2006, 232). Perhaps the increasing deposition of sand in Phase II drove a requirement for a greater quantity of consolidating midden, supplemented by a wider range of material types.

At Pierowall Quarry, the 0.35m deposit of windblown sand overlying the Iron Age roundhouse changed from a yellow to a light brown in the top few centimetres. Furrow scars were observed in the interface between the two colours, and the change in colour was suggested to represent a process of fertilisation or stabilisation of the sand (Sharples 1984, 89). Similar practices have been suggested for the eroding site at Westness Farm (North Ronaldsay) (Moore and Wilson 1999, 367).

At Evertaft (Westray), the upper and lower middens which partially bracketed a 9th century AD sand deposit were noted to contain markedly similar inclusions, and it was suggested by Barrett *et al.* that the upper midden (Unit 6) may have originally been part of the lower midden (Unit 4, dated to the Late Iron Age) which extended across the site, before being redeposited in order to stabilise the sand surface (Sommerville 2003, 110) (see Appendix 1). Similar practices have also been noted in the Norse period occupations at Snusgar, where the settlement mound was found to comprise layers of peat ash, stone and midden punctuated by clean windblown sand (Griffiths, D. 2016, 222). The development of complex masonry and midden 'farm mound' sites of the Medieval period across the northern islands of Orkney is suggested to have stemmed from the successive 'managed' stabilisation events at sites such as Snusgar (Griffiths, D. 2016).

Extensive, archaeologically- and organically-rich soil layers have also been identified within the carbonate sands at several sites in the Outer Hebrides. These horizons were originally described as naturally-derived palaeosols and were suggested to be indicative of natural stabilisation processes and hence as markers of less stormy conditions (Gilbertson *et al.* 1995; Gilbertson *et al.* 1996). However, soil micromorphology confirmed that these deposits too were artificially thickened and anthropogenically-modified (Gilbertson *et al.* 1999). This attests to the analytical value of soil micromorphology, which has the potential to fundamentally alter our understandings of the nature of such deposits.

Soil micromorphology studies were undertaken at Cill Donnain I, Cill Donnain III and Cladh Hallan (South Uist), and the Eoligarry isthumus of Barra to determine the nature and significance of these soils (Figure 6.19). All the sands detected in the carbonate sands were identified as being dune-derived. Between Cill Donnain I and Cill Donnain III, (a distance of c. 1km), a dark, grey-black undulating surface containing shell, bone, seaweed, midden, ash, and boulder-built houses and walls was observed. Sand layers and lenses were also observed in portions of the deposit, notably at Cill Donnain III where it was separated into Bronze Age and Iron Age layers (Gilbertson *et al.* 1999, 453). The depth of the soil ranged from 0.1m – 1.0m, and on more in-depth study was also found to contain excrement, organic grain-coatings, charcoal and heat-affected shell and ceramics. These inclusions may have also been used to improve soil fertility through manuring (Gilbertson *et al.* 1999, 453-4; Edwards *et al.* 2005).

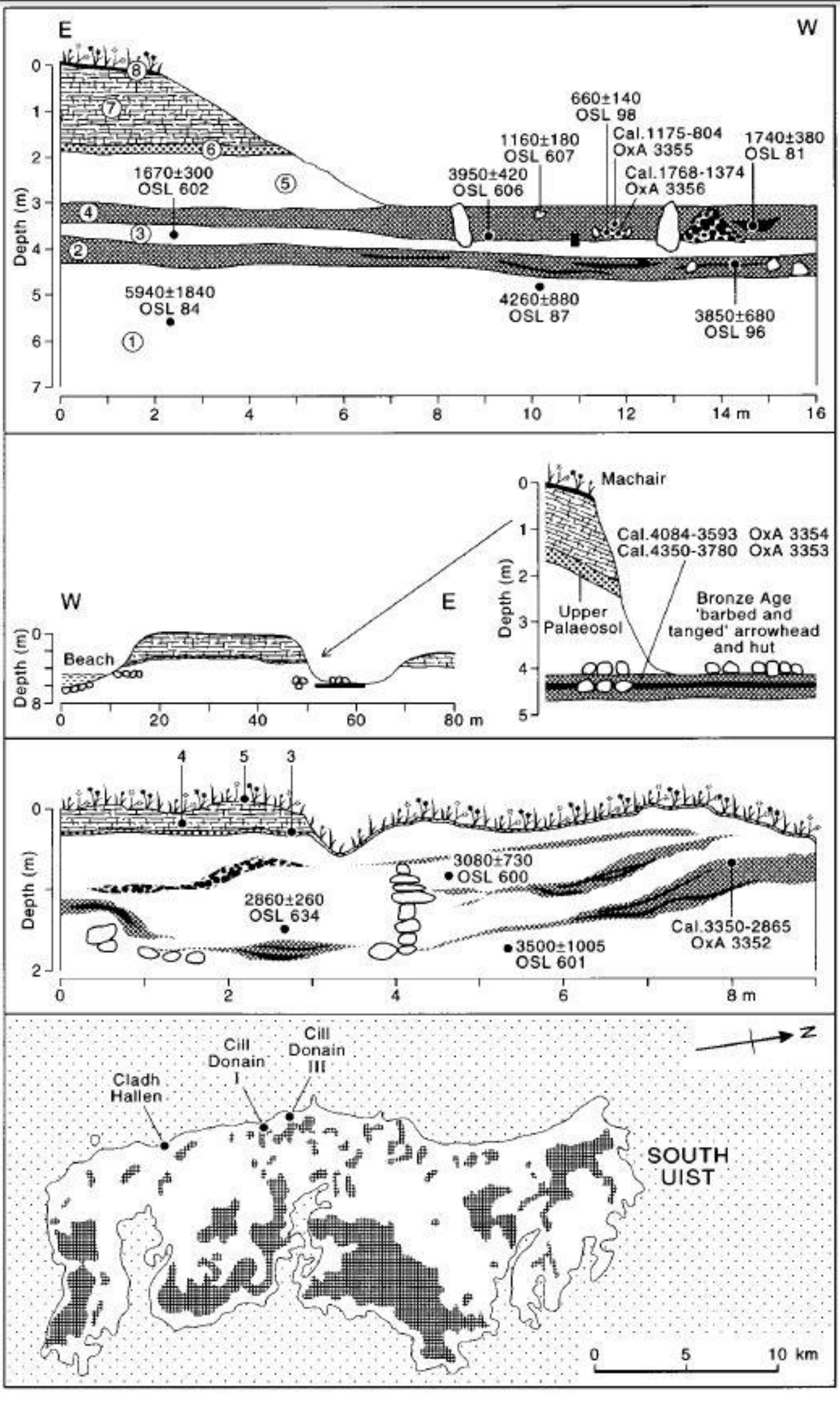

Figure 6.19. Machair and palaeosol stratification at Cill Donnain III, I and Cladh Hallan (highest to lowest). Gilbertson et al. 1999, 447

Such activities also formed important resilience strategies in the more recent past. In the burgh of Ayr on the west coast of Scotland, repeated incidents of sand mobilisation leading the inundation of land and settlements, and the exposure of burials, prompted Robert II to issue a charter in 1380 “giving to anyone, who should prevent the blowing of sand, the right of property on all the waste land” (Chalmers 1810, 501-2 cited in Griffiths, D. 2015, 108). This eventually led to the construction of retaining walls by the burghers and landowners (Griffiths, D. 2015, 108).

The New Statistical Account (1834-1845) makes a number of references to attempts made to stabilise the drifting dunes during the nineteenth century. By far the most successful means of stabilisation was the planting and cultivation of bent (*Arundo arenaria*) grass which could grow up to 2ft in height. The tough and elastic texture of the bent grass also made it an ideal material for many practical uses, including matting, sacks and mounting for creels, although its principle use still appears to have been for dune stabilisation. Many dunes were also artificially sloped and covered with turf, and roads constructed (Finlay McRae, New Statistical Account 1837: 167; 174-5, cited in Leask 1996, 181-2).

Rubble dumping as well as heather, hay and straw layered and weighed down by sand were also common strategies. Stabilisation became increasingly prevalent following the *Act of Preservation of Meadowes, Lands and Pasturages Lying Adjacent to Sand Hills* passed in Scotland in 1695, which prevented the cutting of marram grass (Clarke, M. L. and Rendell 2009, 33-5). Several embankments were constructed on North Uist as a means of halting the encroachment of the sea (apparently saving an estimated 86 Scotch acres), and a similar area of lochs was also drained presumably in an attempt to create new areas for cultivation (Rev. Finlay McRae, New Statistical Account 1837: 167; 174-5, cited in Leask 1996, 181-2). The improvement of large tracts of machair, including Machair Mheadanach on South Uist, allowed them to be brought to cultivation and to yield successful crops (Rev. Roderick Maclean, New Statistical Account 1837: 191-2, cited in Leask 1996, 182-3). During the 20th century, machair land on Harris was only cultivated for three successive years and then lay fallow for a further three years to counteract the risks of soil degradation through sand erosion (Rev. Norman Macdonald 1954, Third Statistical Account, cited in Leask 1996, 178).

Discussion

The evidence discussed has been typically viewed through a practical lense of sustainability and resilience (e.g. Dockrill and Bond 2009, 4-6; Guttmann-Bond 2010). In a more interpretative vein, Sharples and Hamilton have suggested that the cultivation and manuring of soils, as well as the distribution of fragmented beaker pottery across the developing soils in the Outer Hebrides represent a deliberate attempt to ‘enculturate’ the landscape (Evans, J. G. 2003, 81; Hamilton and Sharples 2012, 212). A similar practice can be observed at the Links of Noltland, where the Bronze Age Structures 1-3 overlay up to 1.4m of windblown sand interspersed with palaeosols and cultivation horizons, containing frequent fragments of pottery (Moore and Wilson 2007a, 10).

These activities represent the complex and varied implications of human activity in the dunes. The maintenance of such environments in the ways described above is termed 'pulse stability' by ecologists, where stability is ensured through the application of 'pulses' of fertile materials. In ecological studies, such practices are often undertaken at the junctions of various ecosystems, such as between drylands or lakes (Evans, J. G. 2003, 53). It can be argued that coastal dune cordons, machair and beaches also lie at a distinct junction: between land and sea. These junctions have been referred to as 'ecotones' (Evans, J. G. and O'Connor 1999, 53), representing the division and distribution of activities across the landscape which allowed for a form of social expression demonstrated through the relative productivity and success of different areas of the landscape (Evans, J. G. 2003, 54). In precolonial Fiji, the fragmentation of land holdings (where land owned by individuals or communities was split across the islands) allowed for the reduction of crop exposure to bad weather, as different areas of the island provided different levels of shelter (Campbell, J. 2009, 90).

The curation and use of occupation deposits in various ways attests to their significance beyond practical use. Indeed, such deposits may have represented a key means of the display of 'wealth' and prosperity through fertility. Over time, these became 'inherited resources' – linking with the concept of social memory as a means of resilience. Evans uses the thick agricultural soils of the Northern and Western Isles to illustrate this concept, where an evident disparity may have existed between the fertile soils near settlements (where turves and soil were applied), and the low fertility soils further away, from which the turves had been removed (Evans, J. G. 2003, 67).

6.3.6. Storage and exchange

Poor weather conditions and the resulting social impacts could place whole communities in jeopardy, whose interlinked economic base relied on predictable weather conditions and manageable risks. Some individuals or larger groups could take advantage of negative or disastrous situations, as a means of developing power and social control to encourage social cohesion (Evans, J. G. 2003; Eriksdotter 2013, 32). Halstead and O'Shea assert that sharing and reciprocation lie at the very heart of human cultural interactions, and it has long been recognised that trade and exchange represented a key means of creating and developing social relationships (e.g. Appadurai 1986).

Here, an abundance of resources of any kind following a good year or season could be converted, through social action, into future obligations in times of need. Reciprocity would be expected, and perhaps fealty (Halstead and O'Shea 1989, 4). This could be manifested in the provision of commodities such as building materials, shared land, livestock and/or their products, the provision of human commodities such as labour (for example to assist in a day's sowing or harvesting) or the provision of stored resources (Dockrill and Bond 2009) in exchange for fealty and increased influence. Storing food surplus in 'good years' would allow for intra-community feasting to take place, during which obligations as well as materials could be exchanged (Campbell, J. 2009, 91). Such exchanges could take place within and between communities, where varying food sources could be distributed between different ecological bases – eventually, inter-island networks could also be formed. At Tofts Ness, manuring of sandy soils is interpreted as forming one part of a larger mixed palaeoeconomic strategy which was culturally inherited through time, and which allowed a grain surplus, the storage and redistribution of which may have been the principle means of organising society and exerting control (Dockrill and Bond 2009, 4-6).

Aside from secondary evidence of storage provided by ceramics and some forms of domestic architecture, it is often difficult to directly identify unequivocal evidence for the act of storage in the Orcadian prehistoric record. However, some aspects of the early Neolithic record on Mainland Orkney and Wyre appear to demonstrate arable storage. At Varme Dale (Mainland), sealed beneath a 2nd millennium cal. BC barrow, a large quantity of burnt grain (of comparable quantities to those recovered from Braes of Ha'Breck) was recovered. This early deposit was dated to 3770-3620 cal. BC and 3770-3630 cal. BC (Richards *et al.* 2016, 269). At Wideford Hill, a deposit of c. 6000 charred barley grains was recovered from a posthole or pit in Timber Structure 3, dating to c. 3500 cal. BC (Richards *et al.* 2016, 269; Richards and Jones 2016, 72; Griffiths, S. 2016, 296). At Braes of Ha'Breck (Wyre), thousands of charred barley grains were found to be spread across the floor of House 3 (Figure 6.20). The excavators posit a granary function for the structure, through which a large fire appears to have spread (Thomas 2011, 135; Lee and Thomas 2012). The conflagration of these grains has been dated to 3339–3028 cal. BC (OxA-28861) (Bishop 2015, 845). In the oval houses at the Ness of Gruting, Shetland, a cache of 12.7g of carbonised barley (radiocarbon dated to 2150-1500 cal. BC (BM-441)) was recovered, and a quern stone which was laid up against an earlier wall during the second phase of development (Figure 6.21) (Calder 1958; Turner 1998, 36).

Figure 6.20. Braes of Ha'Breck House 3 with carbonised grain deposits. After Bishop 2011, 846.

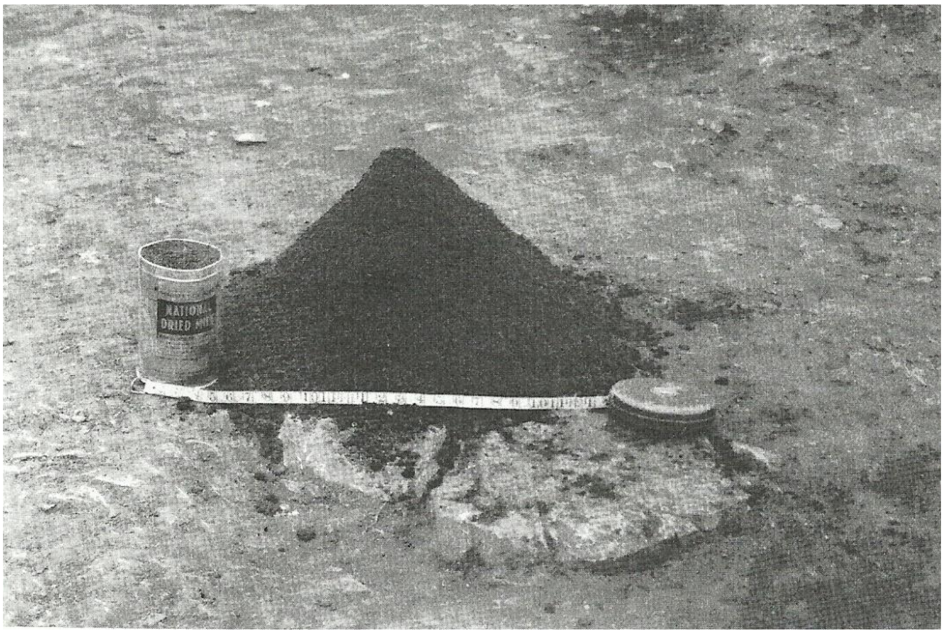

Figure 6.21. Carbonised grain from the Ness of Gruting. Turner 1998, 36

Historically, in the particularly high-risk areas of the western seaboard communities were able to draw upon a range of strategies including famine foods, temporary abandonment and rests or eases of rents during the troubling years (Dodgshon 2005, 333). the importation of goods from other islands and regions became an important means of buffering against the impacts of bad weather. Poor crop was also noted for the years 1782-1785, and 1778 in Orkney. Reporting from the parishes of Eday and Stronsay, the Rev. John Anderson reported that four hours of high westerly winds on 14th August 1778 led to the damaging of "*the crop of the whole country*" through the deposition of sand and sea water. In response to this, the communities imported approximately 18,000 bolls (a Scottish unit of dry capacity, converting to c. 200 litres) of meal and bere barley, as well as potatoes, malt and barley totalling around 15,000 pounds. From 1778 the crop was said to have improved, so much so that many provisions were subsequently exported again (Rev. John Anderson, 1799, Statistical Account Vol. 15, 432-3 cited in Leask 1996, 126).

6.3.7. Abandonment – or mobility?

The final buffering strategy outlined by Halstead and O'Shea is that of mobility. This is a response which was most suited to the inhabitants of earlier prehistoric landscapes, who were generally less tied to a single locality which summed the total of their investment in the landscape. The flexibility of territorial boundaries, landscape use and communal and kin networks would have allowed for the easy development of contingency strategies. A typical interpretation of a hiatus or ceasing of settlement following a windblown sand inundation is that the site has been 'abandoned' as a result. Identifying abandonment in the prehistoric record, and the drivers behind it, is rather more challenging. The lack of precise chronologies and immediately-obvious reasons for perceived abandonment typify the challenges faced. Despite this difficulty, archaeologists have frequently been quick to assign this terminology to the demise of selected prehistoric archaeological sites which experienced windblown sand deposition (e.g. Childe 1931 Sommerville 2003; Dockrill *et al.* 2007). (Shepherd 2016). It is argued here that in the context of the dynamic coastal zone, our conceptions of 'permanent' settlement trajectories – and the perceived abandonment of these trajectories - in the prehistoric period must be reconsidered.

Identifying abandonment in the archaeological record

> "*The huts, when found intact, give an impression of hasty abandonment: cooking-pots and implements had been left on the floor just where they would have been used in everyday life. Valuable objects such as carved stone balls……are found scattered on the hut floors…Had the inhabitants withdrawn at leisure they would surely have taken with them objects made with such labour."* Childe 1931, 61.

Gordon Childe's blow-by-blow narrative of the history of Skara Brae and its perceived abandonment driven by a rapid and extensive sandblow represents one of the earliest archaeological discussions of abandonment driven by sand inundation. The abandonment of houses, settlements or landscapes is frequently cited as one of the most significant outcomes, or responses to, climatic and environmental change to be identified within the archaeological record (Cameron and Tomka 1996). From a westernised perspective, 'abandonment' brings with it connotations of permanence, of significant decisions and negative drivers behind such impacts. In turn, this often influences our understanding and interpretation of the archaeological record and the apparent evidence of abandonment. A more critical analysis of the archaeological record and how it has been excavated and reported, as well as anthropological and ethnographic sources, reveal a nuanced and complex picture of these events in a settlement or house lifecycle.

In the Scottish research context, a number of example case studies have been drawn upon from the prehistoric and historic records in order to examine the concept of abandonment. All appear to be concerned with very different manifestations of apparent abandonment, each demonstrating several variables driving this process. Alongside the abandonment of sites inundated by windblown sand, other case studies covering a number of scales can be identified, including the abandonment of the northern uplands during the Bronze Age (Burgess 1985), the case of the regional abandonment of wheelhouses in the Western Isles in the first millennium AD (e.g. Sharples 2005b), and the widespread abandonment of areas of Scotland during the Little Ice Age (Edlin 1976; Griffiths, D. 2015). These examples demonstrate that abandonment can occur on a number of scales, from intra-site (e.g. areas of activity within a site), structures, and settlements to whole regions (Cameron 1996, 3) and can represent a far more complex picture than destruction or catastrophe.

In the Orcadian context, the final trajectories of the sites outlined in Chapter 4 illustrate the complexity of identifying abandonment driven by marginalisation of settlements and landscapes. An examination of the evidence presented by excavators (summarised in Chapter 4) allows for the identification of two different interpretations of abandonment which were perhaps influenced or directly driven by the deposition of windblown sand. An additional third abandonment trajectory is also considered;

1. Direct, immediate abandonment of the site following a single large-scale sand inundation event. Immediate abandonment has been posited by Childe for Skara Brae (1931 but see below) and by Dockrill *et al.* for Tofts Ness (2007).

2. Abandonment reflecting the reaching of a 'tipping point' on sites where regular sand drifting is noted. Here managing the regular sand fluxes becomes untenable. A decision is then made to abandon a site, where the losses outweigh the benefits of continuation of settlement. This has been suggested by Moore and Wilson for Links of Noltland (2015), and by Griffiths, D. (2016) for several Norse and Medieval sites including Snusgar and Marwick, and Barrett (2012) for Quoygrew.

3. Where the site – or area of the site - appears to have been abandoned some time before sand inundated it. Here sand can be used as evidence of absence – where it has not been cleared away because there is either no value in doing this (for example, if that area of the site is no longer in active use) or, the site is no longer inhabited. This is a tension which can be frequently identified in the archaeology of windblown sand deposition.

1. Direct abandonment after a single episode of sand inundation

One of the earliest mentions of sand inundation events prompting abandonment can be found in Gordon Childe's report (1931) on his excavations at Skara Brae. This interpretation was to have a profound and lasting influence on interpretations of sand-inundated sites, and in many ways continues to do so. Upon excavation of the individual Phase IV domestic structures, Childe interpreted the proliferation of tools and valuable items such as carved stone balls apparently left *in situ* beneath thick layers of blown sand as representative of the "hasty abandonment" of the huts (Childe 1931, 61). In Hut 7, four relatively brief reoccupation horizons were identified as follows; the floor (presumably the final longstanding occupation layer of Hut 7) was covered by a sand layer, followed by a fairly substantial classic square Neolithic hearth comprised of hearthstones enclosing ashy lenses and shell. This was covered by 1ft of blown sand, followed by a thin layer of ash and shell, and then another layer of blown sand. A layer of shell, a red deer skull, and charred bone lay above this sand layer, apparently c. 5ft above the original floor (Childe 1931, 61-2).

Another foot of sand was deposited above the hearth remains and deer skull, over which lay a "chaotic" heap of stones appearing to represent an episode of collapse, or perhaps a more structured dismantling although this is not made clear by the excavator. The sand horizon above this deposit was reportedly slightly different from the apparently sterile prior deposits of blown sand in that it contained a number of antlers (Childe 1931, 62). This series of deposits was interpreted as representing the periodic return of inhabitants or other groups to shelter and cook – a piecemeal and somewhat disorganised picture of social organisation. Childe favoured a catastrophic explanation for this series of events, and also acknowledges that whatever "disaster" occurred in this village may also have impacted on agricultural land and domestic herds, perhaps forcing the survivors of this disaster to live on shellfish and game instead – resources he equated with famine foods (Childe 1931, 63).

For the huts to have been filled with blown sand deposits, presumably they must have been exposed or partially roofed (suggestive of prior abandonment not driven by the sand inundation). This is a point that is acknowledged and countered by Childe, who suggested that some form of "natural agency" such as a storm or very strong winds may have driven this de-roofing and sand drift (Childe 1931, 63). Given the age of Childe's excavations, and the significant advancement of archaeological recording techniques and understanding, aspects of the excavator's reports must be approached with caution. Childe's report is very much a narrative of the life of the site, often at the expense of solid stratigraphic information. It is a product of its time and nevertheless provides a useful picture of past interpretations of sand movement, coastal change and its impacts on prehistoric settlements, as well as the development of archaeological interpretation.

In any summary or description of Skara Brae in the academic or popular literature, there is still invariably reference to the deep sand deposits overlaying the site, coupled with discussion of the original circumstances surrounding its discovery - whereby strong winds and storms removed sand deposits and revealed the remains of stone structures. In the sixth edition (2016) of one of the most influential archaeology textbooks - particularly to students beginning their archaeological studies - Renfrew and Bahn (in a section entitled 'Natural Disasters'), discuss the inundation of Skara Brae:

"Natural disasters sometimes preserve sites, including organic remains, for the archaeologist. The most common are violent storms, such as that which covered the coastal village of Skara Brae, Orkney Islands, with sand...."

Renfrew and Bahn 2016, 59.

This interpretation, then, has prevailed – despite the many misconceptions which informed it (Shepherd 2016). The deep covering of sand over the site did not, as Childe believed, represent a single inundation over the site, prompting its abandonment in a Pompeii-esque scenario. Rather, the deposit Childe encountered represented the surviving remains of sand which had accreted and deflated over the four and a half millennia since occupation ceased at the site (A. Shepherd *pers. comm*.) – which occurred centuries before.

Micromorphological studies demonstrate that windblown sand deposition was actually an issue faced regularly by the inhabitants of Skara Brae (Simpson *et al.* 2006) - one which they had managed to deal with for generations. For an immediate abandonment to take place, a depositional episode of tsunami-like proportions would have been required – leading to Pompeii-like preservation of structures which were in mid-use. Sand deposition, then, is unlikely to have been solely responsible for the end of settlement at Skara Brae – particularly as the period around c. 2500 cal. BC appears to mark the cessation of occupation at many Orcadian Grooved Ware sites which were not inundated by windblown sand (A. Shepherd *pers. comm*.). Given that the cause for cessation of activity at Skara Brae cannot be fully understood, it has been suggested that the term 'abandonment' is not appropriate. Instead, a 'cessation of activity' could be used (A. Shepherd *pers. comm*.).

2. *Tipping points*

It can be argued that a far more common incidence in the Chapter 4 sites is abandonment upon the reaching of a 'tipping point'. This is identified where small, repeated sand inundations - as well as larger-scale influxes – may have eventually proved to be too difficult to manage and mitigate against, thus leading to the abandonment of a site or landscape. Gordon Childe considered the significance of tipping points in a roundabout way, when he suggested that periodic revisits may have been made to resettle the site following a temporary period of abandonment, but that eventually the level of dune creep and the associated volumes of blown sand may have been overbearing and not worth mitigating against any further (Childe 1931, 63). However, more recent evidence suggests that in the Neolithic, those who inhabited Skara Brae and the Links of Noltland would have been well aware of windblown sand moving through the settlements on a regular basis; the middens which accumulated around the houses at Skara Brae were interleaved with thin lenses of windblown sand, as were those at Links of Noltland. The ground surfaces upon which the Links of Noltland structures developed through the Neolithic and into the Bronze Age were fundamentally composed of windblown sand, interleaved with cultivation soils intended to stabilise it. Similar regular accumulations have been noted at Knap of Howar.

These small-scale events, it could be argued, were hardly shocking. In fact, they were to become an important part of life at these settlements, intrinsically linked with the very material of the houses and their middens. When considering environmental change and how prehistoric communities interacted with change, the interplay between periods of gradual and rapid change, and how these interact across chronological and spatial scales, must be acknowledged (Folke 2006, 253). For example, it could be argued that the periods in which these sands infiltrated the settlements, in which manure was added and soils aggraded, were in fact periods of 'stability' – periods of rhythmic, gradual – perhaps seasonal- change. Small-scale, regular incursions allow for experimentation and regulation. It was only when rapid change occurred – for example, in large-scale single inundations such as those suggested for Tofts Ness and Links of Noltland – that new decisions had to be made.

In the resilience literature, it has been suggested that short-term solutions (perhaps akin to the resilience and buffering strategies discussed above) ultimately lead to the erosion of longterm resilience – leading to the collapse of social and environmental systems (Redman 2005, 71). Such an occurrence could perhaps be posited for the widespread abandonment of the machair landscapes of the Outer Hebrides (see below), and of the Links of Noltland in the later Bronze Age. Resilience perspectives in the archaeological literature are frequently concerned with large-scale disasters centring around the collapse of entire societies on a wider global scale, however, and it is often difficult to reconcile these concepts with what can be observed 'on the ground' in the Scottish Islands. The trajectories of cessation of activity at the Links of Noltland are worth considering in more detail here.

Abandonment at Links of Noltland

Several areas of the Links of Noltland, comprising both structures and the wider landscape, were inundated with windblown sand during the Neolithic and Bronze Age. From the start of its occupation from at least c.3000 BC, and up until its abandonment around c.1000BC, episodes of sand drifting and larger-scale inundations were to affect the settlement landscape. The evidence currently available suggests that the Neolithic phases of sand movement are represented by smaller lenses of windblown sand within floor and midden deposits, indicative of smaller-scale, yet fairly regular, sand mobilisation. In contrast, the largest sand inundations took place in the Bronze Age, during which point several structures were inundated by windblown sand either during (leading to their abandonment – as seen at the burnt mound (Moore and Wilson 2017, 16) – or after their main phases of use.

The Bronze Age burnt mound

The burnt mound complex at the Links of Noltland displays some of the most interesting sequences through which the concept of abandonment can be explored. The site was inundated with at least 2m of windblown sand during the second millennium BC, with the deposit likely to have been much thicker prior to deflation (Moore and Wilson 2017, 16). The use of peat (a resource which expanded during the Bronze Age) as a fuel source as well as the multiple sandblow events reveal a complex environmental history at the site (Moore and Wilson 2017, 37).

The burnt mound complex at Links of Noltland was constructed over an area of plough cultivation scars and field banks filled and covered with windblown sand, and a field bank (Phase 1). This soil horizon in turn overlay a further deposit of windblown sand which covered the natural clay (Moore and Wilson 2017, 12). The earliest use of the burnt mound (Phase 2) was represented by a mound with no associated structures, followed by a further deposit of windblown sand, the construction and use of the subterranean structure (Phase 3), repairs and shorter episodes of reuse (Phase 4), and disuse, collapse and sand inundation (Phase 5).

The burnt mound was also covered with smaller deposits of windblown sand during its use; the dumps of ashy soil and stone comprising the waste materials of burnt mound use were interspersed with clean sand layers (Moore and Wilson 2017, 8). This draws parallels with the burnt mound at Meur (Sanday) where frequent lenses of windblown sand were observed in the burnt mound material (Gardner 2017a; 2017b). Moore and Wilson suggest that although the upper levels of the well house were not recovered, it may have been roofed in order to protect it from blowing sand (Moore and Wilson 2017, 33-4).

Abandonment of the burnt mound

Following five phases of use and activity, the site was abandoned around c.1000BC following a massive sand inundation of the burnt mound and the chambered structure, during which at least 2m of sand was deposited (Moore and Wilson 2017, 16). The inundation damaged the roof covering the inner chamber (which was already covered by windblown sand) and destabilised the structure. The upper deposits overlying the central floor comprised collapsed structural stone, roofing and roof capping material. The building was not reinstated (Moore and Wilson 2017, 33). It is likely that thus far (pending further excavation and full publication) the sequence at the burnt mound represents the only compelling evidence for the end of use of a structure because of windblown sand inundation. This was an ending that was clearly marked, however – it was not 'abandoned'.

Structured deposition

Despite an apparent abrupt end to the use life of the burnt mound, a series of structured deposits were made within the sand which inundated the inner chamber. 1m below the upper surface of the windblown sand deposit, three pits were dug into the sand; two contained complete inverted pots, while the final contained articulated cattle vertebrae. All three were backfilled with loose sand (Moore and Wilson 2017, 33). Much has been written about the possible ritual (or ritually-intersecting) functions of burnt mounds in the literature (see, for example, Barfield and Hodder 1987) and it is likely that the burnt mound played a significant and complex role in the Bronze Age community at the Links of Noltland (Moore and Wilson 2017, 10). These objects, then, may represent a 'closing deposit' at the end of a complex and intermittent use biography – and indicate a far more structured process of 'abandonment'. Control was regained. The formalisation of the abandonment of a domestic structure or activity area more generally is also common at various junctures in prehistory.

After the deposition of this deep grey-white windblown sand, a series of later ashy burnt mound deposits were recorded above it, interpreted as dating to a very late use, small-scale of the site - which probably post-dated its abandonment (Moore and Wilson 2017, 16). The composite roof of the passage and cells remained mostly intact, but the central roof partially collapsed during antiquity (Moore and Wilson 2017, 18). It was noted by the excavators that the doorway to the burnt mound structure had been blocked off with coursed masonry late in the sequence (Phase 5) (Moore and Wilson 2017, 19), again attesting to a more structured and planned decommissioning of the structure.

Further evidence for structured abandonment – or the marking of abandonment – can be posited for the Neolithic phases at Noltland. The final abandonment of the passageways in the Grobust house – which filled with windblown sand – was marked by the deposition of some 18 cattle skulls and 6 sheep skulls (Moore and Wilson 2012, 56) (Figure 6.22). Similar examples of structured deposition can be found across Noltland, with a particular significance being attributed to the deposition of red deer remains. Indeed, such a phenomenon appears to have occurred across Late Neolithic Orkney. This is discussed further by Clarke, D. V. *et al.* (2017).

Figure 6.22. Cattle skull deposit in NS passageway of Grobust building. Moore and Wilson 2012, 60

Mobility and abandonment: discussion

The examples cited thus far have aimed to highlight the complication behind traditional trajectories of abandonment, and are used to suggest that a more fluid and planned approach to the cessation of activity at a site following the reaching of a tipping point can be offered. Moore and Wilson suggest that after occupation ceased in the Late Bronze Age, the inhabitants of Links of Noltland did not travel far. It is tempting to imagine, they state, that the community may have transplanted itself half a mile down the coast, where the Iron Age settlement of Queena Howe – “a more forgiving home” was founded (Moore and Wilson 2013). The possibility of a degree of flexibility – and mobility - is an interesting interpretative prospect.

Narratives of settlement trajectories in the Little Ice Age are often dominated by descriptions of agricultural land laid to waste, and mass abandonment of whole villages and settlements after ingresses of windblown sand. However, a more complex picture is offered by Dodgshon (2005) in his discussion of historical buffering strategies used by tenant farmers in the Highlands and Islands. Buffering strategies reminiscent of those discussed above, such as adjustments in cropping, are mentioned. In addition, he describes instances where land was abandoned on a temporary basis, *before* the worst occurred (Dodgshon 2005, 334-5).

This brings discussion to the third form of sand-related abandonment identified in Chapter 4: where sand horizons are an indicator of prior abandonment – or evidence of absence. It is likely that a large number of the sites with sandblow horizons summarised in Chapter 4 can be defined by this category, including the Birsay Bay sites and Pierowall Quarry. These sands were deposited after – or before – recorded settlement at the site. Although this means that they cannot be included in any in-depth discussions of direct human-sand interactions on a site by site basis, they can be used to identify broader patterns of mobility.

In this section is has been suggested that while the abandonment of a site or region is often associated with disaster, environmental change or mass migration, it should not always be assumed that it represents a 'final straw' or indeed an act of finality in a settlement's trajectory. Rather, it should be viewed as a normal part of the settlement process and life cycle of a community and an important part of the formation of the archaeological record (Cameron 1996, 3). It has been argued by John Evans that the concept of 'abandonment' requires further examination within a range of contexts (e.g. Evans, J. G. 2003, 111), with apparent abandonment not always signifying the end of a sites' inhabitation or significance. Here the varied and context-dependent *process* of abandonment is important to any understanding, as well as concepts of seasonality, curation and memory.

Chapter 7. Summaries and conclusions

Some conclusions raised by this thesis will now be presented through the discussion of the results from each chapter. Chapter 1 comprised an introduction to the research, firstly by stating the aims of the research project, followed by an introduction to the study area through a summary of the geographical and archaeological context of Orkney. The rationale for the thesis was then discussed. Here, the thesis was situated within its wider research and theoretical context, centring on the role of archaeology as a discipline within current climate debates. It was demonstrated that a multidisciplinary approach can help inform a more nuanced understanding of human-environment relationships. This led to the discussion of the methodology undertaken by the research project.

The mobilisation and deposition of windblown sand has traditionally been discussed within a climatic context, where it has been used as a proxy for increasing storminess driven by climatic deterioration. Chapter 2 began with a definition of this context, before defining the methodological and conceptual tensions between climate, environment and weather. It was argued that to understand sand deposition within its archaeological context, it must be explored through a framework which places concepts of weather, environment and their perception by humans at a site and landscape scale at its heart. In the first instance, this chapter sought only to introduce the reader to these concepts and their place within the archaeological and anthropological literature.

Following an introduction of the theoretical basis for the study of windblown sand, and the rationale behind its study, the physical basis was considered in Chapter 3. This comprised a discussion of the physical drivers behind the movement of sand following its destabilisation. Two critical thresholds for the movement of sand were introduced and discussed. Following this summary of the 'technical' basis of windblown sand movement, its role and efficacy as a proxy for climatically-induced increased storminess was introduced through a summary of the broader northwest European context for sand movement.

In Chapter 4, the main body of secondary analytical data for this thesis was introduced and summarised. This provided the baseline for discussion in the rest of the chapters. This comprised an island-by-island listing of archaeological sites and landscapes featuring windblown sand deposition. These summaries were organised in roughly chronological order, with the earliest-dated incidences discussed first, followed by the latest-dated incidences. At the end of each island summary, the sites with no satisfactory chronological evidence were discussed; these sites should be viewed as high-priority studies for further research.

Chapter 5 described the results of fieldwork at the site of Pool, Sanday and the lab work which followed. The fieldwork at Pool stood as an exploratory project which formed the of the primary data approach taken in this thesis to answer the research questions (therefore forming one half of the methodology). Fieldwork (and post-processing) at the site of Pool highlighted the tensions and challenges encountered by the author in their interpretation of the archaeological and environmental sequences.

In Chapter 6, the sites summarised in Chapter 3 were explored with specific reference to sand mobilisation and inhabitation in dune landscapes. The impacts of sand movement were discussed (and socio-cultural responses to them) through a consideration of a number of activities undertaken in the settled coastal zone. These activities included construction and dwelling in sand landscapes, with themes drawn from observations made in Chapter 3 about the nature of the archaeological record at each site. Human interaction with sand landscapes lay at the heart of this discussion chapter.

7.1.1. Answering the research questions

At the outset of this thesis, five research questions were posed. These questions were designed to achieve the ultimate aim of the thesis, which was to highlight the broader archaeological significance of windblown sand horizons in prehistoric Orkney, by synthesising all currently-available evidence for the deposition of windblown sand on or near prehistoric archaeological sites. Here, 'prehistory' is defined as the period encompassing c. 4,000 BC – c. AD 500 (from the Neolithic period to the Iron Age). The research questions – and some answers – are summarised below;

Q. What is our current state of understanding of the nature and geographical extent of blown sand deposits in the Orcadian archaeological record?

A. This question was explored using GIS maps, and summaries of chronological evidence. This dataset still requires much exploration and will expand as new discoveries emerge. It is suggested, therefore, that it would be unwise to place any significant weight on geographical patterns at this stage, as many are likely to result from excavation bias. For instance, a lack of sites with evidence for sandblow on North Ronaldsay – an island with extensive drift sand deposits – is likely to be an artefact of a lack of focussed archaeological attention being paid to this island. This issue is illustrated in Figures 130 and 131, where two key areas displaying extensive windblown sand drift deposits are shown: the northern islands of Orkney, and West Mainland Orkney. Here, the investigated sites known to include deposits of windblown sand (summarised in Chapter 3) are represented by green triangles. The grey circles, in contrast, represent all other archaeological sites which have been investigated in some form. To generate this data, a search of the CANMORE database was conducted, where terms such as 'investigation', 'excavation', 'evaluation' were used to bring up all known sites known to have received some form of archaeological consideration. A number of these data points are located in the extensive areas of windblown sand, and yet these do not contain any mentions of the presence of windblown sand. This illustrates firstly the vagaries of windblown sand, which can be transported, deposited and remobilised in different ways across relatively small stretches of landscape. Secondly, it highlights sites and areas requiring further study.

Q. Can chronological variation in patterns of sand movement be detected, and how does this fit within proxy evidence for northwest European storminess?

A. This question is answered more fully in the beginning of Chapter 6. What has been demonstrated is the uncertainty of the relationship between deforestation and sandblow is typical of the challenges of detangling cause from effect when it comes to such environmental dynamics. The 'suck in and smear' approach has been warned against, and it was demonstrated that correlation of the windblown sand events in the Orcadian archaeological record with wider proxy data is challenging at best. This discussion paved the way for the alternative discussions presented in Chapter 6.

Q. How have sand horizons on prehistoric archaeological sites previously been identified and interpreted?

A. Chapter 6 formed the majority of discussion for this research question. It demonstrated that traditional interpretations were focussed upon trajectories of abandonment and disaster, and suggested that three forms of abandonment can be identified. Firstly, immediate abandonment as a result of a large sand mobilisation and deposition event. Secondly, on the reaching of a tipping point, where a decision was made to mobilise before sand deposition became an overwhelming problem. Thirdly, sand as 'evidence of absence' was considered. Overall a distinct trend of interpretations being guided by westernised perspectives of marginality was identified. These interpretations left little freedom to consider alternative trajectories of change, and ways in which people interacted with the environments in the coastal zone.

7.1.2. Directions for future research

Theoretical considerations

From the outset of this research, attempts to reconcile the human scale of interpretation of the environment (and therefore impacts) with broader environmental timescales were found to be challenging and at times, unfulfilling. A deeper understanding of the social significance of windblown sand (which has rarely been previously discussed) found fruition through the consideration of distinct spheres of engagement in the coastal zone, and the activities undertaken within them. It is argued that approaches like that undertaken in Chapter 6, when combined with site-by-site palaeoenvironmental investigations, can lead to a much more detailed understanding of the nature and significance of archaeological windblown sand horizons.

Practical considerations

This thesis presented the most common approaches to the archaeology of windblown sand and has sought to emphasise both the successes and limitations of these approaches. During the OSL dating process at Pool, a number of challenges were faced. This highlighted that there is a need for more well-developed chronologies of windblown sand movement, and sand sampling strategies which relate directly to archaeological activity. While luminescence dating of windblown sediments has used with considerable success in other regions and geological contexts (e.g. Duller 2008), numerous challenges are faced when OSL dating is applied to sediments in the Northern and Western Isles. The use of radiocarbon dating as a constraining tool for OSL dating is highly encouraged, and it is suggested that the development of tight radiocarbon chronologies and age-depth modelling of bracketing deposits is almost more important than continued experimentation with OSL dating, which yields varying results.

Following consideration of the variation in approaches, it is suggested that a promising way forward for studying the archaeological significance of windblown sand is the continued development of micromorphological studies of archaeological sediments. These should focus not only on the application of anthropological materials and the development of soils, but also on the presence and density of lenses of windblown sand. Studies undertaken by Hamlet (2014), Simpson *et al.* (2006), Guttmann (2001), and Gardner (2017a; 2017b) demonstrate the variability in sand accumulation, and highlight the possibility of identifying ‘microhistories’ at structure level. This proved particularly pertinent at Skara Brae, where only larger accumulations were visible to excavators. Upon micromorphological study, thinner lenses of windblown sand representing small-scale, but continuous, influxes of sand were evident (Simpson *et al.* 2006). Such studies have the potential to fundamentally alter long-standing interpretations of the scale, variability and chronology of windblown sand influxes. Here, the dynamism and varying materialities of the sands are highlighted; settlements and landscapes were not just inundated with large amounts of windblown sand.

Extensive, archaeologically- and organically-rich soil layers identified within the carbonate sands at several sites in the Outer Hebrides were originally described as naturally-derived palaeosols and were suggested to be indicative of natural stabilisation processes and hence as markers of less stormy conditions (Gilbertson *et al.* 1995; Gilbertson *et al.* 1996). However, soil micromorphology confirmed that these deposits too were artificially thickened and anthropogenically-modified (Gilbertson *et al.* 1999). This is a promising method which can reveal wider practices of anthropogenic interaction with windblown sands, and will go some way to contributing to questions surrounding the presence of stabilisation horizons and their origins.

The archipelago-wide survey of all archaeological sites with windblown sand deposit highlights a great number of high-potential sites which hold little in the way of chronological data. The majority of these fall within the groups identified by the Coastal Zone Assessment Surveys, and more recently the SCAPE Trust. Actively-eroding archaeological sites are an important source of archaeological material which can be used to inform understanding of settlement density in the coastal zone.

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SCAPE Sites at Risk Map. www.scharp.co.uk/sites-at-risk/

Appendix 1

Windblown sand sites of Orkney: supplementary information

Contents

Figures

Tables

Appendix 1 contains the entire list of windblown sand sites identified during this thesis. Sites with a lack of detailed archaeological information (for example, many of the actively-eroding and recently identified sites compiled by the Coastal Zone Assessment Survey, and the SCAPE Trust) are presented here. Unless otherwise stated, all radiocarbon dates are quoted at the 95% probability range.

1. Mainland Orkney

1.1. Bay of Skaill.

1.1.1. Skara Brae

Database ID: 14

CANMORE ID: 1663

Site type: Settlement

Period: Late Neolithic (c. 2920-2885 cal. BC to c. 2545-2440 cal. BC) (*central_phase_1_start; central_phase_2_end*) (Bayliss *et al.* 2017 [Supplementary Material], 89).

Sandblow period: Early-Middle Neolithic (before 3350-3020 cal. BC (SUERC-12717 (GU14731)); Late Neolithic (at c. 2920-2690 cal. BC (SUERC-12733 (GU14741)); from c. 2870–2815 cal. BC to c. 2840-2685 cal. BC (*central_phase_1_end; central_phase_2_start*); to c. 2620-2460 cal. BC (SUERC-12470 (GU14686)); after 2545-2440 cal. BC (*central_phase_2_end*).

1.1.2. Skara Brae (Sandwick)

Database ID: 121

CANMORE ID: 91751

Site type: Spread (animal bone and tools)

Period: Late Neolithic

Sandblow period: ?Late Neolithic

1.1.1. Sand Fiold

Database ID: 128

CANMORE ID: 1689

Site type: Cist burial

Period: Bronze Age (from c. 2900-2500 cal. BC (UT-1483; UT-1485) to c. at c. 1000-800 cal. BC (UT-1560).

Sandblow period: Unknown (post- 1000-800 cal. BC (UT-1560)).

1.1.2. Skaill

CANMORE ID: 138798

Database ID: 126

Site type: Cist inhumation, palaeoenvironmental section

Period: Late Iron Age-Pictish (Skeleton dated to cal. AD550-680 (GU-7245) (James *et al.* 1999, 773).

Sandblow period: Between 765±620 BC <SUTL-621> and cal. AD550-680 (GU-7245)

1.1.3. Snusgar and East Mound

Database ID: 13

CANMORE ID: 1674

Site type: Settlement

Period: Viking

Sandblow period: 14^{th} – 16^{th} centuries AD, and possibly earlier (pre-Late Iron Age)

1.1.4. Skaill House

CANMORE ID: 123653

Database ID: 129

Site type: Cemetery

Period: Late Norse-Medieval (from at least cal. AD1043-1290 (GU-7244) to cal. AD1220-1392 (GU-7243)

Sandblow period: Before c. cal. AD1043-1392 (GU-7244; GU-7243); between cal. AD1043-1392 and the 17^{th} century AD (no scientific date available).

1.1.5. Marwick

Database ID: 16

CANMORE ID: 1920

Site type: Settlement

Period: Viking/Norse

Sandblow period: Viking, Medieval

The site at Marwick was investigated as part of Oxford University's Birsay-Skaill Landscape Archaeology Project, and although it lies between Birsay Bay and the Bay of Skaill, it is considered here. Geophysical survey across the bay revealed a mound complex within an erosive coastal area containing deposits of windblown sand, although these are not marked on the sand dune vegetation survey map (Figure 1.1). At Marwick Bay, an eroding settlement mound containing walling, windblown sand and shell midden was recorded, sampled and surveyed in 2009 (Figure 1.2**Error! Reference source not found.**). This led to the identification of the site as a Viking house (Griffiths 2009, 128).

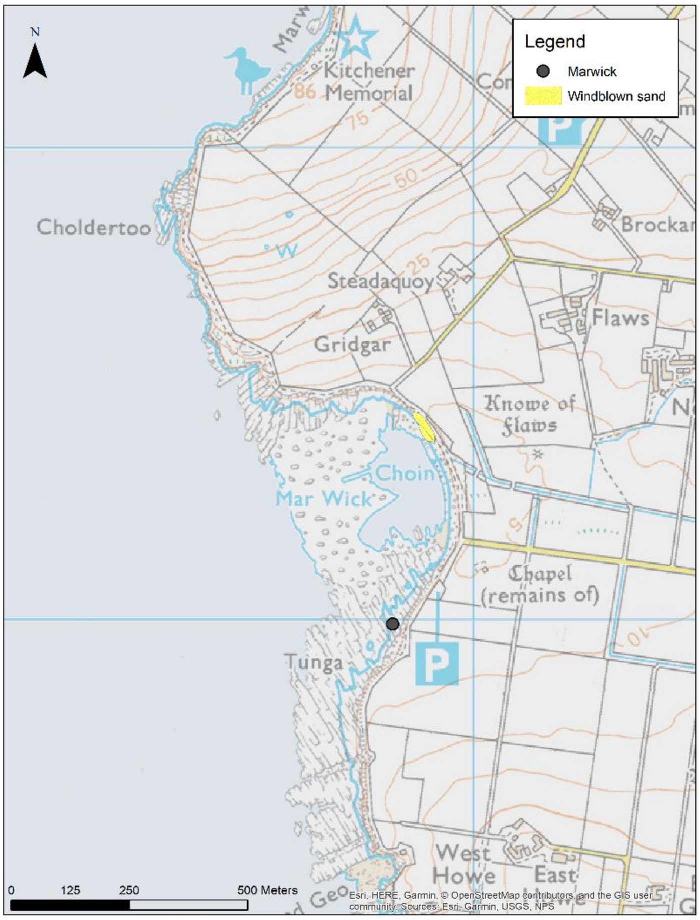


Figure 1.1. Location of the site at Marwick

Figure 1.2. Excavations at Marwick. D. Griffiths.

Windblown sand at Marwick

Extensive periods of sand mobilisation and associated site inundation took place at Marwick and its vicinity during its occupation and into the Medieval period. Micromorphological analysis of soil samples indicate that turf and manure were deposited across the frequently-mobilised dune pasture in order to develop a deep ploughsoil, likely to have been driven by a need to stabilise the drifting sands and ensure a profitable harvest from managed infields (Simpson 1997; Griffiths, D. 2015). Unfortunately, there is limited information available for Marwick at the time of writing, with a full investigation expected in Griffiths, D. *forthcoming*).

1.1.6. Ring of Brodgar

Database ID: 122

CANMORE ID: 1696

Period: Late Neolithic (completed at c. 2750-2210 cal. BC) (Bayliss *et al.* 2017 [Supplementary Material], 8).

Sandblow period: Late Neolithic (2191±200 BC <SUTL-2281>).

The Ring of Brodgar, a henge monument and stone circle, lies south of the Brodgar/Stenness peninsula within the UNESCO Heart of Neolithic Orkney World Heritage Site. Three sections across the ditch (A-C) were originally excavated by Colin Renfrew in 1973 (Renfrew 1979), during which two organic mud-silt samples from high in the ditch fills of A (0.60m and 0.70m down respectively) were dated by radiocarbon. These yielded very late determinations of 398-149 cal. BC (SRR-502) and 541-347 cal. BC (SRR-503), suggesting that the ditch had continued to infill into the Iron Age (Bayliss *et al.* 2017 [Supplementary Material], 8; Table S1).

The re-excavation of Colin Renfrew's Trench A (which wasn't bottomed in 1973) and C across the ditch commenced in 2008, with the aim of recovering further radiocarbon dating material in order to refine the dating of the construction of the ditch. Although suitable organic material for radiocarbon dating was not recovered, 15 OSL samples were taken from the ditch fills and a suite of dates produced, 14 of which were used to create a model for the date of completion for the Ring of Brodgar at 2750-2210 cal. BC (*Ring of Brodgar*; Bayliss *et al.* 2017 [Supplementary material], 9).

Windblown sand at Ring of Brodgar

High sensitivity quartz (as well as lower sensitivity quartz from the lower primary ditch fill), was recovered from sand lense samples taken from the fill of both sections of the Brodgar ditch for OSL dating. The high sensitivity quartz was dated to c. 2191±200 BC <SUTL-2281> (D. Sanderson *pers. comm.*; Sanderson *et al.* 2010), although the significant error is worth noting. Since the sensitivity of the quartz samples did not match that of any modern beach sands (with all modern beaches represented) sampled by SUERC and Anne Sommerville (2003), it is likely that the high-sensitivity source for the sand lenses deposited within the ditch at the Ring of Brodgar is no longer present, and is perhaps now located offshore or in an unidentified sedimentary sink elsewhere. Alternatively, the quartz could have been sensitised by fire although this is not viewed as a likely explanation for the sands at the Ring of Brodgar (see below) (D. Sanderson *pers. comm.*).

1.1.7. Ness of Brodgar

Database ID: 124

CANMORE ID: 269123

Period: Late Neolithic (From c. 3065-2950 cal. BC (*start_NoB,* Model A) to c. 2285-2100 cal. BC (*end_NoB*, Model A) (Card *et al*. 2017, 35-6).

Sandblow period: ?Late Neolithic

Windblown sand deposits (which were highly sensitive to preliminary radiation tests) were noted during a site visit to the Ness of Brodgar by D. Sanderson and T. Kinnaird (D. Sanderson *pers. comm.*). The sand deposits were identified as being potentially Late Neolithic in date, although without further investigation, any potential link with the windblown sand at the Ring of Brodgar cannot be posited. The Late Neolithic settlement complex at the Ness of Brodgar lies on the Brodgar Peninsula between the lochs of Harray and Stenness, to the south of the Ring of Brodgar. It was occupied from c. 3065-2950 cal. BC (*start_NoB*, Model A) until c. 2285-2100 cal. BC (*end_NoB,* Model A) (Card *et al*. 2017, 35-6; Table 3).

After windblown sand deposits were identified at the Ring of Brodgar and Ness of Brodgar (D. Sanderson *pers. comm.*), the excavation report at a third, partly contemporary site in the Brodgar landscape, Barnhouse, was also reviewed by the author. Excavated from 1985-1991, the site comprised the remains of 13 structures and a large Grooved Ware assemblage (Richards 2005), and was occupied from 3160-3090 cal. BC (86% probability) or 3080-3045 cal. BC (9% probability) (*start Barnhouse*) to 2890-2845 cal. BC (*end Barnhouse*) (Bayliss et al. 2017 [Supplementary material], 85-6; Table S4). It is notable that no windblown sand deposits appear to have been observed during the excavations at Barnhouse, although micromorphological studies highlighted the use of turf with significant additions of fine lacustrine silts and sands. These were likely to have been sourced from the immediate vicinity given the loch-side location of the settlement, and were utilised in midden and as building materials at both Barnhouse and Maes Howe (Spencer in Richards 2005, 372-3).

1.2. Birsay Bay

1.2.1. Point of Buckquoy

Area 6

Database ID: 163

CANMORE ID: 1800

Site type: Settlement

Period: Late Neolithic-Early Bronze Age (from at least 2630-2180 cal. BC (GU-1557)); Pictish-Modern (c. 9th-10th centuries AD to 18th-19th centuries AD)

Sandblow period: Late Neolithic-Early Bronze Age (around 2630-1690 cal. BC (GU-1557; GU-1640); Pictish-Modern (between the c. 9th-10th centuries AD and 18th-19th centuries AD)

Cuttings 5 and 6

Database ID: 164

CANMORE ID: 1800

Site type: Midden

Period: Late Neolithic-Early Bronze Age (from at least c. 2150-2000 cal. BC (*Boundary start_cutting_6*)); unknown historic

Sandblow period: Late Neolithic-Early Bronze Age (before c. 2150-2000 cal. BC (*Boundary start_cutting_6*) to c. 1600-1400 cal. BC (*Boundary end_cutting_6*; Marshall *et al.* 2016, 14). After c. 1600-1400 cal. BC (*Boundary end_cutting_6*)

Excavations South of Red Craig, Birsay (Area 1).

1.2.2. Brough Road Cutting 1

Database ID: 161

CANMORE ID: 73552

Site type: Cist inhumations

Period: Late Iron Age (from at least cal. AD230-570 (GU-1550).

Sandblow period: Unknown prehistoric; before cal. AD230-570 (GU-1550).

1.2.3. South of Red Craig, Birsay: Area 1

Site type: Cist inhumations

*Database ID:*160

CANMORE ID: 73553

Period: Late Iron Age-Norse (from at least AD550-570 (GU-1554) to at least c. cal. AD880-1140 (GU-1552).

Sandblow period: Unknown prehistoric (before AD55-570 (GU-1554));

Iron Age-Norse (between c. cal. AD55-585 (GU-1554, 1551) and c. cal. AD620-1035 (GU-1956, 1957)

Pictish-Norse (after c. cal. AD880-1140 (GU-1552) (Morris *et al*. 1989).

1.2.4. South of Red Craig, Birsay Area 2

Database ID: 162

CANMORE ID: 1804

Site type: Settlement, human remains

Period: Late Iron Age-Norse (From at least cal. AD625-895 (GU-1955) to cal. AD885-1245 (GU-1667)).

Sandblow period: Norse (around cal. AD855-1050 to cal. AD885-1245 (GU-1980, 1667)); late historic (after c. cal. AD670-1020 (GU-1555) to cal. AD885-1245 (GU-1667).

1.2.5. St Magnus' Kirk

Database ID: 165

CANMORE ID: 1838

Site type: Church

Period: From at least cal. AD800-1030 (GU-1631) to the 17^{th}-19^{th} centuries AD.

Sandblow period: 9^{th}-11^{th} centuries AD.

1.2.6. Beachview Burnside Area 3

Database ID: 169

CANMORE ID: 1807

Site type: Midden

Period: Norse-Early Medieval (from at least cal. AD1020-1320 (GU-2279)).

*Sandblow period***:** Norse (around, and after, cal. AD1020-1320 (GU-2279) (Morris et al. 1996, 292-3).

1.2.7. Beachview Burnside Area 2

Database ID: 166

CANMORE ID: 1807

Site type: Midden

Period: Norse (from at least c. 1020-1280 cal. BC (GU-2280, 2281).

Sandblow period: Norse (around 1020-1280 cal. BC (GU-2280))

1.2.8. Beachview 'Studio' site

Database ID: 167

CANMORE ID: 1807

Site type: Settlement, midden

Period: Norse-Early Medieval (from c. cal. AD980-1206 (GU-2272) to at least cal. AD1020-1280 (GU-2269)).

Sandblow period: Norse (around cal. AD980-1206 (GU-2272) to c. cal. AD1030-1280 (GU-2268); Norse-Early Medieval (from cal. AD1020-1280 (GU-2269) (Morris et al. 1996, 292-3).

1.2.9. Buckquoy

Database ID: 132

CANMORE ID: 1802

Site type: Settlement

Period: Late Iron Age-Pictish (from at least cal. AD232-418 (TO-6695)); Norse

Sandblow period:

Prior to its excavation from 1970-1971, the site at Buckquoy, northwest Mainland, comprised an eroding coastal mound on the Point of Buckquoy promontory. Measuring some 20m in length and a height of 0.50m, it was estimated that around half of the original mound was destroyed by previous coastal erosion (Ritchie 1977). Upon excavation, the remains of eight superimposed structures (defined as farmsteads) were discovered, appearing typologically to span a period of occupation from the 7th – 10th centuries AD. Six phases of occupation were originally identified, with Phases I and II defined as Pictish (including a long-cist burial), and III-V as Norse with Phase VI represented by what was interpreted as a Viking burial inserted into the remains of the final structures, and an Iron Age long cist grave to the north (Ritchie 1977, 175 and see Brundle *et al.* 2003).

The earlier Phase I structures were characterised by their cellular construction, whereas the Phase II houses were more reminiscent of the classic 'jellybaby' or figure-of-eight house construction. Phases III-V comprised a number of byres and other sub-rectangular domestic structures, interpreted as being Norse in origin (Brundle *et al.* 2003, 95). No scientific dating was undertaken at Buckquoy during the original excavations, and any statements made by Ritchie in her 1977 publication, concerning the chronology of the site, were informed by architectural parallels and artefact typology.

Pictish artefacts dominated the finds assemblages in all phases, originally leading Ritchie to conclude that many forms of local material culture had been adopted by the later Viking settlers as opposed to the later rectilinear structures being Pictish in date (Ritchie 1977, 180-7). Subsequent excavations at other sites have failed to reveal comparable rectilinear constructions to those at Buckquoy of Pictish date, with the recorded examples all dating to the Norse/Viking period. Despite the lack of Scandinavian artefactual material retrieved, the Phase III-V houses still appeared to fit typologically with dated Norse architecture (Brundle *et al.* 2003, 96-7).

Later investigation of the site has allowed for some reinterpretation or confirmation of the architectural and chronological evidence (Brundle *et al.* 2003). More recent radiocarbon dating of skeletal material from the site (all calibrated using Stuiver and Reimer 1993) confirmed a 5^{th}-6^{th} century AD Iron Age date for the long cist burial (cal. AD404-596 (TO-6693)), and yielded another Iron Age date of cal. AD232-418 (TO-6695) for the grave originally interpreted as being of Viking age (Barrett in Brundle *et al.* 2003, 103). The original dating interpretation of the Viking grave was founded on the recovery of a 10^{th} century half coin from among the grave goods. Brundle *et al*. suggest the rib bone (which was recovered from poorly-preserved, fragmented remains) used as a radiocarbon sample may have been accidentally incorporated into the grave fill from an unrecorded Iron Age grave (Brundle *et al.* 2003, 99). It was noted by Barrett (in Brundle *et al.* 2003, 103) that an anomalous date was unlikely to have been due to sample contamination due to poor preservation. The skeleton was described as poorly-preserved, lying in a shallow grave cut which had been truncated by ploughing. An early 10^{th} century ring-pin was also recovered from the grave, lending further corroboration to a Norse date. Another option to consider is whether the Norse coin and pin were later deposits accidentally incorporated into the grave fill at a later date. The coin, which was purposely halved, showed little wear and tear and perhaps represented a luck token or personal effect rather than currency (Ritchie 1977, 190).

The stratigraphy of the site is described as "essentially one of stonework" with little preserved soil stratigraphy due to robbing, plough damage and erosion. An understanding of the surrounding environment, and soil stratigraphies possibly associated with the settlement, was developed through the sampling of an eroding coastal section 200m to the north. Sampling of this section was primarily guided by the desire for environmental reconstruction through land snail studies, and also sheds some light on the history of sand mobilisation in this area. The stratigraphy described by J. Evans (in Ritchie 1977) is as follows;

Depth below surface (m)	Description
0-0.20	Topsoil and dark sandy loam subsoil.
0.20-0.45	Midden. Compact, sandy loam with numerous stones, bone fragments and marine shells, mainly limpets and edible winkles.
0.45-0.62	Pale, compact orange-brown calcareous sand.
0.62-0.67	Top of buried soil. Dark-brown clay loam with intermixed shell sand.
0.67-0.75	Base of buried soil. Non-calcareous, dark-brown clay-loam free of shell sand.
0.75-	Solifluxion debris. Pale yellow-brown stony loam with large angular stones pitched in all directions; stones in the upper part (75-90 cm) relatively horizontal.

Table 1. Buckquoy coastal section stratigraphy after Evans in Ritchie 1977.

The top of the buried soil beneath the orange-brown calcareous sand (62-75) contained notable inclusions of shell sand, attributed to later earthworm mixing of a thin layer of windblown sand with the uppermost portion of the top of the buried soil (Evans in Ritchie 1977, 217). A thicker layer of calcareous windblown sand was then deposited above the buried soil (Table 1). Containing grassland snail species (e.g. *Vallonia excentrica*), the sand may have coincided with a period of deforestation. Marine shells recovered from the base of the deposit have been interpreted as food debris, indicative of human activity prior to the onset of sand deposition (Evans in Ritchie 1977, 217). The stratigraphic relationship between the midden in the section and the archaeological site has not been confirmed due to the absence of radiocarbon dating from both the site and section. Additionally, much of the midden recorded at the Buckquoy site lay within the remains of the earlier houses themselves, with any extensive external midden deposits directly associated with the site likely to have been eroded (Ritchie 1977, 191). If the middens are related, it may be tentatively inferred that the sand was deposited either before the Pictish period, or between the Pictish and Norse periods. Without radiocarbon dates, however, it would be unwise to do so.

1.2.10. Saevar Howe

*Database ID***:** 98

*CANMORE ID***:** 1835

Site type: Settlement

Period: Pictish-Norse (from at least cal. AD540-720 (GU-1401), to at least cal. AD660-990 (GU-1400).

Sandblow period: Pictish-Norse (from at least cal. AD660-890 (GU-1402) to at least cal. AD660-990 (GU-1400)).

1.3. Deerness

1.3.1. Skaill (Deerness)

Database ID: 133

CANMORE ID: 2932

Site type: Settlement

Period: Early Bronze Age-Middle Iron Age (Site 5) (Between 1949-1752 cal. BC (OxA-1716) and 370-1 cal. BC (Birm-413));

Early Iron Age-Pictish (Site 6) (from at least c. 700-200BC (no scientific dating) to c. AD600-770 (Birm-765)

Pictish-Norse (Site 2) (9^{th}-11^{th} centuries AD – no scientific dating)

Norse-Medieval (Sites 1-4) (c. AD900-1600 – no scientific dating).

Sandblow period: Later Prehistoric (Sites 5 and 6) (between 1513-1392 cal. BC (OxA-1437) and the 8^{th}-10^{th} centuries AD)

Late Iron Age-Pictish (Site 6) (c. cal. AD420-775 (Birm-592, 763, 765)

Norse (Site 2) (c. AD800-900)

Norse-Medieval (Site 4) (c. AD900-AD1600)

Medieval (Site 1) (c. AD1100-1200)

1.3.2. Newark Bay

CANMORE ID: 351741

Database ID: 134

Site type: Chapel, inhumations

Period: Bronze Age, Medieval

Sandblow period: unknown

The coastal section at Newark Bay lies on the southeast coast of mainland Orkney, within a pocket of windblown sand deposits immediately east of Newark Bay. It near the Chapel site at Newark Bay (CANMORE ID 3033). During coastal section recording and rescue excavation in 2014, it was estimated that c. 1-1.5m of coastline has been lost at the site since 2000 (Card *et al.* 2015, 150). Inhumations eroding from the cliff section were excavated under a rescue remit, and a 40m length of coastline at Newark Bay itself was photographed and recorded (centred on HY 57420 04180), during which a Bronze Age vessel, cremation and soil enhanced with midden were noted. A further isolated inhumation thought to date to the post-Medieval period was recorded in the sand dunes in this area. Remains of the Medieval chapel at Newark and thirteen burials contemporary with the chapel were also recorded (Card *et al.* 2015, 150).

2. Hoy

2.1. Melberry

Database ID: 100

CANMORE ID: 306776

Site type: Animal remains and palaeosol

Period: Unknown

Sandblow period: Unknown

The site at Melberry consists of an organic, peaty soil (within which a fragment of butchered animal bone was noted, but not recovered) exposed in an eroding sand dune section at the southernmost end of Hoy (Figure 2.1). The section extends for c.6m with a depth of 0.25m. The soil overlies a series of discoloured sand lenses, and is covered by c.2m of windblown sand (Moore and Wilson 1997). The soil may be agricultural in origin, and it is possible that the discolouration of the sand derives from manuring practices, although this is purely speculation. A lack of scientific and artefactual dating evidence makes it impossible to confirm the date of the sand deposition. Melberry is the only date known to contain windblown sand layers on Hoy. This is perhaps unsurprising given that the island contains only two notable beach deposits, at Rackwick and Melberry. Nevertheless, further survey and excavation may produce more evidence for windblown sand sites.

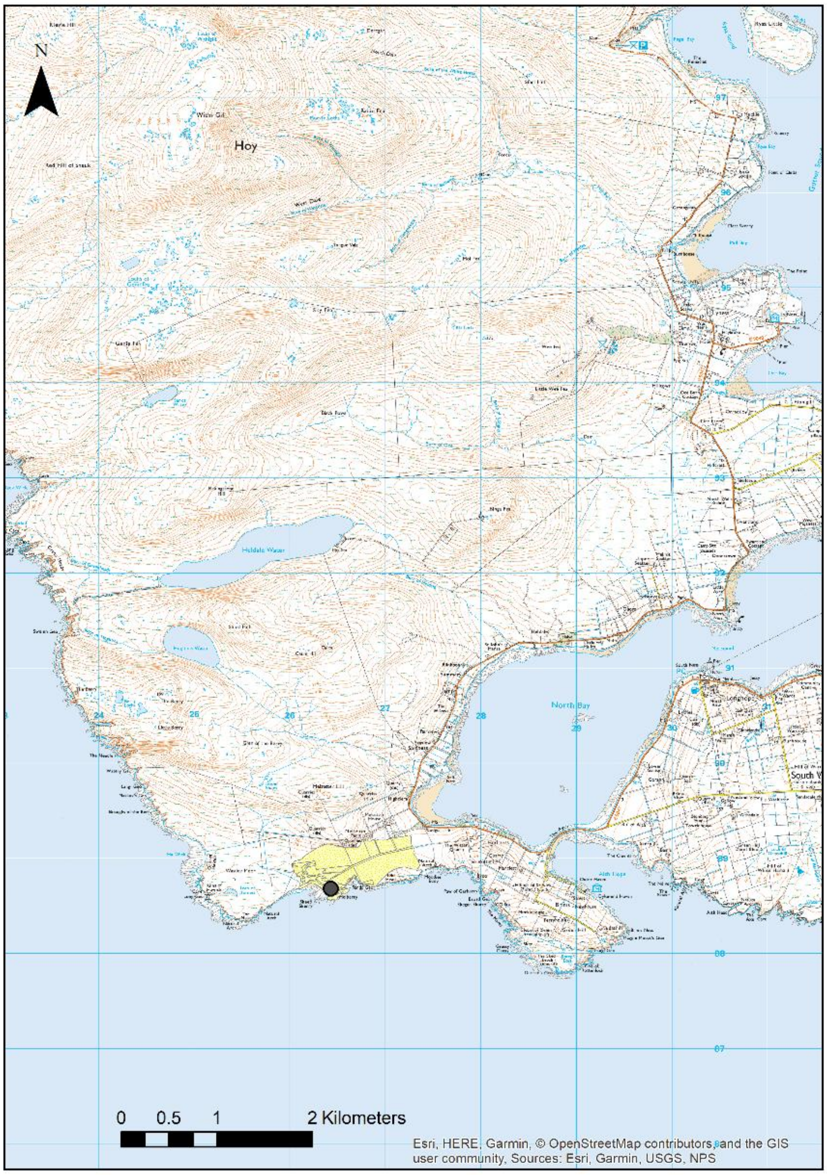


Figure 2.1. Location of Melberry

3. Stronsay

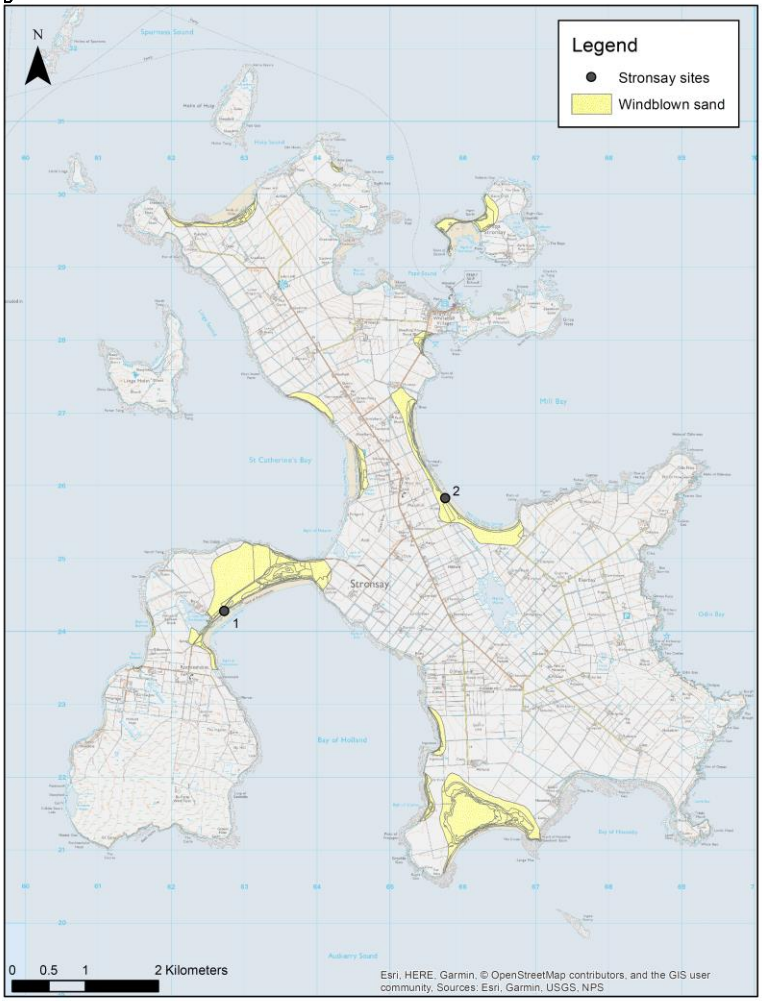


Figure 3.1. Stronsay windblown sand sites. 1. Sands of Rothiesholm. 2. Mill Bay.

3.1. Mill Bay

Database ID: 91

CANMORE ID: n/a

Site type: Palaeoenvironmental section

Period: n/a

Sandblow period: Early Bronze Age (c. 1450-1150 cal. BC) (BETA-300344); Late Bronze Age-Early Iron Age (from 850-310 cal. BC (BETA 300342; SUERC-26654)); Medieval (AD1360±75 <SUTL-2321>), Modern (AD1865±20 <SUTL-2322>, and AD1960±5 <SUTL-2323>).

NB: Luminescence dates in BP (where BP=year of lab processing (2010) have been converted to BC dates for ease of interpretation.

Although the windblown sand deposits are not directly associated with an archaeological site, the eroding section at Mill Bay is important in that it has provided a suite of radiocarbon and OSL dates for landscape change (Kinnaird *et al*. 2012) (Figure 3.2). The coastal exposure lies within Mill Bay, an east-facing semi-circular bay reaching a width of c. 1km. The nearest archaeological site - Mesolithic occupation remains and flint scatter - lies c. 200m inland (Lee and Woodward 2009). The coastal exposure is characterised by glacial deposits overlain by a series of intercalated calcareous windblown sands and sandy peat measuring c. 1.00m in thickness. The weathered surface at the base of the 0.25m deep peat yielded a luminescence date of 1750±330BC <SUTL-2324>, and was used to demonstrate a minimum age constraint its development (Kinnaird *et al*. 2012, 196).

Cessation of peat development corresponding with a period of greater windblown sand mobilisation was luminescence dated to the Late Bronze Age-Early Iron Age (690±265 BC <SUTL-2328>), when c. 0.75m of calcareous windblown sands covered the peat (Figure 3.2). That sand comprised a significant component within the peat demonstrates that sand was being mobilised in smaller quantities prior to this. Further sand mobilisation in the Medieval and modern periods was dated to AD1360±75 <SUTL-2321>, AD1865±20 <SUTL-2322>, and AD1960±5 <SUTL-2323> (Kinnaird *et al.* 2012, 197-8).

Additional sampling for radiocarbon dating of organic sediments at an adjacent palaeoenvironmental section revealed a similar sequence, with AMS radiocarbon dating of the peat constraining its formation to between 2192-2037 cal. BC (SUERC-26655) and 891-802 cal. BC (SUERC-26654) using IntCal09 (Reimer *et al*. 2009) (Tisdall *et al.* 2013, 208). An increase in windblown sand deposition was dated to c. 1450-1150 cal. BC (BETA-300344) and between c. 850-310 cal. BC (BETA-300342; SUERC-26654) (Tisdall *et al.* 2013, 205). Further phases of short-lived, less extensive windblown sand deposition punctuated by vegetation colonisation then took place until AD1360±75 <SUTL-2321> (dated by Kinnaird *et al*. 2012) when an extensive sand layer measuring c. 0.60m in thickness was deposit. The sand contained rip up clasts and rounded beach pebbles characteristic of a high-energy depositional event which took place as a result of both aeolian and marine depositional processes (Tisdall *et al*. 2013, 213). Radiocarbon determinations were calibrated using the Intcal09 curve (Reimer *et al.* 2009). Although the two eroding sections are not directly associated with archaeological remains, they provide more contextual data for change in coastal environments. The substantial error ranges on the OSL ages ensure that their efficacy for developing a meaningful chronology for prehistoric sand mobilisation is limited. Rather, it seems appropriate to use them only to confirm the AMS radiocarbon chronology developed by Tisdall *et al.* (2013), with the exception of the OSL ages for the sand depositions from the 14th century onwards, where the errors are more acceptable.

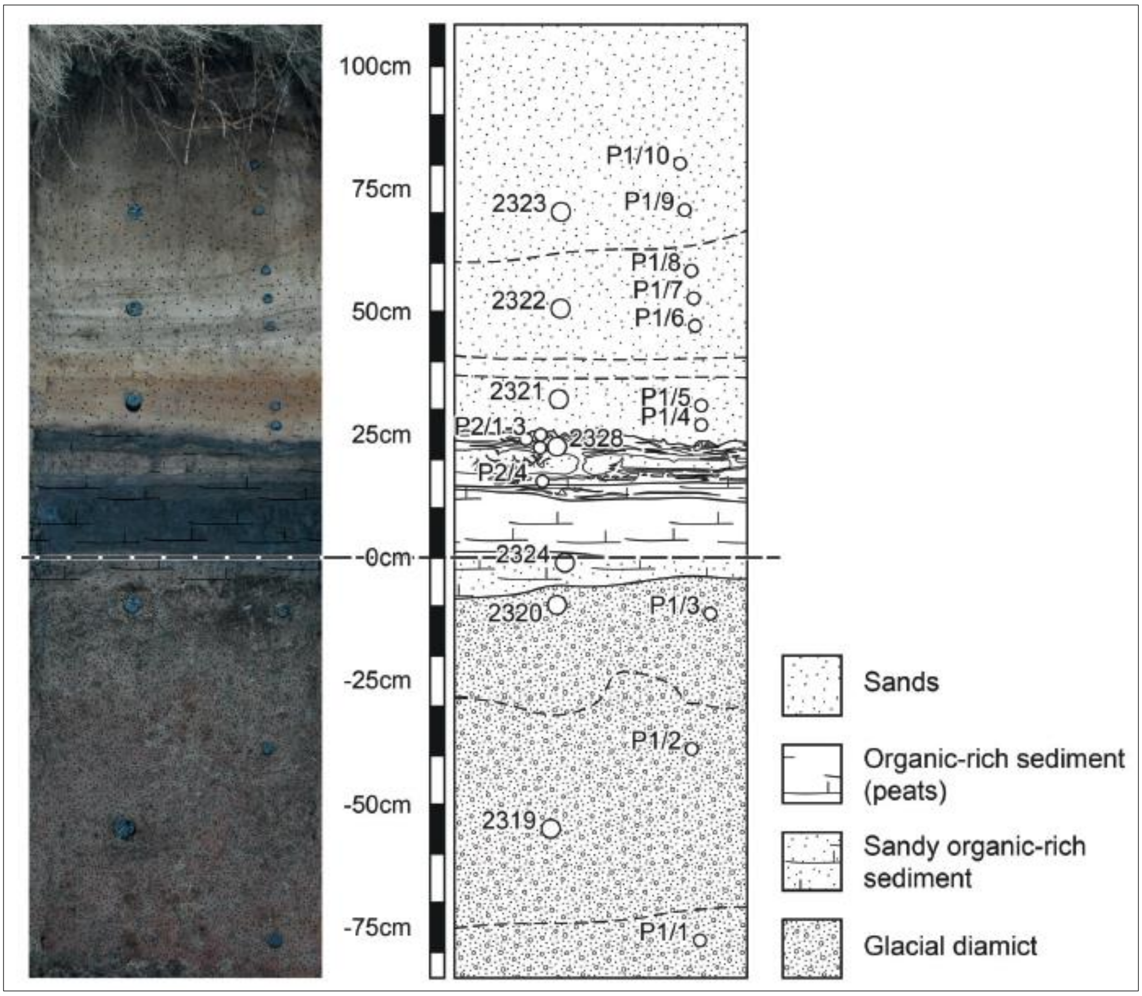


Figure 3.2. The Mill Bay palaeoenvironmental section with OSL sample locations marked by white circles. Kinnaird et al. 2012, 194.

3.2. Sand of Rothiesholm

Database ID: 153

CANMORE ID: 3389

Site type: Midden, cultivation soils

Period: Iron Age, Norse

Sandblow period: Early prehistoric (pre-Iron Age), post- Iron Age/Norse

The c. 68m long eroding section at Rothiesholm lies to the southwest of Stronsay, within an elongated sand dune at the Bay of Holland. It has been visited – but not directly investigated - by the RCAHMS and EASE Archaeology survey teams, during which a number of observations were made. The exposed section is comprised of midden deposits, cultivation soils, and drystone masonry representing at least two structures. Above the midden deposits (which contained animal bone, artefacts, metalworking debris and marine shell), alternating sequences of blown sands and peat deposits were identified (RCAHMS 1984, 26). It has been estimated by a RCAHMS coastal erosion pilot programme that up to 17m of this stretch of coastline has been eroded since 1881, suggesting that the remaining section provides a very fragmentary record. The EASE Coastal Zone assessment Survey interpreted the remains as being Iron Age or Norse in date, and as representing a “high status farmstead” (Moore and Wilson 1996).

Windblown sand at Sand of Rothiesholm

The exposed structures appear to have been constructed directly above clean sand, as do the midden deposits which extend for some 20m. A complete Iron Age pot was recovered from the occupation deposits in the eroding section. An earlier prehistoric date can therefore be assigned to the deposition of this sand. A period of windblown sand accumulation and peat formation (with one peat horizon measuring up to 0.50m thick) can be estimated to have taken place from the later prehistoric or Norse period onwards (RCAHMS 1984, 26).

4. Eday

Site	Site type	Period of human activity	Sandblow period	Reference
Green	Settlement	Early-Late Neolithic (c. 4045-3365 cal. BC to c. 3320–2520 cal. BC)	Early Neolithic (before 3340-3020 cal. BC)	Miles 2008
Skaill	Burnt mound	Middle Bronze Age (c. 1030±80 BC)	AD1060±100	Anthony 2003
Sandhill	Palaeo-landscape	n/a	1380±95 AD	Sommerville 2003
Stackelbrae	Settlement	Medieval, post-Medieval (17^{th}-19^{th} centuries AD)	pre-17^{th} century AD	Brend 2008

Table 2. Eday windblown sand sites showing periods of occupation and sand movement.

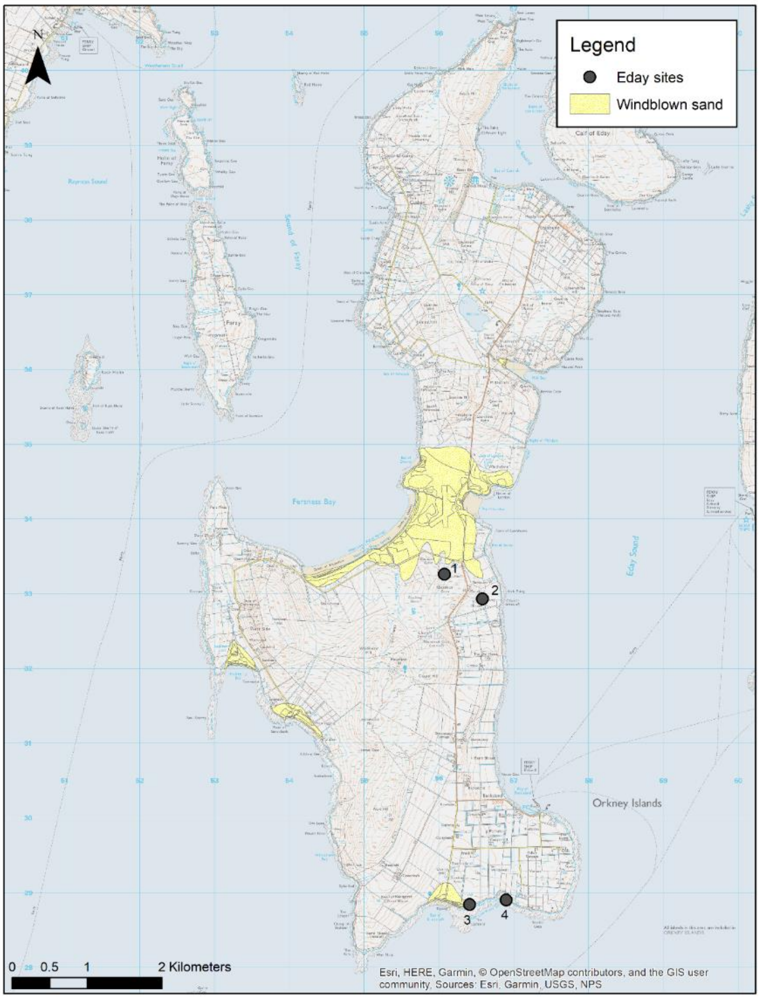


Figure 4.1. Eday windblown sand sites. 1. Sandhill; 2. Skaill; 3. Stackelbrae; 4. Green.

4.1. Green

Database ID: 110

CANMORE ID: 108272

Site type: Settlement

Period: Early Neolithic-Late Neolithic (From c. 4045-3365 cal. BC to c. 3320–2520 cal. BC)

Sandblow period: Early-Middle Neolithic (Before 3340-3020 cal. BC (OxA-28864))

Green is situated at the low-lying southernmost tip of Eday, on the south shore of the Sands of Green. Following a series of geophysical surveys in 2006, and test pitting in 2007, the presence of Early Neolithic rectilinear structures beneath the ploughsoil was confirmed (Miles 2008, 128-9). Following a series of excavations from 2007-2012, three Early Neolithic structures (1-3) were revealed. Post-excavation and reporting are ongoing at the time of writing. Short-lived charred grain recovered from Structure 1 and a post hole which may be associated with a timber structure has provided a small suite of four radiocarbon determinations (Griffiths, S. 2016, 296; Bayliss *et al.* 2017, 15 [Supplementary Material]), all of which were calibrated using OxCal v4 (Bronk Ramsey 1995; 1998; 2001; 2009). Bayesian modelling estimates the start of activity at Green to lie to 4045-3365 cal. BC (*start Green*), and the end to 3320–2520 cal. BC (*end Green*) (Bayliss *et al.* 2017 [Supplementary Material], 92; Table S4).

Carbonised naked barley (*Hordeum vulgare* var. *nudum*) grains from the lower fill of the House 1 hearth yielded a date of 3360-3020 cal. BC (OxA-29155) (Griffiths, S. 2016, 296). The structures were surrounded by a series of domestic midden deposits which overlay a windblown sand deposit (no dimensions available). This sand in turn overlay the natural boulder clay outwith the structures (Miles 2011). Carbonised grains of barley (*hordeum*) and wheat (*triticum*) from the midden overlying the sand and post-dating Structure 1 have been dated to 3340-3020 cal. BC (OxA-28864) (Griffiths, S. 2016, 296), providing a *terminus ante quem* for the deposition of the sand. Extensive sand deposits are visible at the Bay of Greentoft (Figure 4.1), and could conceivably be the source for the sands at Green.

4.2. Skaill

Database ID: 111

CANMORE ID: 3197

Site type: Burnt mound

Period: Middle Bronze Age (c. 1030±80 BC <SUTL-1361-1367>)

Sandblow period: AD1060±100 <SUTL-1364>

The Skaill burnt mound is located on the southeast coast of Eday, in a low-lying heathland landscape containing extensive peat deposits. The site was investigated as part of a wider project which sought to undertake thermoluminescence (TL) dating of the heated stones commonly associated with burnt mounds on Eday (Anthony 2003). Standing c. 2m in height, the mound was crescentic in shape with a diameter of c.20m x 10m. The site at Skaill contained a windblown sand deposit, and the decision was taken to undertake additional OSL dating and radiocarbon dating as well as TL in order to link the formation of the mound with possible storm events and windblown sand deposition. Excavation of a section through the burnt mound in 2000 and 2001 revealed a series of formation deposits which included windblown sand lenses. Beneath the modern turf and topsoil, a series of sand lenses measuring c. 0.20-0.25m in total were encountered, overlying the main body of the mound (Anthony 2003, 118). TL dating places the use of the Skaill burnt mound to the mid-1st millennium BC, with an average date of 1030±80 BC <SUTL-1361-1367> (Anthony 2003, 289).

Windblown sand at Skaill

The sand deposits were sampled for OSL dating <SUTL-1361 – 1367> in order to date their deposition and ascertain their relationship to the mound and its use. The OSL dating procedure revealed that the windblown sands were deposited later in the site’s history at c. AD1060±100 <SUTL-1364>, after its abandonment. The OSL dates for the sands were further constrained by radiocarbon dating of the upper and lower peats bracketing the sand deposits (Table 3). A radiocarbon date of cal. AD260-430 (GU-9794) for the bottom and cal. AD660-810 (GU-9793) (calibrated by OxCal 3.1 (Bronk Ramsey 1995)) for the top of the lower peat deposit were yielded for its development, in the mid-late first millennium AD. This growth was interrupted by the deposition of the windblown sand at AD1060±100 <SUTL-1364>, which was likely to have derived from Fersness Bay on the west coast of Eday (on the basis of sample sensitivity and calcium content) and deposited by a large storm event (Sommerville 2003). Other OSL samples yielded dates from the late 14th-early 18th centuries AD, interpreted as representing the re-exposure and re-zeroing of the original sand deposit. Peat growth began again from the mid-14th century AD, at cal. AD1300-1400 (GU-9795) (Anthony 2003, 303).

Lab ID	Context	Radiocarbon Age (BP)	Calibrated date (cal. AD) at 95% probability
GU-9793	Lower peat deposit (011) in North-facing section	1280±60	660-810
GU-9794	Lower peat deposit (011) in South-facing section	1670±50	260-430
GU-9795	Upper peat deposit (003) in North-facing section	620±50	1300-1400

Table 3. Radiocarbon dates from Skaill burnt mound. Anthony 2003, 299.

4.3. Sandhill

Database ID: 119
CANMORE ID: n/a
Site type: Palaeolandscape
Period: Medieval
Sandblow period: Medieval (1380±95 AD)

The landscape deposits (which contained stratified windblown sands) across the narrow, low lying central neck of Eday were sampled for OSL dating in 2001 (Sommerville 2003) (Figure 4.3). Sampling concentrated on Sandhill, a small hill to the south of this zone, with 10 test pits excavated to the west of the burnt mound at Skaill. Stretching from Fersness Bay in the west to Skaill Farm in the east, the landscape comprises peat and heather moorland with some sandy pockets (Sommerville 2003, 112). The test pits measured from 0.35-0.65m in depth (Figure 4.3), with each revealing a sequence of interleaved fine-grained calcareous blown sands and peat accumulations. The sand deposits varied from between 0.17 and 0.45m in depth, with the sharp contact between peat and sand attesting to rapid sand deposition.

The sequence consisted for the most part of a lower peat layer, overlain by a windblown sand which was in turn overlain by another peat (Figure 4.3). Test Pit 10 notably included two sand deposits - likely due to the test pit having been excavated to a deeper level than the others. Both upper <SUTL1299>, and lower <SUTL1300> sands were sampled for OSL dating (Table 4). Alongside OSL, three peat samples were taken for radiocarbon dating from Test Pits 2 and 5, with results calibrated using OxCal 3.1 (Bronk Ramsey 1995). The lower peat in Test Pit 5 yielded a Middle-Late Iron Age radiocarbon determination of cal. AD135-420 (GU-9240), while the upper peat was dated to the Medieval-modern period, at cal. AD1525-1950 (GU-9241), providing some broad chronostratigraphic constraint for <SUTL-924>. The lower peat recorded in Test Pit 2 yielded a late Pictish-Norse date of cal. AD885-1030 (GU-9242). The variance in age between these two basal peat deposits may indicate the occurrence of more than one sand accumulation event in the Sandhill landscape (Sommerville 2003, 113).

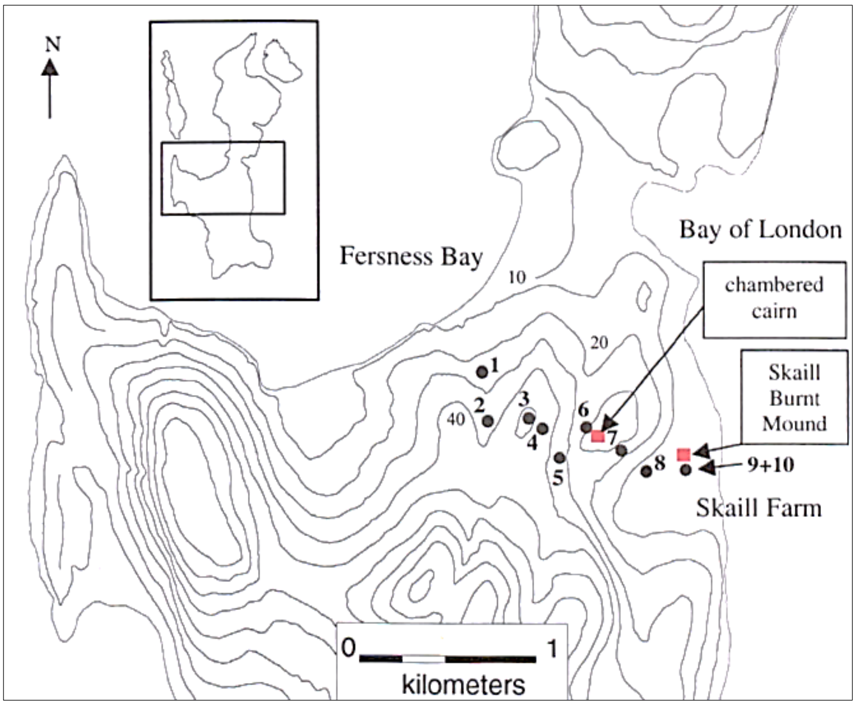


Figure 4.2. Map showing locations of test pits, burnt mound and chambered cairn within the Sandhill landscape. After Sommerville 2003, 114.

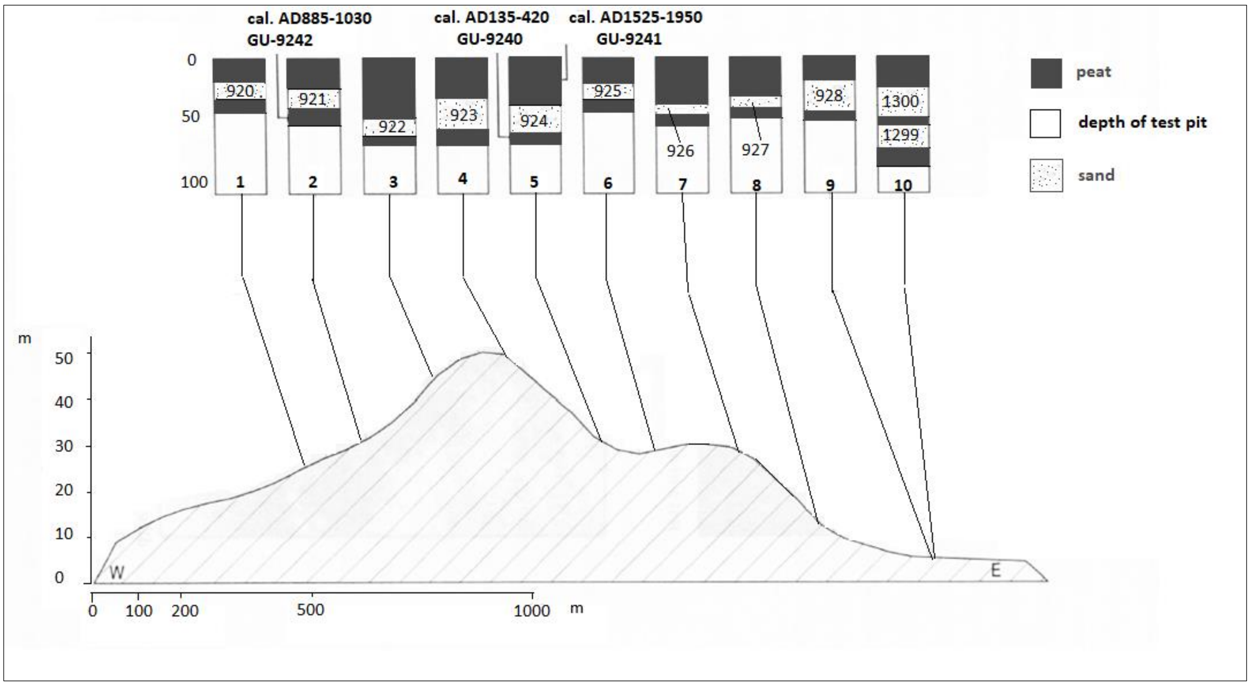


Figure 4.3. Topographic section of sandhill showing location of test pits, sand deposits, OSL and radiocarbon sample locations. After Sommerville 2003, 115

Like those sampled at Evertaft (Westray) and Bay of Skaill (Mainland), the sands from Sandhill proved to be comparatively insensitive to stimulation with c. 80% of the Sandhill discs rejected due to recycling errors and scattered data (Sommerville 2003, 240). This low sensitivity accounts for the significant errors, leading to restrictions in accuracy. Comparatively low quantities of shell were recovered from the samples, correlating with the low quantity of shell material found in modern beaches on the island. Given the nature of the sand inclusions, response of the modern beach sands to OSL sensitivity procedures, and the dominant westerly wind direction, the source of the sand was suggested to be the shallow inlet at the Bay of Ferness to the west of the site (Sommerville 2003, 317).

Lab ID	Test Pit	Age (years before 2000AD)	Date (AD)	Weighted mean
920	1	1215±1420	785±1420	AD1380±95
921	2	All discs rejected	All discs rejected	
922	3	725±620	1275±620	
923	4	980±670	1020±670	
924	5	840±695	1160±695	
925	6	410±195	1590±195	
926	7	505±390	1495±390	
927	8	1165±425	835±425	
928	9	760±220	1240±220	
1300	10 upper	85±1915	1915±1915	
1299	10 lower	580±155	1420±155	

Table 4. OSL dates and ages of Sandhill samples with their weighted mean. After Sommerville 2003, 322.

The presence of a second, lower sand layer in Test Pit 10 attests to the occurrence of more than one incident of sand deposition. Being within error of each other and with inclusion of the lower sand layer date from Test Pit 10, a weighted mean age of 1380±95 AD (based on the dates from Test Pits 1, 3-9, and the lower sand from Test Pit 10) was proposed for a single sand event which took place in the 14th century AD (Table 4). Similar OSL dates recovered from Pierowall (1385±50 AD, <SUTL-878>) and the upper sands from Lopness (1475±90AD) are indicative of the occurrence of significant sand movements during the 14th-15th centuries AD.

4.4. Stackelbrae

Database ID: 120

CANMORE ID: 3118

Site type: Settlement mound

Period: Medieval, post-Medieval (17th-19th centuries AD)

Sandblow period: pre-17th century AD

The site at Stackelbrae is located on the south coast of Eday, and when first discovered comprised a large eroding settlement mound measuring c. 73m long, extending c. 27m into the hinterland. The erosion face contained stone structures and midden deposits interpreted as dating to the Medieval through to the post-Medieval period. A tapestry rescue excavation in 2008 revealed five phases of activity (Brend 2008, 129-30):

Phase 1: Extensive paved areas were constructed onto an old ground surface, which in turn overlay the natural boulder clay. The paved area was inundated by windblown sand (no dimensions or composition given) at a maximum depth of 1.20m along the section.

Phase 2: Parts of the windblown sand were removed, and a building constructed from orthostats and coursed masonry constructed above.

Phase 3: Infilling of the drystone structure.

Phase 4: A series of later buildings were built, which incorporated the earlier infilled structure. 17^{th} century artefacts were recovered from drains and structures. Midden deposits had accumulated to the east of the structures, which are interpreted as having accumulated from Phase 2. These deposits were capped during Phase 4 with paving.

Phase 5: The Phase 4 structures were infilled, with paving to the east was capped with paving.

Further, open-area excavations were undertaken behind the eroding section in 2009. This exposed more of the structural elements recognised during the tapestry excavation and confirmed that the farmstead or settlement complex was occupied for at least 200 years, from the 17^{th}-19^{th} centuries. This places the windblown sand accumulation to a point before occupation began in the Medieval period (Brend 2009, 128-9), but no further unpublished material could be retrieved to expand on this interpretation and as yet no scientific dates appear to have been commissioned.

5. North Ronaldsay

5.1. Howmae Brae

Site type: Settlement

Database ID: 108

CANMORE ID: 3691

Period: Early-Middle Iron Age

Sandblow period: Unknown prehistoric (pre-Iron Age), 18th/19th century

Howmae Brae lies to the south of the island, at South Bay, within a significant expanse of blown sand (Figure 5.1). Despite the extensive windblown sand deposits recorded across the northeast and southwest coasts of the island, Howmae Brae is the only site containing notable windblown sand deposits. This is doubtless an artifact of the comparative lack of excavation activity across the island as a whole. Howmae Brae was partially excavated in 1884 by William Traill, and in 1889 by John Traill (Traill 1885; Traill 1890), following which the exposed buildings began eroding. Today it survives as a mound up to 3m high, c. 70m long and 45m wide, covered by windblown calcareous sand, with its southwesterly quadrant exposed. The settlement comprises two roundhouses lying either side of a paved courtyard, with a series of small rectangular ancillary buildings. It was dated artefactually and architecturally to the Early - Middle Iron Age, and may have been occupied contemporaneously with the nearby broch at Burrian (Moore and Wilson 1999). The roundhouses were constructed into a sand dune with revetting walls, and were noted to contain internal radial partitions and partial corbelling (Mackie 2002).

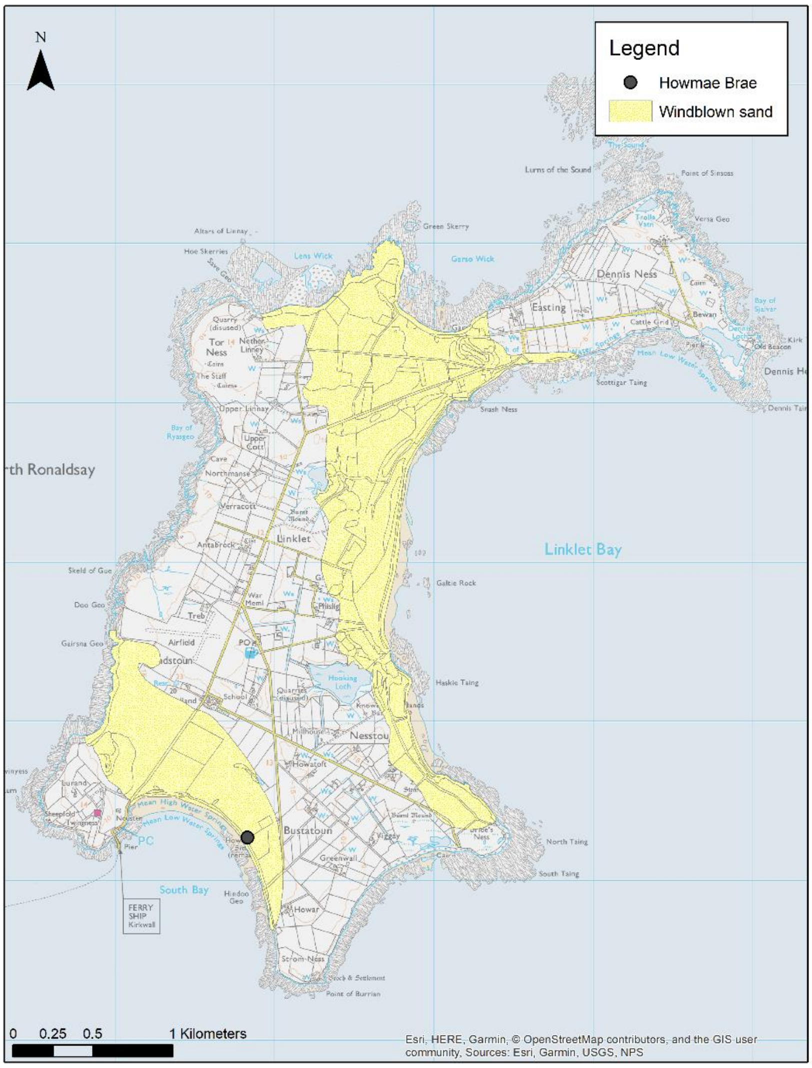


Figure 5.1. Location of Howmae Brae

6. Papa Westray

6.1. Knap of Howar

Database ID: 15

CANMORE ID: 2848

Site type: Settlement

Period: Early Neolithic (From c. 3635-3370 cal. BC (*start_knap_of_howar*) to c. 3305-2835 cal. BC (*end_knap_of_howar*).

Sandblow period: Early Neolithic (Between c. 3635-3370 cal. BC (*start_knap_of_howar*) and 3345-3020 cal. BC (OxA-16476) (Bayliss et al. 2017 [Supplementary Material], 14; 19); after c. 3500-2850 cal. BC.

6.2. St Boniface

Database ID: 155

CANMORE ID: 2856

Site type: Cists, settlement, farm mound, chapel.

Period: Middle Neolithic (possibly around c. 3020-2700 cal. BC (AA-9561) to Norse/Medieval (c. cal. AD1010-1280 (GU-3069c)

Sandblow period: Early-Middle Neolithic (3020-2700 cal. BC(AA-9561)),

Early Bronze Age (between 1610-1320 cal. BC (AA-9560) and 1535–1115 cal. BC (AA-9562))

Early-Middle Iron Age (625-190 cal. BC (GU-3268c))

Middle Iron Age (c. 340 cal. BC-cal. AD115 (GU-3275c; GU-3061c))

6.3. King's Craig

Database ID: 102

CANMORE ID: 2853

Site type: Settlement, midden

Period: Multiperiod. Prehistoric, Norse

Sandblow period: Unknown prehistoric

The eroding site at King’s Craig is located on the southwest coast of Papa Westray, centred on the headland at Whitehowe. The site is currently actively eroding (SCHARP Sites at Risk Map). It comprises a broad mound of settlement deposits extending c. 26m along the coastline. These substantial deposits are c. 2.3m thick, with the eroding section containing closely-associated stone structures, flagged floors, midden and shell layers and agricultural deposits (RCAHMS 1946; 1983) (Figure 6.1). Overlying the glacial till at the base of the eroding section is a cultivation soil of c. 30-50cm in thickness. This was overlain by a c. 0.25m deep layer of windblown calcareous sand, over which the earliest structural remains, comprised of flagged surfaces, drains and up to three structures, were constructed (Moore and Wilson 1998). The walls of two structures were revetted, with the walls of the remaining structure comprising double-facing with a hollow core. Midden deposits and anthropogenic soils infill and surround these early structures, with some structural remains likely to represent a secondary phase of occupation activity. These deposits are overlain in turn by shell midden and more agricultural soils. Dating of the site is uncertain as it has not been excavated, but it appears to have been a location for longterm occupation, beginning with cultivation activity and developing into a large settlement with the immediate landscape again cultivated following its abandonment. The later structures have been interpreted as Viking or Norse architecturally, while the earlier deposits are likely to be prehistoric in date (Moore and Wilson 1998). This may infer a prehistoric date for the sand layer, but no more precise conclusions can be drawn without scientific dating.

Figure 6.1. Eroding section at King’s Craig. R. G. Lamb via RCAHMS Online Digital Images SC 400989

6.4. Bay of Moclett

Database ID: 101

CANMORE ID: 296885

Site type: Cultivation soil

Period: Unknown

Sandblow period: Unknown

The site at Moclett lies to the west of the Bay of Moclett, which is located to the south of Papa Westray. The landscape around the bay is covered by a large expanse of blown sand, known as the Links of Moclett. The eroding 20m coastal exposure contains deposits reaching c. 2.5m in depth. The basal glacial till is covered by blown sand deposits (no dimensions available), overlain by a 'B' horizon followed by a substantial buried cultivation soil which is covered by turf and topsoil. The site remains uninvestigated, unrecorded in any detail, and therefore undated (Moore and Wilson 1998).

6.5. Cott

Database ID: 150

Site ID: 2866

Site type: Settlement, midden

Period: Prehistoric, Norse

Sandblow period: Unknown prehistoric

The eroding section at Cott lies between the Bays of North Wick and South Wick on the east coast of Papa Westray, in an area of blown sand above the rock and promontory shingle of Surhoose Taing. Comprising deposits of stone walling, blown sands and midden deposits (containing charcoal, peat ash and animal bone), the section extends for c. 100m with its deposits measuring some 3.5m in depth (Figure 6.2). The richest and most extensive remains are visible to the centre of the eroding section.

The earliest archaeological deposits are covered by a storm beach, but at least four structures were identified during the Coastal Zone Assessment Survey, with visible walls appearing to represent at least two structural phases (Moore and Wilson 1998, 301). Some of the structures were revetted against the midden deposits, with the latest structural phase appearing to lie beneath a 'farm mound', which is then overlain by a c. 18th-20th century farmstead. The structures were proposed to be prehistoric in date (pre-Iron Age – categorised as dating to the 3rd -1st millennia BC) (Moore and Wilson 1998, 301) although later investigation by the SCAPE Trust suggested that the visible structures are more likely to be Norse in date. Two structural phases separated by a later of windblown sand (no measurement given) were observed to the north of the section (SCAPE Shoreupdate 2015) and it may be that these two structural phases are those earlier identified by Moore and Wilson.

The date of the archaeological remains at this site is uncertain, with both prehistoric and Norse dates suggested, and the earliest evidence of activity obscured by a storm beach. At least four phases of occupation have been tentatively identified (the two phases separated by the blown sand, the farm mound and the post-Medieval farmstead). The windblown sand identified in the section is likely to be prehistoric or early Norse in date, and it is possible that earlier sand horizons would also be identified lower in the section.

Figure 6.2. Detail of Cott structures and windblown sand to north end of eroding section. T. Dawson

6.6. Mayback

Database ID: 151

CANMORE ID: 2887

Site type: Midden, farm mound

Period: Medieval, post-Medieval (14^{th} – 18^{th} centuries AD)

Sandblow: Unknown Prehistoric or Norse-Early Medieval.

The eroding section at Mayback lies to the south of Cott (above) in the bay at South Wick, and comprises deposits of limpet shell and organic soils with post-Medieval pottery extending for c. 100m, with a remaining width of c. 40m E-W. The deposits are around 5m in depth and are overlain by a modern farmstead. At the base of the section, beneath the farm mound material, at least one structure was built on c. 3.5m of windblown sand. It is likely that this farm mound dates to the Medieval period with later post-Medieval activity – from approximately the 14^{th} – 18^{th} centuries AD (Moore and Wilson 1998, 303). The date for the earlier structure is unclear, and as such all that can be posited for the windblown sand beneath it is that it was deposited at some point before the 14th century AD. Recent visits (2015) showed that the section is now mostly obscured by sand dumping and modern farming debris (J. Hambly *pers. comm.*). A number of mounds, likely to represent the remains of burnt mounds (the Knowes of Mayback, CANMORE ID 2915), lie to the southwest of the site.

7. Westray

7.1. Pierowall Quarry

Database ID: 5

CANMORE ID: 2789

Site type: Chambered cairn, settlement (roundhouse)

Period: Neolithic (from at least 3040-2605 cal. BC (*start_pierowall_quarry*) to 2860-2600 cal. BC (*cairn_levelled*) (Bayliss *et al.* 2016, 38); Early Iron Age (from at least 800-410 cal. BC (GU-1580) (Sharples 1984, 89).

Sandblow period: Bronze Age (between 2860-2600 cal. BC (*cairn_levelled*) and 800-410 cal. BC (GU-1580) (Sharples 1984; Bayliss *et al.* 2016, 38; Figure S15); after the Early Iron Age (After 670-400 cal. BC (GU-1581))

7.2. Links of Noltland

Database ID: 10

CANMORE ID: 2790

Site type: Settlement

Period: Late Neolithic (from c. 3160–2870 to 2170–1840 cal. BC (*start_LoN; end_LoN*); Bronze Age (from c. 2170–1840 cal. BC (*end_LoN*)) – until c. 1000 BC.

Sandblow period:

Late Neolithic. Trench D: from at least 3160–2870 cal. BC until 2850–2640 cal. BC ((*last_Phase_II*); between 2230-2130 cal. BC (*Red_deer*), and 2200-1930 cal. BC (*last_Trench_D*) (Clarke *et al*. 2017, 72; Illustration 11);

Trench C: before wall construction 2780–2340 cal. BC (GU-1693); *around* 2340–2035 cal. BC (GU-1432) until c. 2265–1975 cal. BC (GU-1690).

Trench A: after 2470-2140 cal. BC (GU-1433) and 2480-2135 cal. BC (GU-1692), perhaps until 2470–2005 cal. BC (GU-1695) (Marshall *et al.* 2016, 29; Table 4).

Burnt mound: Middle-Late Bronze Age (c. 1000BC).

Cemetery: Late Neolithic - Early Bronze Age: before 1630-1460 cal. BC (GU-27901) and 1690-1510 cal. BC (GU-27908).

7.3. Berst Ness

Database ID: 104

CANMORE ID: 2841

Site type: Settlement

Period: Multiperiod**.** Neolithic, later Prehistoric, with use of cemetery into the Norse period

Sandblow period: Unknown prehistoric

The multiperiod prehistoric settlement at Berst Ness (also known as the Knowe of Skea) lies within a wider landscape of prehistoric remains including cairns, domestic settlement remains, a cemetery, and field systems (RCAHMS 1983). Lying at the southwest tip of the island on the highest point of a tidal islet, the site is exposed to the Westray Sound to the south, and lies at the edge of a large expanse of blown sand drift deposits which blanket the southwest end of the island. After initial recording by RCAHMS in the 1920's and 1970's, a programme of rescue excavation was undertaken at the site, which was at risk of substantial coastal erosion, from 2001-2003 and 2006 (Moore, Wilson and Barrett 2001; Moore and Wilson 2002; 2003; 2006).

Excavation of the visible mound in 2001 revealed a sub-rectangular house (Figure 7.1) posited to be of later prehistoric date, beneath the thick exterior walls of which were placed a series of inhumations. The structure reused some walls and remains of a substantial earlier structure (Moore and Wilson 2001, 72-3). Continued excavation in 2002 revealed that the thick exterior house walls encountered during the previous season actually represented four skins of outer wall facing, constructed in rapid succession (Moore and Wilson 2002). Floor deposits and two hearths were encountered, but little in the way of domestic refuse. Beneath the floor deposits lay a thick windblown sand deposit (dimensions not stated), beneath which lay the remains of an earlier stone structure, for which a Neolithic date has been posited (Moore and Wilson 2002, 89).

A number of inhumation burials, as well as some additional disarticulated remains, were recovered from outside the structure, indicative of the use of the immediate vicinity as a cemetery over a long duration, until around the 7th century AD. A high proportion of the remains recovered were identified as infants and children. The 2003 excavations revealed further structures in this area (Moore and Wilson 2003, 103), which were constructed over natural deposits. Without scientific dating information it is difficult to estimate a date for the deposition of the windblown sand; however, if the later building is indeed later prehistoric, then a date prior to this can be posited.

Figure 7.1. Berst Ness/Knowe of Skea under excavation. Moore and Wilson 2001, 73.

7.4. Evertaft

Database ID: 6

CANMORE ID: 2858

Site type: Midden

Period: Iron Age (from at least cal. AD130-420 (AA-39134)).

Sandblow period: Middle Iron Age (240±165AD), Viking (940±110AD)

The eroding site at the Bay of Skaill, Westray (known as Evertaft) lies at the eastern edge of a large drift deposit of windblown sand covering the north east of the island. The site is located at the southernmost point of the sandy bay, on a headland separating the bay from the Ouse on Westray's northeast coast. The site comprises structural remains within an eroding sand dune (RCAHMS 1946; 1983). In 1999/2000, the settlement was recorded with EDM survey, the exposed section drawn, and twenty test pits excavated in the hinterland which revealed little in the way of archaeological material (Barrett *et al.* 2000, 68). In section, the site comprised nine stratigraphic units of interleaved middens, windblown sand, and stone structures (Figure 7.2) reaching c.4.5m in depth, with the entire exposure extending some 60m along the coastline, and c. 0.25m inland. A cereal grain from low in the section (Sommerville's Unit 4, see below) yielded a radiocarbon date of cal. AD130-420 (AA-39134), suggesting a Middle Iron Age date for its accumulation. In 2001 further investigation was undertaken at the site (Sommerville 2003), with five samples for OSL dating taken from the clean coarse-grained calcareous sand identified in the eroding section (Table 5).

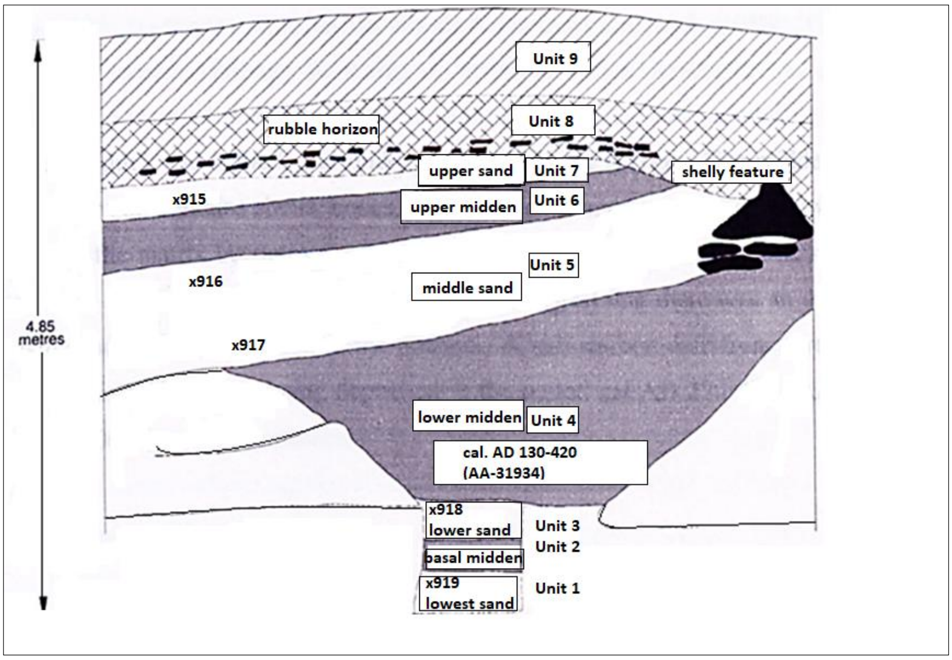


Figure 7.2. Eroding section at Evertaft with OSL sampling locations. After Sommerville 2003, 108.

Stratigraphic Unit	Dimensions (m)	Description
Unit 9	0-80	Modern soil comprised of medium-coarse grained calcareous sand with limpet shells.
Unit 8	0.80-1.40	Rubble layer containing cobbles, flagstones and burnt stone, clast-supported in a matrix of brown calcareous sand. Gradational contact with Unit 7
Unit 7	1.40-1.48	Pale brown, fine grained calcareous sand with yellow-brown bands throughout. 60% shell. <SUTL915>
Unit 6	1.48-1.98	Brownish-yellow midden, sharp underlying contact
Unit 5	1.98-2.98	Pale yellow, fine grained calcareous sand <SUTL916> at top, <SUTL917> at base. Increase in shell content with depth, from 37% - 51%
Unit 4	2.98-4.00	Dark brown midden interrupted by calcareous sand lenses towards top (Radiocarbon sample recovered from this deposit (AA-39134) (Barrett *et al.* 2000)
Unit 3	4.00-4.15	Lighter yellow-grey, medium-fine calcareous sand, 60% shell <SUTL918>

Unit 2	4.15-4.35	Dark grey-brown basal midden, sharp contact
Unit 1	4.35-4.85	Light yellow-grey fine-grained calcareous sand, 51% shell <SUTL919>

Table 5. Stratigraphic units and sample numbers at Evertaft, after Sommerville 2003, 107-110.

It was noted that the contents of the upper and lower middens (Units 6 and 4) were markedly similar, and it was suggested by Barrett *et al.* that the upper midden (Unit 6) may have originally been part of the lower midden (Unit 4) and redeposited in order to stabilise the Unit 5 sand surface (Sommerville 2003, 110). This would have required excavation of parts of this midden outwith the pit in order for the overlying sand not to have been disturbed, and it is unclear how this process may have taken place. As no radiocarbon dating of the upper midden was undertaken, this cannot be accurately confirmed.

The OSL dating programme identified two periods of increased sand movement using weighted means (Table 6), despite a slight lack of chronostratigraphic order and error overlaps. It can be observed that the lower sand (918) appears to have accumulated in the Middle Iron Age (c. 240±165AD), while the upper and middle sand layers appear to have accumulated during the later Pictish/early Norse period (c. 940±110AD). It is the oldest determination in the section, although overlies a lower midden deposit and the lowest sand layer with a later determination. This is likely to have been caused by partial bleaching, leading to low precision (see Sommerville 2003, 313). The radiocarbon date from the Unit 4 midden appears to broadly correlate with the middle and lower sand OSL weighted mean.

Lab ID	**Location in section**	**OSL age (years before AD2000)**	**Weighted mean (years before AD2000)**	**Date (BC/AD)**
SUTL-915	Upper sand	1080±165		
SUTL-916	Middle sand	1195±210	1060±110	940±110AD
SUTL-917	Middle sand	910±200		
SUTL-918	Lower sand	1875±195	1760±165	240±165AD
SUTL-919	Lowest sand	1450±325		

Table 6. Weighted mean ages of upper/middle sands and lower sands identifying two periods of increased sand movement. After Sommerville 2003, 309.

The thickness of the sand layers led to an initial interpretation of periodic abandonment of the site following their deposition. The imprecise nature of the samples due to low sensitivity means that any evidence for abandonment (e.g. a more constrained date with low errors) is lost (Sommerville 2003, 313). Given the contrast in sensitivities between the samples from Pierowall, Quoygrew and Evertaft, it has been suggested that the sands from Evertaft had a different source, which is surprising given their relatively close proximity.

Four of the five samples <SUTL-915-917, 919> from Evertaft displayed similar dose responses to stimulation, and it is may be that these samples derive from the same, albeit unknown, source. In contrast, the Iron Age <SUTL-918> had a similar dose response to a modern beach sample from Pierowall. The alternative sand source may be indicative of its deposition under different environmental conditions than the others at Evertaft; it is possible that it was deposited during a storm event with a wind direction dominating from the south. The low sensitivity of the sample may indicate that the transport and subsequent deposition of the sand may have occurred at night or in low light conditions, leading to only partial bleaching. OSL dating of samples at the upper and lower boundaries of this deposit would confirm whether the sand was deposited gradually or during a single event. If these dates emerged as being notably younger than the original date for <SUTL-918>, this would confirm the partial or complete lack of bleaching and thus an age overestimation (Sommerville 2003, 316).

The relatively high errors (15%-20%) present in all samples from Evertaft indicate all were only partially bleached. The low precision has been attributed to low sensitivity of the samples, but it has also been posited that a wide range in equivalent dose (De) for each sample could have contributed to the low precision (Sommerville 2003, 316-7). Furthermore, Sommerville (2003) and Barrett *et al.* (2000) have suggested that continual sand drift may have been a problem at Evertaft, which would have led to heterogeneous bleaching.

7.5. Quoygrew

Database ID: 118

CANMORE ID: 2919

Site type: Settlement

Period: Late Viking – Medieval

Sandblow period: Late Pictish-Norse, Medieval (between cal. AD677–959 (TO7118), until cal. AD1243-1381 (AA52358) (Simpson et al. 2005, 365; Table 1).

The site at Quoygrew lies at the Atlantic-exposed north-west tip of Westray, at the northern edge of a large expanse of medium-fine grained windblown sand which covers the entirety of the south of the Rackwick-Aikerness tip of Westray (Figure 7.3). Occupation spans the 10^{th}-13^{th} centuries AD, encompassing the Viking and Middle Ages. Three mounds, one of which was coastal and eroding, were identified. The site was first investigated in 1978 with the excavation of a test pit (Clarke and Colley 1978, 18; Barrett 2011, 45). More sustained investigation was undertaken in 1997, with the coastal middens sampled for environmental studies, and later dated to the 10^{th}-12^{th} centuries cal. AD (Barrett *et al.* 2000).

Following extensive augur, geophysical and topographic survey, excavations at the site were undertaken from 1999 to 2006, during which time the site was identified as a late Viking and Medieval settlement containing a fish midden, ‘farm mound’, plaggen infields, and structures. Remains comprised three mounds (Figure 7.4), one which was coastal and eroding (Area A). The coastal site comprised an erosion exposure of dense midden material and a cellular stone structure, stretching for c.30m in length, up to 1.75m in height, and at least 10m inland. A ‘farm mound’ was located c.50m inland (Area G), containing the remains of three Viking-Age buildings, middens (dated artefactually to the Viking period) and relict anthropogenic topsoils (over 0.90m at their maximum depth), interpreted as an infield (Wickham-Jones and Hope

1977, 25; Barrett *et al.* 1997, 61; Barrett 2012, 46). The Area A and Area G midden deposits are of particular interest here.

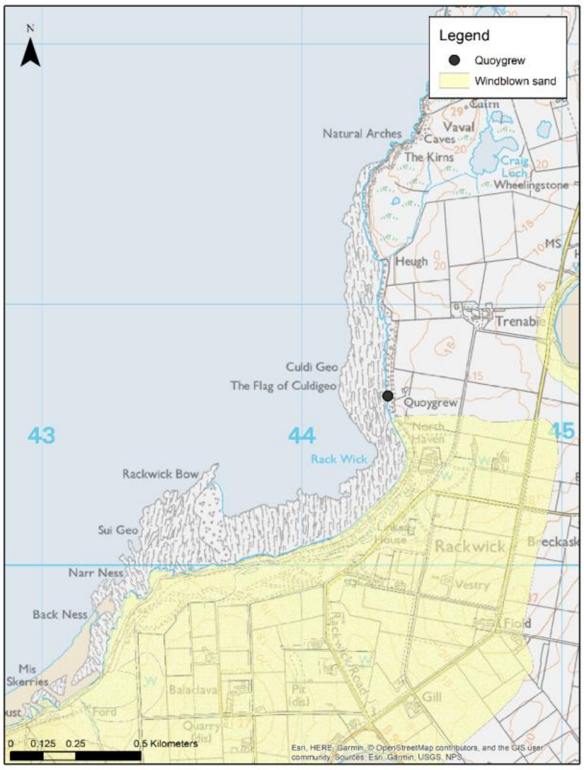


Figure 7.3. Location of Quoygrew in the wider landscape

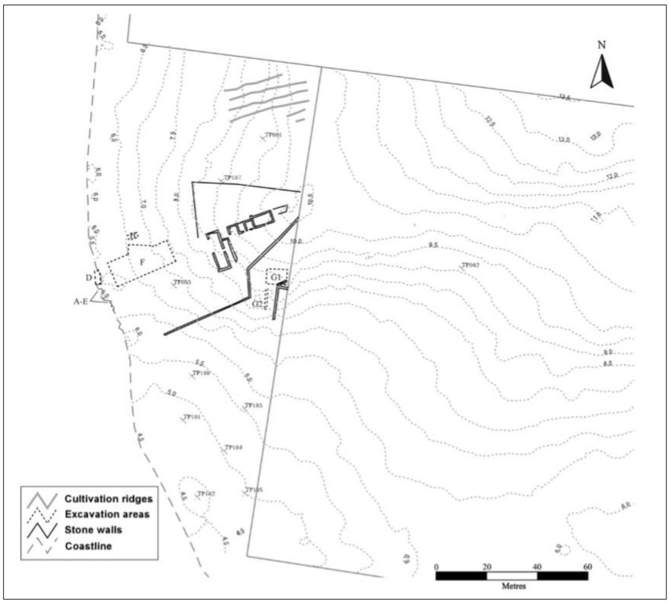


Figure 7.4. Location of site at Quoygrew, showing Areas (mounds) A and G. The standing walls represent the latest (post-Medieval) phases of occupation. Milner et al. 2007, 1463; Figure 2.

Area A and G deposits

Upon excavation, two distinct functions were evident in the deposits of the mounds, with Area A appearing to have functioned as a fish-waste midden while Area G was more characteristic of a classic ‘farm mound’. Given the existence of two seemingly different mounds, micromorphological analysis was undertaken in order to characterise the evidently differing formation processes. Analysis of the cultural soils at the fish midden Area A demonstrated that they comprised a thickened midden with significant quantities of peat ash, fish bone, shell, and well-sorted windblown calcareous sand components (Simpson *et al*. 2005, 366). The windblown sands do not appear to have had a particular impact on the structures themselves. The Area G midden deposits provide an interesting contrast in that they contained far fewer windblown sand components (Simpson *et al.* 2005, 372) with the midden rich in fish bone and shell in the upper strata, as well as occupation debris including peat, fish bone, turf residues, and animal bedding. The increasing exploitation of shellfish (particularly limpets) was noted, and as this increase was concurrent with an increase with fish bone the excavators argued that they represented the increased exploitation of fish at the site on a significant scale (Milner et al. 2007, 1471).

At Area A, a barley grain with a range of cal. AD677–959 (TO7118) provided a *terminus post quem* for the development of the midden, while a cereal grain near to the top of the soils yielded a determination of cal. AD1243-1381 (AA52358) (Simpson et al. 2005, 365; Table 1). The earliest age for the development of the farm mound and structures in Area G was yielded on a pig skull, with a range of cal. AD782-995 (AA50702). The aforementioned interface between the lower midden (dominated by mammal bone) and the upper midden (dominated by fish bone) was dated to cal. AD1004-1262 (AA39135) (on a horse pelvis) (Simpson *et al.* 2005, 364). A cereal grain (species not stated) from the raised soil overlying the farm mound yielded a determination of cal. AD1256-1400 (AA54914), offering a *terminus ante quem* for the development of the mound. The early iterations of the Area F structures were dated typologically to the 12th century by the presence of Medieval coarse wares, while the later remodelled structures were associated with Scottish Red Ware of 13th-15th century date (Barrett et al. 2000, 69-70). The determinations indicate that sand was being frequently turned and intermixed with the midden deposits from cal. AD677–959 (TO7118), until cal. AD1243-1381 (AA52358) (Simpson *et al.* 2005, 365; Table 1).

7.6. Mae Sand

Database ID: 154

CANMORE ID: 295707

Site type: Midden

Period: Unknown

*Sandblow period***:** Unknown

The site at Mae Sand lies within an area which has undergone significant deflation as a result of sand quarrying (Figure 7.5) to the southwest of Westray at Langskaill. Sand quarrying in the area removed significant sand deposits of considerable depth, and exposed an old ground surface (described as possibly being of "considerable date" by Moore and Wilson (1998)) in which concentrations of shell, bone and anthropogenic deposits were recovered. A (2m by 1m) setting of stones within organic soil, possibly representing a hearth, was the only archaeological feature identified during the Coastal Zone Assessment Survey (Moore and Wilson 1998), and is currently invisible.

Figure 7.5. General view of sand dunes at Mae Sand. SCAPE Trust.

7.7. Noup

Database ID: 147

CANMORE ID: 295340

Site type: ?Settlement

Period: Unknown

Sandblow: Unknown

Three earthen mounds within windblown sand deposits have been exposed by deflation in the Bay of Noup at the north-west of Westray (Figure 7.6). Each mound measures between 10m-30m in diameter, and each appears to contain a structure encased and constructed in blown sand deposits (Moore and Wilson 1998, 237). No further conclusions on the formation of these mounds – and their relationship with the windblown sand deposits – can be drawn at present.

Figure 7.6. Noup mound 1 showing blown sand and masonry. SCAPE Shoreupdate 6137.

8. Sanday

8.1. Tofts Ness

Database ID: 1

CANMORE ID: 3572

Site type: Settlement

Period: 3330–2910 cal. BC (*start Tofts Ness 1*) to 2120–545 cal. BC (*end Tofts Ness 2*) with Bronze Age 'hiatus' (Bayliss *et al.* 2017 [Supplementary Material], 94).

Sandblow period: Late Neolithic (2260±100BC) <SUTL-602-3, 612-3, 616-7>;

Early-Late Bronze Age (between 1880-1600 cal. BC to 1680-1440 cal. BC (*span 3*) and c. 11^{th}-9^{th} centuries BC <SUTL-95, 103-6>), possibly before c. 1740-1520 cal. BC (SRR-5249)

Late Bronze Age (after 11th-9th centuries BC <SUTL-95, 103-6>) and before 1450-900 cal. BC (GU-2183) to 770-410 cal. BC (GU-2208) only

Late Bronze Age-Early Iron Age (After c. 1000-200 cal. BC (GU-2207), possibly 625±185BC <SUTL-608-9, 611, 614-5, 618>

8.2. Meur

Database ID: 138

CANMORE ID: 282775

Site type: Complex burnt mound

Period: Early-Late Neolithic; Bronze Age-Early Iron Age (from at least 3336-3023 cal. BC (GU-41721) until at least 40 cal. BC-cal. AD87 (GU-37107).

Sandblow period: Neolithic (c. 2475-2299 cal. BC (GU-36668)); Middle Bronze Age (1297-1115 cal. BC (GU-36245); Late Bronze Age-Early Iron Age (c. 810-540 cal. BC (GU-15746).

8.3. Lopness

Database ID: 3

CANMORE ID: 306622

Site type: Cist inhumation, palaeoenvironmental section

Period: Early Bronze Age (remains interred at c. 1890-1520 cal. BC (GU9481; 10382)).

Sandblow period: Middle Bronze Age (1015±140BC) <SUTL-890-891>, Medieval (c. AD1515±35) <SUTL-884-889>).

8.4. Scar

CANMORE ID: 3494

Database ID: 159

Site type: Walled structure; boat burial

Period: Late Iron Age/Pictish (cal. AD430-640 (GU-3825); Norse (remains interred at c. AD895-1030 (AA-12595-97)).

Sandblow period: Unknown prehistoric; before cal. AD435-650 (GU-3825); Late Iron Age/Pictish-Norse (between cal. AD435-650 (GU-3825)) and c. cal. AD895-1030 (AA-12595-97)). Norse (shortly after c. cal. AD895-1030).

8.5. Quoy Ness

CANMORE ID: 3416

Database ID: 142

Site type: Midden, possible farm mound

Period: Unknown

Sandblow period: Unknown

A series of kitchen midden deposits, likely to represent the remains of an extensive, undated site, lie to the north west of Quoy Ness (south-west Sanday) in an area of stabilised dunes interspersed with loose, moving sand deposits. These sands are likely to be the source for the later prehistoric and historic sands observed at Pool Bay. The midden deposits were observed during a 1928 RCAHMS field visit (RCAHMS 1946), but these are now not visible, and likely to have been obscured by moving sand (SCAPE Shoreupdate 2013). Given the dynamic dune cordon in which it is located, it is likely that this site and its landscape was inundated by sands in the deeper past, although without further exploration of obscured remains this cannot be clarified.

8.6. Woo

CANMORE ID: 3492

Database ID: 143

Site type: Midden, structures

Period: ?Prehistoric

Sandblow period: Unknown

The site at Woo is located at the north of Sanday, at the westernmost extent of the dunes at Sand Ayre. The site comprises an eroding section through a c. 100m long deposit of midden, composed largely of fish bones, limpets, ash, flint and pottery (Figure 8.1). Additionally, a c.6m length of stone walling and paving is visible. The midden is c. 0.20m thick, and covers till. It underlies a deposit (potentially an old ground surface) comprising layers of dirty sand and frequent shells, with the deposits as a whole reaching a total of c. 2m in height (Moore and Wilson 1999, 281). A rough date for the pottery was not suggested, but Moore and Wilson suggest that the midden may be prehistoric. A period for the sand accumulation, then, cannot be posited – it can only be said that its deposition (or multiple depositions) post-date the site.

Figure 8.1. Midden, sand and structural remains at Woo. C. Parker, SCAPE Shoreupdate 6803.

8.7. Northskaill

Database ID: 144

CANMORE ID: 3503

Site type: Farm mound

Period: Possible Bronze Age activity; 13^{th} century AD.

Sandblow period: At c. cal. AD1040-1280 (SRR-2352)-cal. AD1290-1430 (SRR-2353)

The eroding mound at Northskaill (also known as Langskaill) lies at the northeastern end of Otterswick Bay, Sanday, east of the Burness peninsula. The c.150m long eroding section comprises deeply-stratified deposits of cultivation soils with shell, peat ash, bone and charcoal, as well as calcareous windblown sand layers and masonry remains (Figure 8.3, Figure 8.4), founded on very soft blown sand deposits. Following geoarchaeological investigation, the remains were classified as that of a classic Orcadian 'farm mound'. Lenses of fibrous organic material deriving from byre waste interspersed with, sand, soils, and food waste are typical of these sites (Davidson *et al.* 1988). Although the founding and accumulation of this mound has been dated to the mid-13th century cal. AD (Table 8), Bronze Age straight-sided pottery recovered from the basal deposits (which developed over sterile sands) may suggest that this site was the location for much earlier inhabitation (SCAPE Shoreupdate (3503)).

The mound sediments are characterised by high proportions of blown sand within the matrix, suggesting that destabilised sand from the bay was moving throughout its accumulation. When the radiocarbon determinations, sections recorded by Davidson *et al.* (Table 7), and the SCAPE Trust sections (Figure 8.2) are compared with each other, some preliminary conclusions can be made with regards to the chronology of the windblown sand horizons. Two radiocarbon samples were recovered from the section at the depth of c.1.60m (where the most notable windblown sand deposits were recorded), and yielded determinations of cal. AD1040-1280 (SRR-2352) on soil, and cal. AD1290-1430 (SRR-2353) on shell respectively (Davidson *et al.* 1988, 52) and it can be posited that the deposition of the sand observed by the SCAPE Trust investigations (Figure 8.2, deposit 5 at c. 1.50m) correspond with this broad 10^{th}-12^{th} century AD date bracket. Although these radiocarbon dates are helpful in ascertaining a broad chronology for the development of the mound, it would be unwise to draw more specific conclusions given the nature of the site, which has undergone significant erosion and has not been directly excavated.

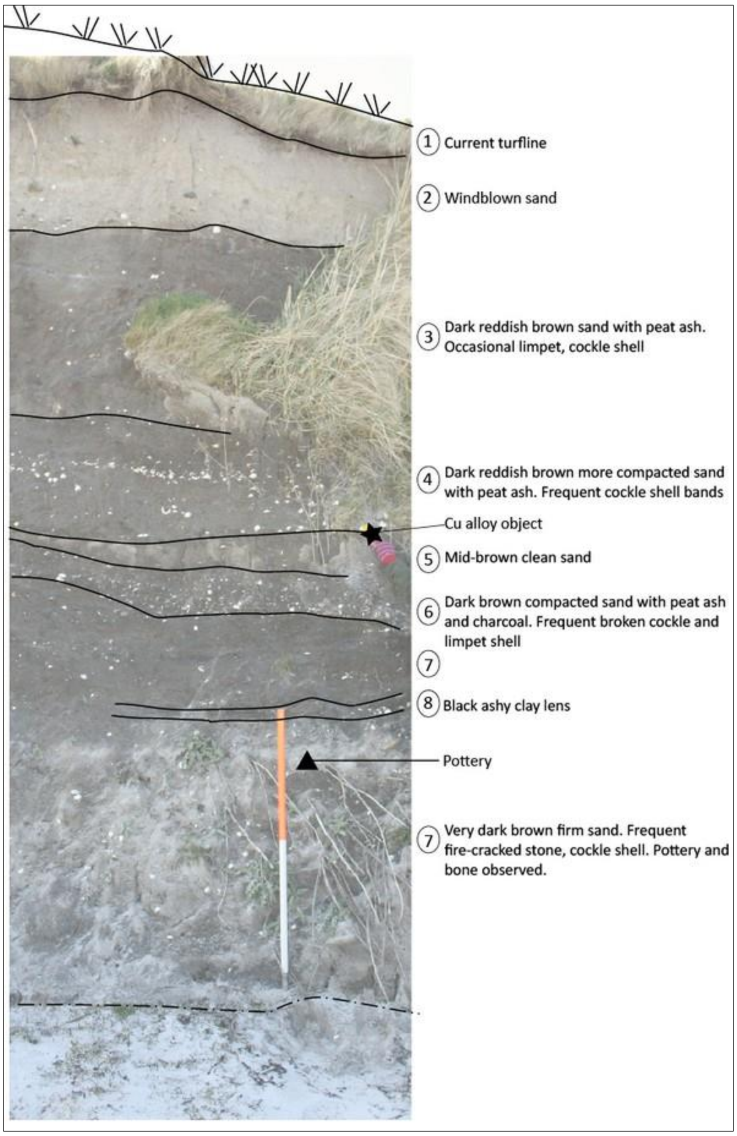


Figure 8.2. Representative section of deposits at Northskaill/Langskaill. J. Hambly.

Depth from surface (m)	Description
0-0.54	Blown sand and modern turf/topsoil
0.54-2.30	Sequence of mineral sediments with many lenses and shells
2.30-3.90	Sequence of thicker, more homogenous mineral sediments with shells and stone lines
3.90-4.18	Layer of cockle shells with a sandy matrix
4.18-4.28	Basal occupation layer
4.28-4.70+	Sterile sands

Table 7. Northskaill stratigraphic sequence. Davidson et al. 1988, 52.

Depth (m)	Lab ID	Lab age (BP)	Radiocarbon age range cal. AD at 95% probability
1.65	SRR-2352	820±80	1040-1280
1.65	SRR-2353	1000±70	1290-1430
1.85	SRR-2354	1010±60	1280-1420
2.62	SRR-2355	910±50	1020-1210
2.62	SRR-2356	1060±60	1280-1400
3.25	SRR-2357	1190±90	690-980
3.25	SRR-2358	1010±70	980-1150
3.25	SRR-2359	1110±60	1260-1390
4.05	SRR-2360	1170±50	1220-1280

Table 8. Radiocarbon dates and calendar ages from Northskaill, calibrated using Stuiver (1982) (Davidson *et al.* 1988).

Figure 8.3. Peat ash rich deposits and concentrations of cockle shell at Northskaill/Langskaill (SHOREUPDATE 6817)

Figure 8.4. General view of Northskaill section. Stone structure to left of standing figure. (SHOREUPDATE 6817)

8.8. Sanday, Long Taing of Newark

Database ID: 140

*CANMORE ID***:** 306538 and 313943

Site type: Farm mound

Period: Possibly 10th – 14th century (Norse/Early Medieval)

Sandblow period: ?Norse, Medieval

The Long Taing of Newark represents an extensive eroding farm mound site located on the east of Sanday, at the southernmost extent of the Bay of Lopness. The eroding section extends for c. 60m, with deposits comprising windblown sands, stonework, midden with charcoal, fish and mammal bone and anthropogenic soils (Figure 8.5). Frequent fish remains, many of which are articulated, may indicate that fish-processing activities were undertaken here, perhaps associated with a substantial settlement at Newark. The remains appear to date roughly to the Norse/Viking period (Moore and Wilson 1999; SCAPE Shoreupdate 6681). The central c. 15m of the exposed mound contain the maximum depth of deposits, which reach at least 1m in thickness but are perhaps deeper as the section base is current obscured by extensive windblown sand deposits (SCAPE Shoreupdate 6681).

The remains of around three courses of drystone walling, measuring c. 4m in diameter, is visible at the base of the section. The structure is constructed upon the till, and is now buried beneath a sand dune. It is likely that the remains are related to those c.10-20m to the south, at SCAPE Shoreupdate 6681 (SCAPE Shoreupdate 13229). A further series of drystone walls to the north of the section – tentatively identified as being typologically Norse in date - appear to have been constructed on windblown sand 1m above the current beach level. The sand beneath must have accumulated before their construction, but no firmer conclusions can be drawn without excavation and scientific dating.

Figure 8.5. Ash, midden and blown sand deposits at Newark (SCAPE Shoreupdate 6681).

8.9. Newark

CANMORE ID: 313944

Site type: Farm mound

Period: 10th-14th centuries AD

Sandblow period: ?Norse

The site, which lies at least 200m to the south of the Long Taing of Newark (above) has been identified as a substantial eroding ‘farm mound’ located in dunes at the site of modern farm buildings. It is possible that this site is related to that described above, although they are separated by a mill lade and modern pipe which may have obscured any relationship (J. Hambly *pers. comm*.). The remains of the c. 50m diameter mound comprise c. 3m of deposits, mostly midden, sands and organic soils containing bone, charcoal, peatash and shell. The deposits extend for over 100m along the coast edge, and include the remains of drains (Figure 8.6) and coursed drystone walling, some of which reach around eight courses in height. The nature and density of the remains are indicative of a long period of occupation, with the structural remains being tentatively dated to the Norse/Viking period typologically (Moore and Wilson 1999; SCAPE Shoreupdate 6682).

Figure 8.6. Stone lined drain at Newark. SCAPE Shoreupdate 6682 (J. Hambly).

8.10. Cata Sand

Database ID: 97

CANMORE ID: 354969

Site type: Settlement

*Period***:** Early Neolithic

Sandblow period: Early Neolithic

The site at Cata Sand lies in the intertidal zone of the Bay of Newark on the east coast of Sanday, centring on the Grithies dune on a gravel ridge linking the point of Tresness to Sanday. The ridge was likely to have formed by c. 2000 BC, with further sand inundation and dune formation episodes in the first millennium BC (Rennie 2006 in Cummings *et al.* 2016, 8). The site is at high risk of being further eroded and eventually destroyed due to its location in the dynamic intertidal zone. Following the identification of prehistoric material eroding to the south of the Grithies dune in 2015, preliminary survey took place in 2016, in advance of excavation in 2017 and 2018 (Cummings *et al.* 2016; 2017; 2018).

Geophysical survey in 2016 revealed the presence of a number of stone anomalies across the area to the south of the dune, with removal of the overlying windblown sand confirming these anomalies to represent extensive structural remains (Cummings *et al.* 2016). Excavation of these remains in 2017 and 2018 confirmed that they comprised an Early Neolithic house constructed on sand (Figure 8.7), and the remains of four hearths and remodelled walls and piers - indicative of longer-term occupation. Midden deposits post-dating the Early Neolithic house are also indicative of a later phase of occupation (Figure 8.8). A pit containing multiple whale skeletons butchered in the 19th century has truncated the site, as have wind and tidal erosion and the development of the dune system. This has led to a mixed level of preservation on site, which is truncated, patchy and ephemeral in some places but well-preserved and stratigraphically-sound in others (Cummings *et al*. 2017, 14; 2018, 4).

Figure 8.7. The Early Neolithic house constructed on sand at Cata Sand. The lower central hearth is labelled (5). Cummings *et al.* 2018, 5; Figure 3.

Figure 8.8. The eastern wall of the Early Neolithic house with the later occupation midden deposits to the right. The darker cut represents the missing wall of the house with the remains of the blown sand which banked against it while it still stood. After Cummings *et al.* 2016, 7.

Windblown sand at Cata Sand

The Early Neolithic house at Cata Sand and its early hearth were constructed directly over a calcareous sand ground surface. At least two phases of Early Neolithic occupation appear to have been separated by the incursion of windblown sand. The earliest hearth (the lower central hearth) (Figure 8.7) was filled with c. 0.20m of calcareous windblown sand, and overlain by another central hearth which was later dismantled. The eastern wall of the house was missing, having potentially been robbed out and the stone reused. The existence of the formerly upstanding wall is evidence by a windblown sand deposit which had banked up against the now absent wall (Figure 8.8) (Cummings *et al.* 2017, 6). If the house is indeed Early Neolithic in date, then this may suggest that the sand was deposited during the Neolithic although it is not yet known when the stone was robbed. Radiocarbon dates, which would clarify this situation, are as yet unpublished.

The double-faced northern wall was found to contain a core of largely sandy material, perhaps attesting to the use of the dune sands surrounding the settlement as a construction material, and perhaps its collection, resultantly, causing dune destabilisation in the vicinity. Alternatively, this may just reflect increasing amounts of sand being mobilised in the general environs of the site. This, the deposit of banked windblown sand to the east of the house, and the infilling of the early hearth with sand, could be cited as evidence for the location of a frequently-remodelled settlement within a dynamic coastal dune environment, with dune instability and sand movement occurring during the life of the settlement and perhaps driving its eventual abandonment (see Chapter 6).

8.11. Pool

CANMORE ID: 3422

Site type: Settlement

Period: Neolithic-Norse (with Late Bronze Age-Early Iron Age hiatus in Phase 4) (from at least 3210–2935 cal. BC (*start Phase 2.2-2.3*) to 2460-2280 cal. BC (*end Phase 3*); from at least cal. AD 200-800 (GU-2244) to c. 1020-1220 (GU-1808)

Sandblow period:

The Neolithic, over the archaeological site between Phases 2.1 and 2.2 (between 3889±303BC <SUTL-75a, 78a, 79, 82, 83> and 3606±282BC <SUTL-26, 27, 30, 35> (Spencer and Sanderson 2012, 3548-9), and between 2.2 and 2.3 (c. 3210-2935 cal. BC to 2815-2650 cal. BC (*start Phase 2.2-2.3; end Phase 2*) (Macsween *et al*. 2015, 15; Figure 9).

Late Bronze Age-Late Iron Age (between 1090-920 cal. BC (UBA-32509) and AD660-780 (UBA-32508))

Late Iron Age-Norse (between cal. AD660-780 (UBA-32508) and AD1377±341 <OSL-2>

Appendix 2

Luminescence dating: supplementary data

1. Luminescence dating methods

1.1. Laboratory methods

All sample preparation, dating procedures and post-processing were undertaken at the CERSA Luminescence Laboratory, University of St Andrews School of Earth and Environmental Sciences. Further information on the principles of luminescence dating can be found in Appendix 3.

1.2. Preparation of quartz

Twelve of the fifteen samples (labelled 1-12 as well as being equated to their test pit and context numbers) were initially processed in order to develop the luminescence chronology for sand movement in the landscape at Pool (Table 1). From these 12 samples, 9 were selected for the full SAR dating procedure. Guidelines for sample preparation and running set by King and Valla (2013) on coarse grain sample preparation were followed. The samples were sieved at >250, 212, 180, 125 and 90µm. Carbonates were removed through treatment in 10% hydrochloric acid (HCl) for 10 minutes. Sample 1 (retrieved from the eroding coastal section) was noted to have a high mineral content, whereas samples 2-12 were dominated by carbonates. Organics were removed using hydrogen peroxide. Density separation was undertaken using sodium heteropolytungstates (LST flastfloat) at densities of 2.58 and 2.7 gcm-3. The 180-212 µm fraction treated previously in HCl and hydrogen peroxide was etched in 40% hydrofluoric acid (HF) for 40 minutes. This was then washed in 10% HCl for 30 minutes to remove any precipitated fluorides.

Sample	Test Pit	Context	Height (m)	Grid ref.	Lat.	Long.	Description
1	Pool section	Pool section	5.32	361946/1037838	59.22443	2.66846	Mid-orange, coarse mineral sand
2	2	203	12.5	361857/1037511	59.22249	2.66996	Mid greyish-orange sand with grey mottling and some orange staining
3	2	204	12.5	361857/1037511	59.22249	2.66996	Pale grey, coarse calcareous windblown sand
4	2	212	12.5	361857/1037511	59.22249	2.66996	Dark grey, fine-medium calcareous windblown sand
5	3	304	13.9	361768/1037438	59.22183	2.67151	Light grey calcareous windblown sand with yellow staining
6	4	403	9.9	362147/1038015	59.22704	2.66497	Mid yellowish-brown windblown calcareous sand.
7	6	603	12.6	362039/1037749	59.22464	2.66681	Mid yellowish-grey medium calcareous sand with shell fragments and some dark organic content
8	9	902	8.4	361937/1037718	59.22435	2.66859	Light orange-grey calcareous windblown sand, medium-coarse with orange mottling
9	9	904	8.4	361937/1037718	59.22435	2.66859	Mid grey calcareous, finer-grained windblown sand
10	11	112	8.5	361925/1037605	59.22334	2.66879	Mid grey, fine-medium grained clayey shelly sand with orange mottling
11	1	103	7.4	361991/1037726	59.22443	2.66765	Mid yellowish-orange windblown calcareous sand, medium-coarse
12	11	113	8.5	361925/1037605	59.22334	2.66879	Mid grey, fine-medium calcareous sand with orange mottling

Table 1. OSL dating samples with their context numbers, heights in m (OD), locations and descriptions.

1.3. SAR luminescence measurements

Following initial sample preparation under subdued orange light, the 180-212 µm fractions of samples 1-3, 5-8 and 11-12 were selected for full analysis by the author at the University of St Andrews Centre of Earth Resources (CERSA). The Single Aliquot Regeneration (SAR) protocol (Murray and Roberts 1998; Murray and Wintle 2000) was used for the OSL dating process. The regenerative process measures the luminescence signal and its intensity from the natural radiation dose. The luminescence signal within the sample is then reset by exposing it to a controlled illumination source. Varying known laboratory radiation doses are then given to the sample in order to characterise the growth of the luminescence signal after the earlier resetting with the radiation dose being received. Finding the radiation dose that gives the same luminescence signal intensity as that found during sample recovery allows for the equivalent dose (D_e - the energy absorbed by the sample) to be calculated.

The protocol begins with a measurement of the natural OSL signal from the quartz grains after a preheat, until its signal reaches zero. These grains then undergo another cycle of irradiation, preheat, and measurement to generate a regenerated OSL response, and measure sensitivity of the quartz. The natural OSL signal can then be compared with the regenerated OSL response. In other words, the SAR protocol therefore allows for estimates of equivalent dose to be produced for each aliquot (sample portion) , by making paired (natural and regenerated) measurements of OSL intensities (Galbraith *et al.* 1999). Here each natural or regenerated dose luminescence measurement is corrected for changes in sensitivities using the luminescence response to a following test dose (generally 10±20% of De).

Samples were mounted using Silkospray silicone oil on stainless-steel discs, with each disc containing c. 5-7mg of quartz. Measurements were undertaken using an automated RISØ TL/OSL reader. Beta source calibrations were performed relative to RISØ quartz on 30/04/2012. Optical stimulation of single aliquots was undertaken using a blue light-emitting diode (LED), with OSL measured using a photomultiplier tube and irradiation carried out. Within the SAR protocol, two further protocols were employed; (1). SAR post-TL for samples 1 and 11, and (2). SAR with variable preheats and no TL for samples 2-8, 10 and 12.

1. *Samples 1, 9, 10: SAR post-TL.*

Following dose recovery tests to ascertain the responses given by samples to stimulation, runs of 24 aliquots were run at preheats of 162°c and 182°c TL for a sequence of regenerations of 50, 100, 150, 0 and 50 seconds with measurements carried out at 125°c using blue LED’s.

2. *Samples 2-8, 10, 12: SAR with variable preheats.*

32 aliquots were run at ascending preheats of 200, 220, 240 and 260°c for 30 seconds, with measurements carried out at 125°c using blue LED's. These preheats and measurements were interspersed with natural signals. Regenerations of 52, 104, 208, 0, and 52 seconds were used for samples 2-3 5 and 12, and 13, 26, 52, 0 and 26 seconds for samples 6-8. Responses to test doses were then measured to monitor sensitivity.

1.4. Dosimetry and radionuclide concentrations

To calculate the luminescence age of the samples, dose rate (the amount of radiation received by the sample each year) was measured. The combination of radiation dose (the amount of radiation absorbed by the sample during the period since the event being dated: D_e) and dose rate are what allows an age to be determined. Quartz grains contain a small internal alpha dose (assumed as 0.03 0.006 Gy/ka) as well as external beta, gamma and cosmic ray components. Alpha particles, beta particles and gamma rays are types of environmental radiation which originate from elements which occur naturally in the sample and its surroundings. Uranium (U), thorium (Th) and potassium (K) are the most important sources for the luminescence process (Duller 2008, 16).

Geochemical methods were employed in this case to measure the concentration of elements delivering the radiation dose (Table 3). Radioisotope concentrations were measured on dried and ground subsamples and determined through Inductively Coupled Plasma Mass Spectrometry (ICP-MS).

1.5. Water content

Following the opening of the sample tubes under subdued orange light, sediment which had been exposed to light was extracted from both ends of the tube (c. 0.01-0.02m), ensuring the removal of any light-contaminated material, which would 'reset' the date of the sample. The bulk samples were then dispensed into pre-weighed plastic beakers, which were then weighed again, before being dried in a hotbox oven at 50°c to constant weight. After drying, each sample was reweighed thus allowing the calculation of water content (Table 2). The dry and saturated water contents were then determined as fractions of dry weight, along with consideration of field conditions during sampling (for example, the season, and levels of groundwater encountered. This is an important step as research has demonstrated that water content can affect the amount of radiation a sample receives during deposition (e.g. Aitken 1998). The equation for determining water content is as follows;

$$Actual\ water\ content = \left(\left(\frac{w}{dw}\right) - 1\right) * 100$$

$$Saturated\ water\ content = \left(\left(\frac{sw}{dw}\right) - 1\right) * 100$$

Where w = sediment weight as submitted in grams

dw = dried sediment weight in grams

sw = saturated sediment weight in grams

Sample	Wet weight (g)	Dry weight (g)	Water content (%)
1	554.6	514.1	7.30
2	295.8	226.1	23.50
3	48.2	38.2	20.74
4	172.9	122.4	21.95
5	172.4	147.1	14.60
6	121.2	104.2	14.02
7	51.7	46.5	10.05
8	52.9	47.7	9.82
9	413	368.1	10.80
10	60.4	45.9	24.00
11	51.5	46.5	9.70
12	46	29.4	36.00

Table 2. Sample water content.

Sample	K	Rb	Th	U
	%	Ppm	Ppm	ppm
POOL1	1.51	45.06	2.19	0.85
POOL2	1.19	34.21	1.80	0.52
POOL3	1.16	34.58	1.72	0.51
POOL4	1.13	34.21	1.46	0.64
POOL5	0.72	20.71	1.01	0.55
POOL6	1.21	42.70	1.74	0.72
POOL7	1.06	34.75	1.48	0.65
POOL8	0.73	21.19	0.93	0.46
POOL9	0.82	24.88	1.12	0.52
POOL10	1.06	32.86	1.53	0.52
POOL11	1.28	41.58	1.76	0.60
POOL12	0.65	19.79	0.82	0.34
POOL13	1.24	37.70	1.61	0.58
POOL14	1.25	37.09	1.53	0.50
POOL15	1.40	43.18	1.90	0.56
POOL 1 Repeat	1.50	44.95	2.15	0.85
POOL 1 Repeat	1.52	44.98	2.17	0.86
POOL 1 Repeat	1.52	45.18	2.22	0.85
POOL 1 Repeat	1.49	45.12	2.24	0.87
POOL 1 Repeat	1.52	45.06	2.16	0.88

POOL 1 Repeat	1.53	45.13	2.11	0.82
Avg	**1.51**	**45.07**	**2.18**	**0.86**
2SD	**0.03**	**0.18**	**0.09**	**0.04**

Table 3. Radionuclide concentrations for Pool samples 1-15. Repeats were undertaken on Sample 1 to assess experimental accuracy and precision.

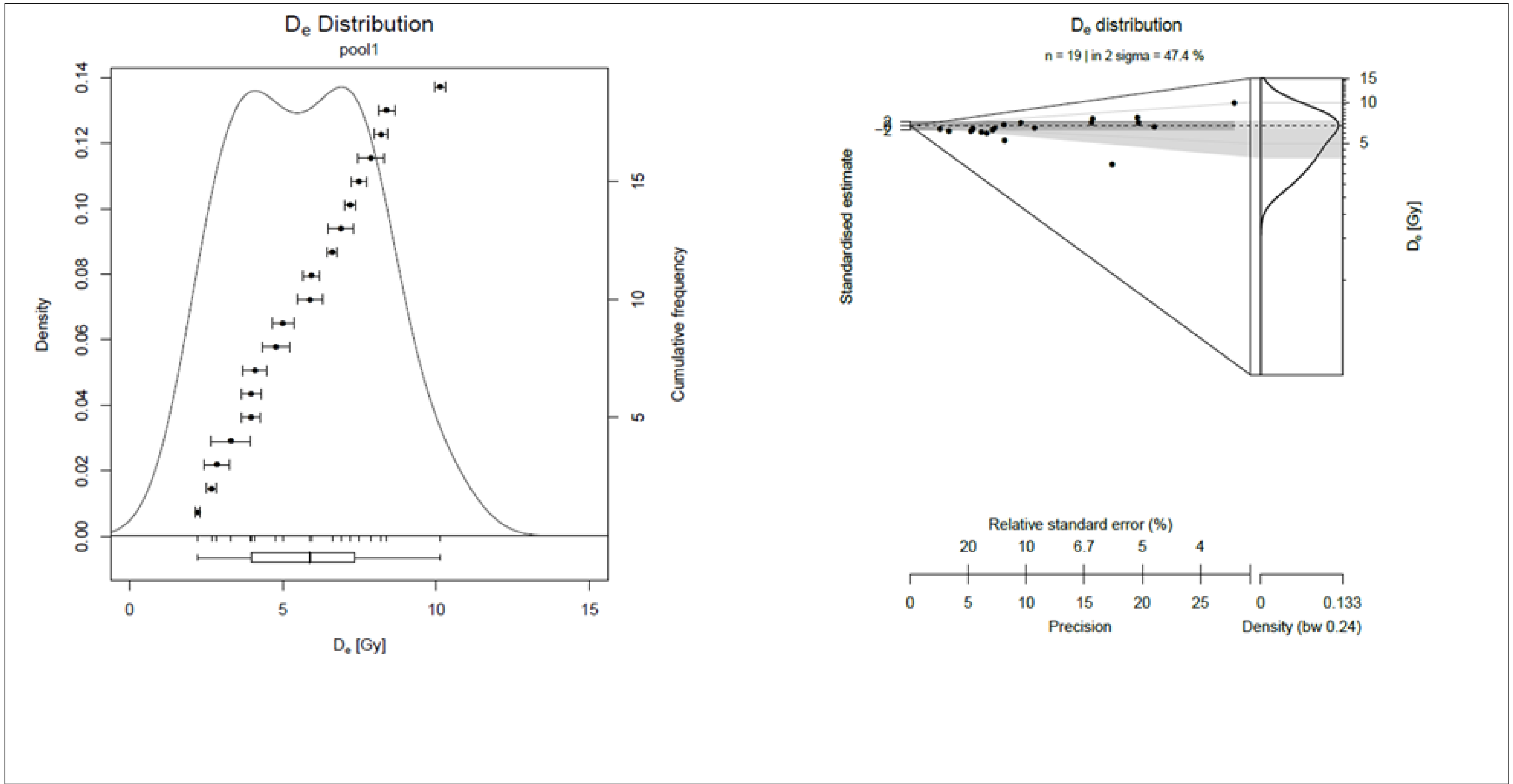
1.6. Equivalent dose determinations

To determine equivalent dose, data from the SAR dose measurements were analysed using the Risø TL/OSL Analyst programme. Dose response curves were generated in Analyst for each aliquot and their preheating temperatures, using a fit to linear function. They were then used to estimate equivalent dose values for individual and collective discs within each sample. Summary files were then exported and further analysed in MS Excel and R (developed at Bell Laboratories). Equivalent dose value distributions were examined in R using Kernel Density Estimate (KDE – a continuous curve estimating the population distribution of dated aliquots) and radial Abanico (a combination of a radial plot and kernel density estimate curve, displaying individual standard errors) plots to evaluate sample homogeneity and the weighted means calculated (see Galbraith and Roberts 2012; Dietze *et al.* 2016). Aliquots were selected for, or rejected from, further final analysis based on their response to radiation doses by analysing their sensitivity and recuperation. Aliquots with significant errors and anomalous outlying data populations displayed in the KDE and Abanico plots were also removed.

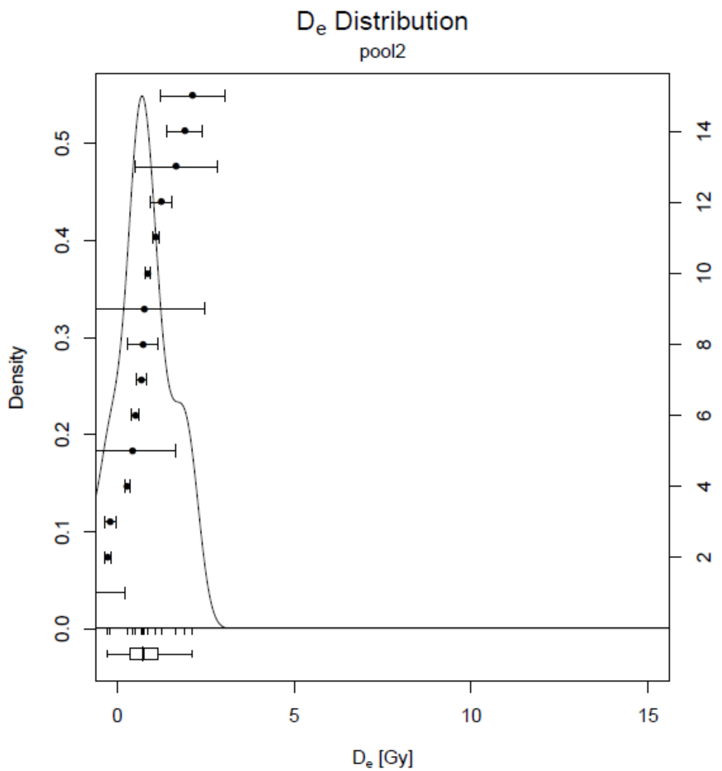
The total dose rate is determined from the sum of the equivalent beta and gamma dose rates and the cosmic dose rate. Age estimates are calculated by dividing the equivalent stored dose by the dose rate. Age estimate errors are calculated by combining the errors on the dose rates and stored doses. Table 4 shows the total dose rate, stored dose and corresponding sample age in years BP (2017) and calendar years.

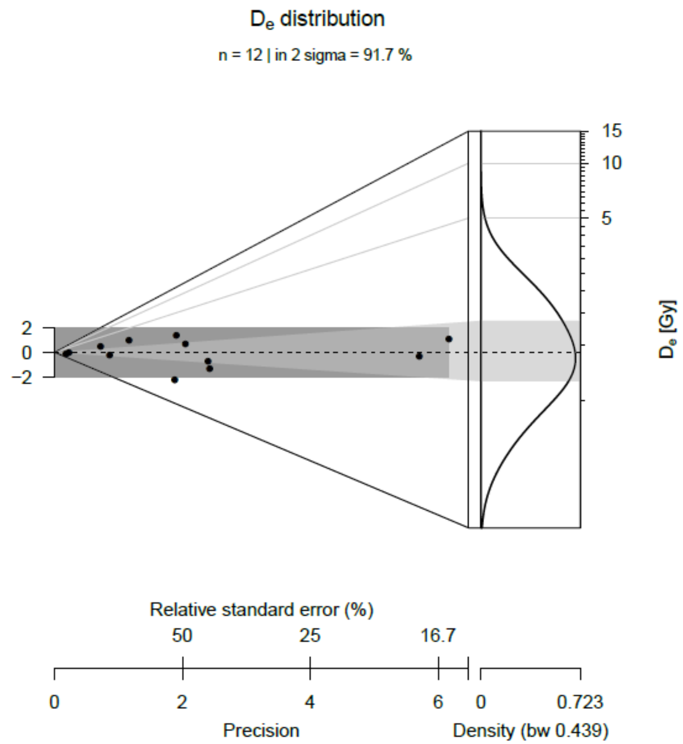
Sample	Context	Number of accepted discs	Dose Rate (mGy a-1)	Stored Dose (Gy)	Age	Years BP	Calendar years	Period
1	Pool section	9	1.860	7.716	4.15 ± 1.20	4150±1204	2130±1204 BC	Spans Early Neolithic-Late Bronze Age
2	203	4	1.311	0.839	0.64 ± 0.34	640±341	AD 1377±341	Medieval
3	204	4	1.304	2.971	2.28±0.12	2280±108	261±108 BC	Middle Iron Age
5	304	2	1.272	2.812	2.90±2.55	2900±2553	886±2553 BC	Spans Neolithic-Medieval
6	403	8	0.969	1.464	0.99±0.41	990±408	AD 1021±408	Medieval
7	603	14	1.471	1.201	0.89±039	890±388	AD 1130±388	Medieval
8	902	2	1.354	2.584	2.59±1.16	2590±1162	572±1162 BC	Spans the Early Bronze Age-Late Iron Age
11	103	29	0.998	2.706	1.73±0.47	1730±468	AD 294±468	Middle-Late Iron Age
12	113	9	1.089	3.309	4.07±0.45	4070±454	2057±454 BC	Late Neolithic/Early Bronze Age

Table 4. Pool samples, context numbers, accepted discs, total dose rates, stored dose and age estimates.

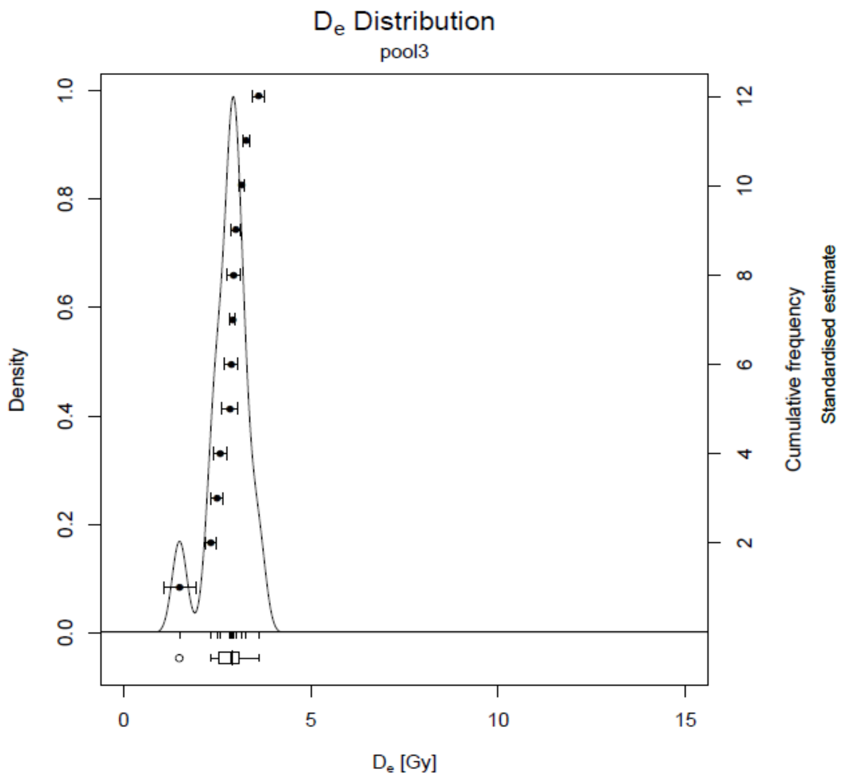


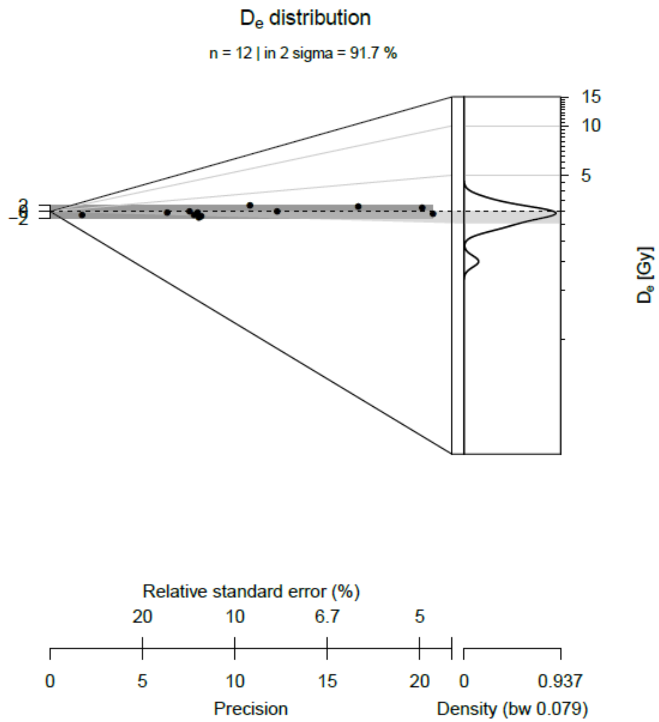
POOL1	**Gy**	**Stdev**	**Sterr**	**N**
Linear mean	5.653	2.244	0.515	19
Weighed mean	4.156	1.896	0.094	19
Robust mean	5.653	2.244	0.515	19
After reduction				
Weighted mean	3.835	2.492	0.10	9



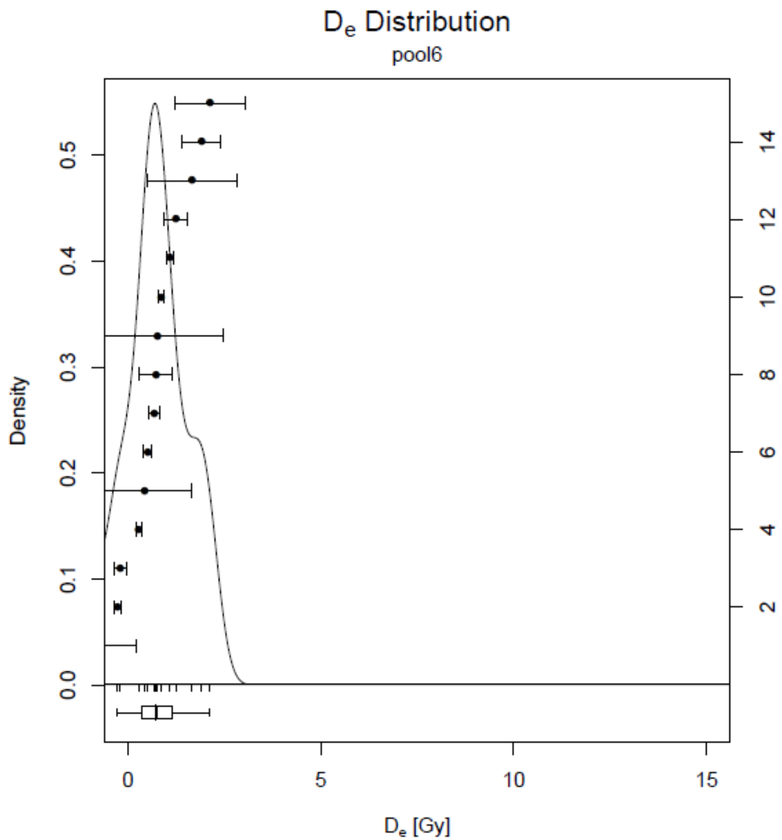


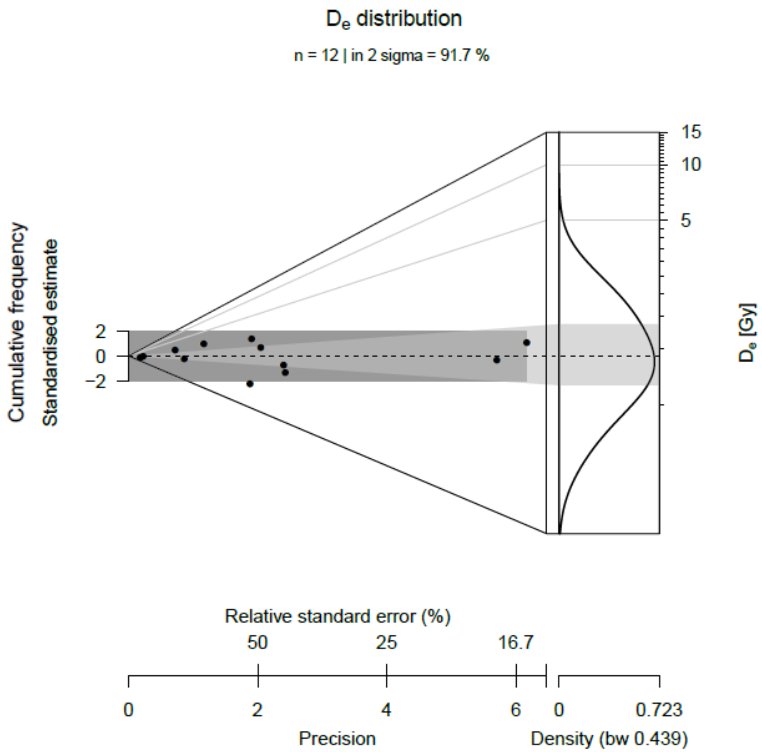
POOL2	Gy	stdev	Sterr	N
Linear mean	1.025	0.596	0.172	12
Weighed mean	0.690	0.201	0.081	12
Robust mean	1.025	0.596	0.172	12
After reduction				
Weighted mean	0.595	0.321	0.09	4



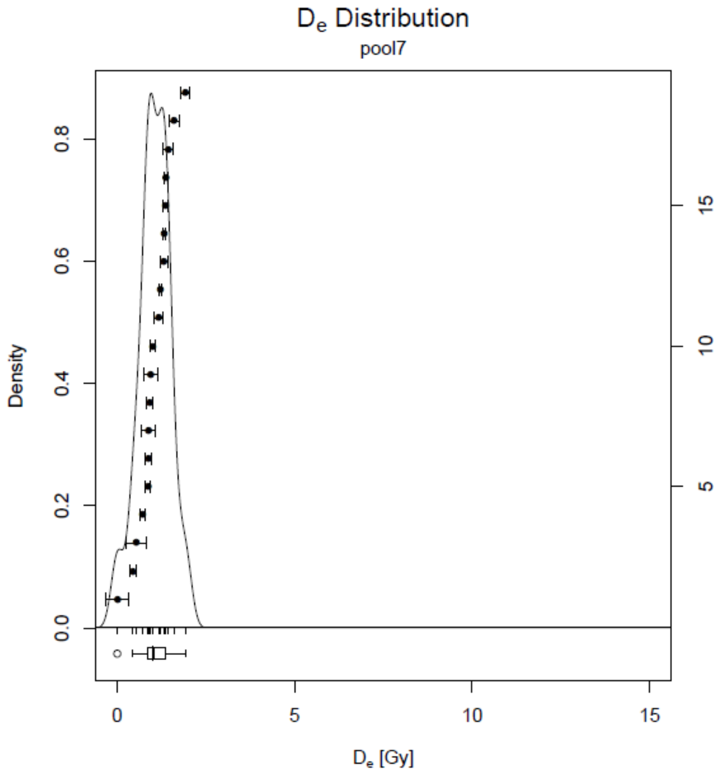


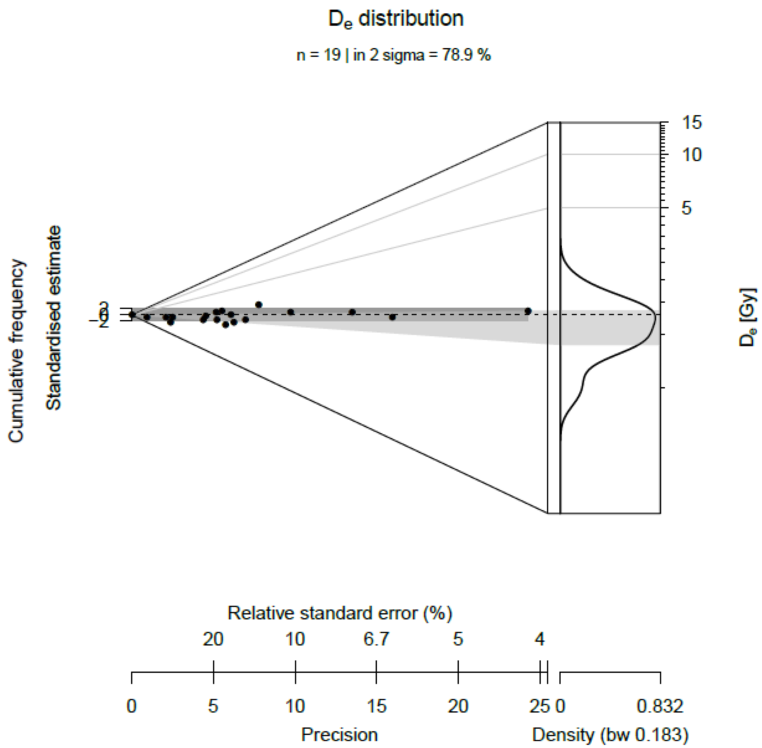
POOL3	Gy	stdev	sterr	n
Linear mean	2.232	1.248	0.322	15
Weighed mean	2.961	0.131	0.071	12
Robust mean	2.907	0.360	0.108	11
After reduction				
Weighted mean	2.735	1.905	0.11	4



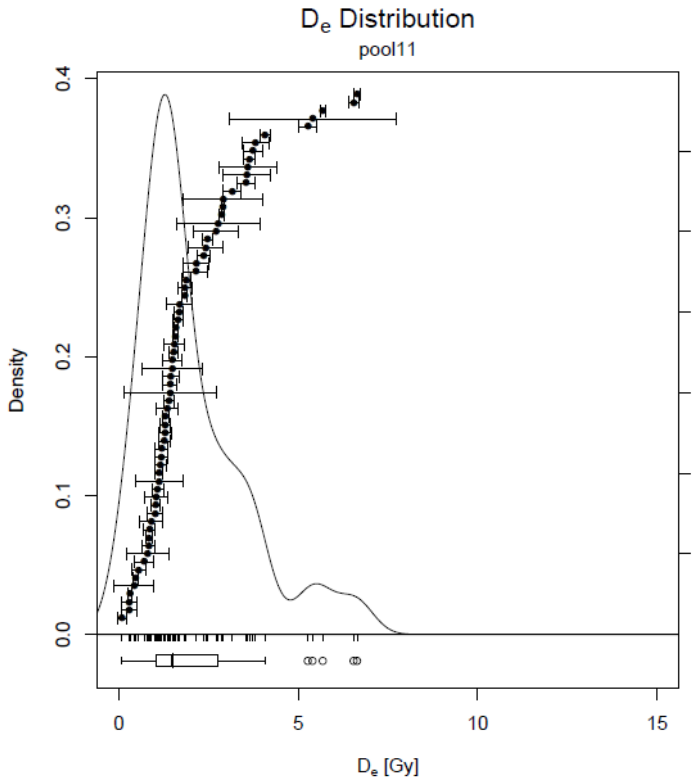


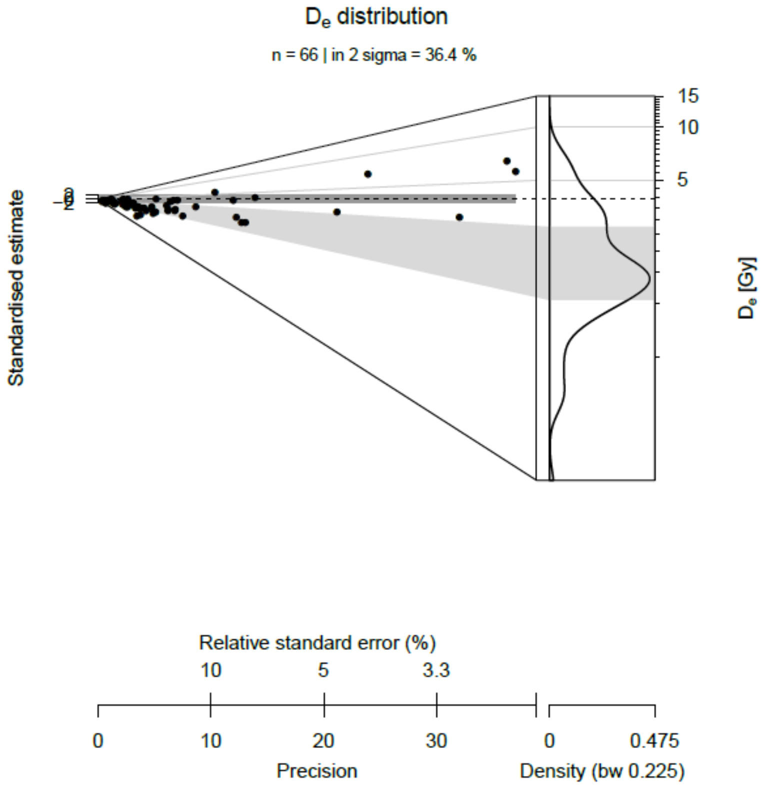
POOL6	Gy	stdev	sterr	n
Linear mean	1.025	0.596	0.172	12
Weighed mean	0.690	0.201	0.081	12
Robust mean	1.025	0.596	0.172	12
After reduction				
Weighted mean	0.595	0.321	0.09	4



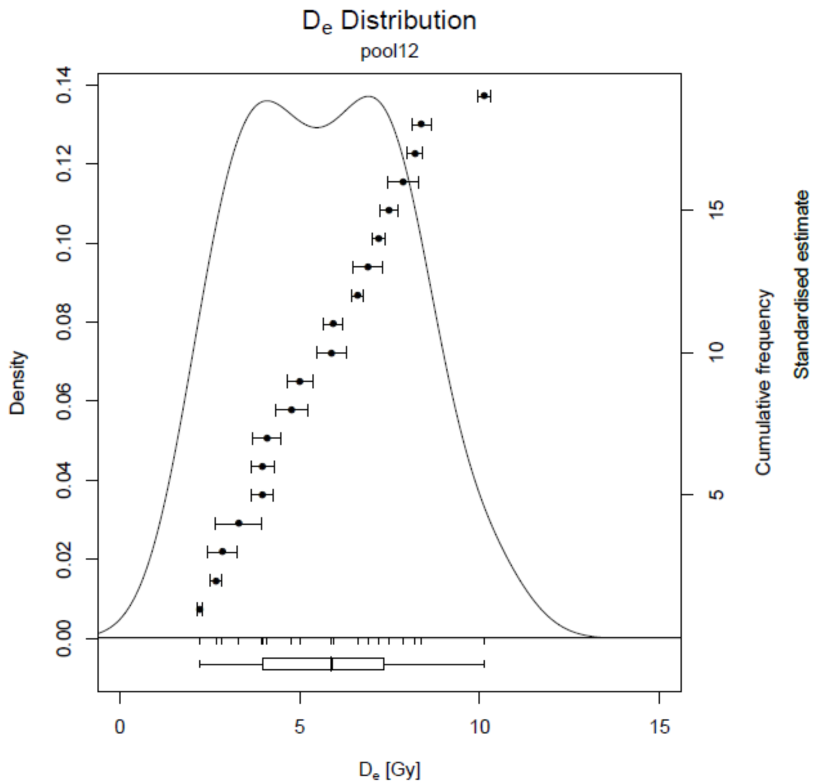


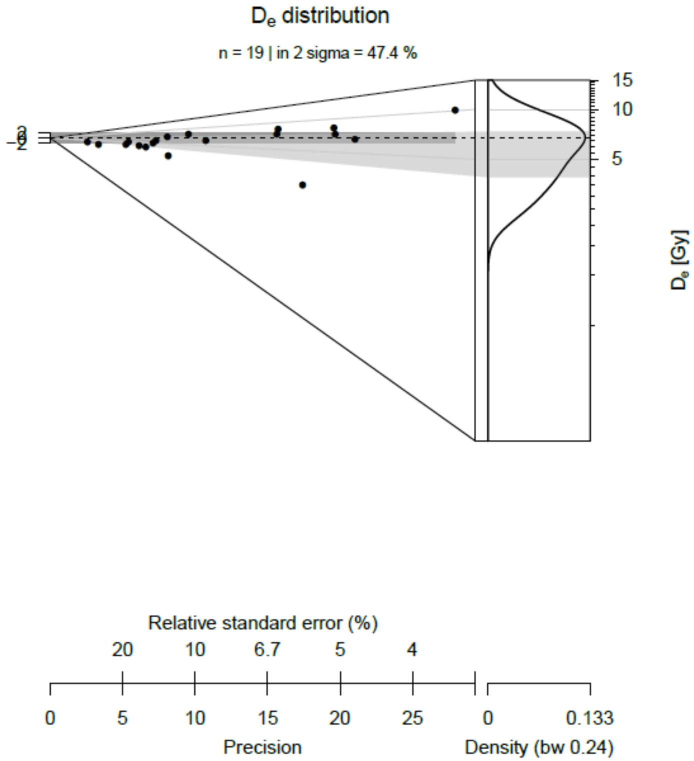
POOL7	Gy	stdev	sterr	n
Linear mean	1.051	0.444	0.102	19
Weighed mean	1.205	0.147	0.035	19
Robust mean	1.061	0.327	0.079	17
After reduction				
Weighted mean	1.199	0.522	0.03	14





POOL11	Gy	stdev	sterr	n
Linear mean	2.027	1.490	0.183	66
Weighed mean	1.772	0.396	0.083	66
Robust mean	1.269	0.568	0.082	48
After reduction				
Weighted mean	2.133	0.546	0.04	29





POOL12	Gy	stdev	sterr	n
Linear mean	5.653	2.244	0.515	19
Weighed mean	4.156	1.896	0.094	19
Robust mean	5.653	2.244	0.515	19
After reduction				
Weighted mean	3.835	2.492	0.10	9