A palynological view of selected Norse-era cultural landscapes and subsistence strategies in Greenland

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Abstract

This thesis is a palynological examination of Norse-era landscape change and subsistence strategies at the Norse Western Settlement of southern Greenland. A central focus is an attempt to understand Norse settlers' actions to maximize the agricultural potential of what many have characterized as a marginal landscape. This thesis accomplishes that task by reporting sheep and goat (caprine) foddering/husbandry strategies at several sites in the Western Settlement and a single Eastern Settlement site. A second chapter explores environmental data from the high-status Western Settlement farm of Sandnes. Landscape management and modification practices of Norse farmers have been a topic of study through several generations of researchers, and I add to this discussion by focusing on the less investigated Western Settlement and ancillary sites of the Eastern settlement using palynological techniques on a probable anthrosol and midden recovered caprine coprolites. These are two potentially significant sources of data that have rarely been utilized. The first chapter reveals caprine foddering strategies in a Western Settlement farm, Eastern Settlement farm, and a potential shieling. The results reinforce previous assumptions regarding the Norse usage of seasonally available resources in foddering strategies. The second chapter led to new interpretations of chronology and land use at Sandnes, a chiefly farm. Notably, the curation of this Norse cultural landscape was a slowly occurring process and may have ended before previously thought. The data presented here offers an example of the Greenlanders' subsistence strategies that allowed them to persist on the western arctic edge of the Norse cultural sphere for at least 425 years.

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Chapter 1: Introduction

1.1 Background

1.1.1 Norse Greenland: chronology and historical record

Icelandic historical sagas claim that the first European inhabitants of Greenland were Norse settlers from Iceland who arrived in the year AD 985/986, led by the recently ostracized Eric the Red (Krogh, 1967; Nedkvitne, 2018; Seavor, 2010). This initial period of colonization is called *landnám*, a term that comes from Old Norse and meant taking land (Benediktsson, 1968). The Norse settlers established two communities, known as the Eastern and Western Settlements, in the fjords of southwestern Greenland (Roussell 1941). The more heavily populated of these (the Eastern Settlement) was located within the fjord systems between c. 59° and 60°N, and the smaller Western Settlement was located at 64°N. Myriad factors influenced how the Norse settler's culture changed through time, including, for example, the involvement of the state and church, fluctuating environmental conditions, and shifts in demand for their trade goods (Barlow et al., 1997; Nedkvitne, 2018; Star et al., 2018). The last documented (i.e., historical) record of the Norse Greenland settlements relates to the Hvalsey wedding, which took place around AD 1408. The Western Settlement had likely already been abandoned by this point, and the once more heavily populated Eastern Settlement probably followed by the mid-15th century (Arneborg et al., 2012; Dugmore et al., 2007; Lynnerup, 2014).

1.1.2 Norse cultural sphere

Norse settlers arrived in southern Greenland as part of a North Atlantic colonization commonly associated with the Viking Age of northern Europe (Arneborg, 2008). This expansion witnessed first the settlement of the Orkney and Shetland isles between the 7th and 8th centuries, followed by colonization of the Faroe Islands around AD 825 and Iceland around AD 870 (Figure 1.1) (Dugmore et al., 2005; Friđriksson & Vésteinsson, 2003). It has been well documented that Iceland was settled rapidly with desirable land at a premium by the early to mid-10th century (Vésteinsson & McGovern, 2012). This is a familiar story of the Viking Age, in which Norse expansion is often explained in terms of a desire for new pasturelands, although it is not the only explanation (Arneborg, 2008; Barrett, 2008). Population movement in the North Atlantic was a continuation of a century-long expansion from Western Norway. This occurred in places that were either primarily uninhabited (Faroes and Iceland) or had an indigenous population with whom the Norse mixed with or displaced, like what occurred in Ireland, Shetlands, Orkneys, and Hebrides (Price, 2011). Regional differences developed at each location, reflected in each sub-group's material culture (Barrett, 2008).

Throughout the North Atlantic, Norse settlers brought all the necessary technology to continue their subsistence economy, which had developed over a millennium (Arge et al., 2005; Dugmore et al., 2012; Hem Eriksen et al., 2014; Sveinbjarnardóttir, 1991). Norse settlement in the North Atlantic followed a dispersed pattern centered upon farms that were often interconnected and dependent on each other for social ties and trade goods (Arneborg, 2008). The subsistence strategies brought to Greenland were part of a continuation of a suite of activities developed in the sub-artic conditions of Norway and then refined to suit the diverse geographies of the North Atlantic region.

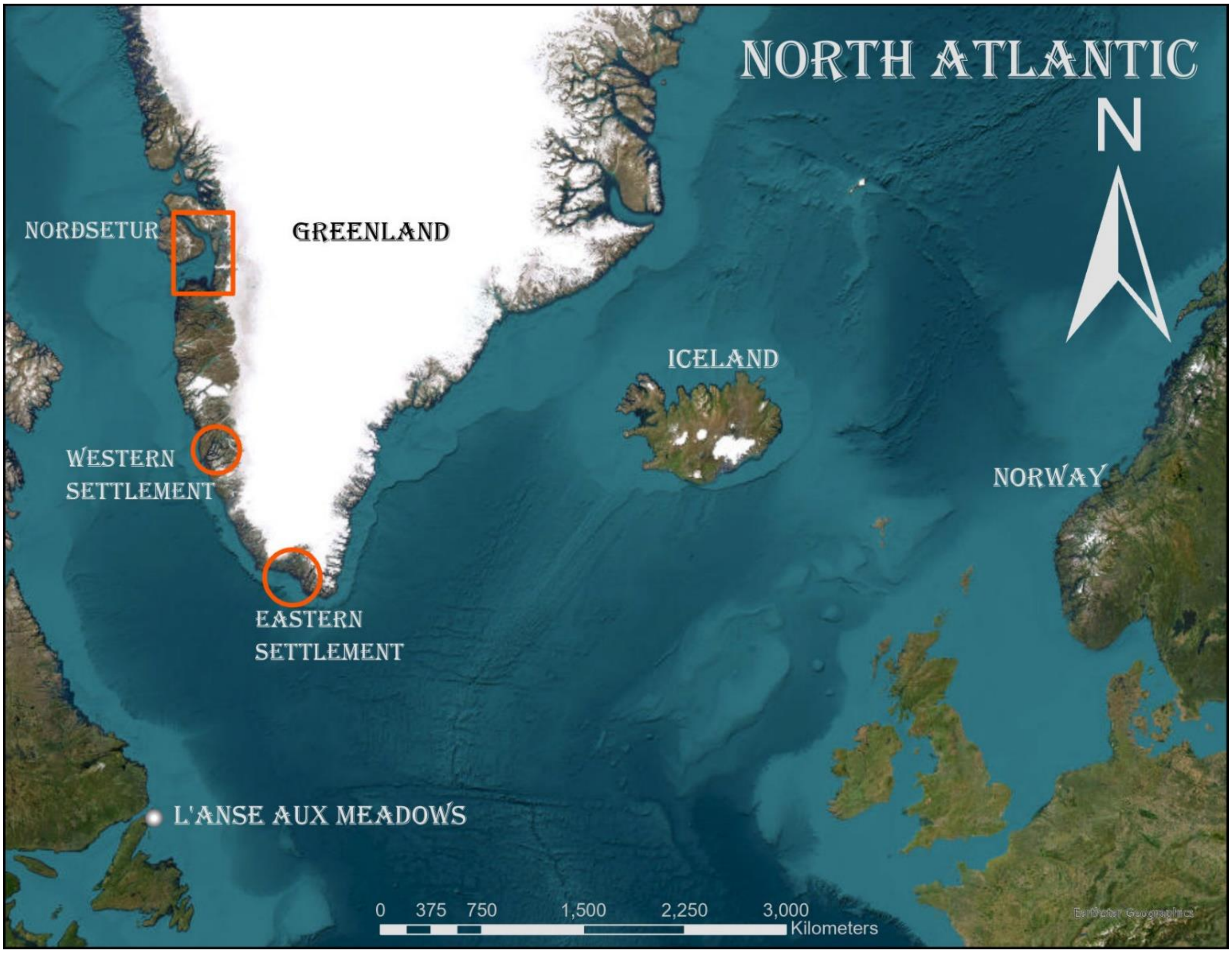

Figure 1.1: Satellite map of the North Atlantic highlighting the primary locales mentioned in this thesis. The area of the Eastern and Western settlements has been demarcated with orange circles.

1.1.3 Greenland geography

Greenland is the world's largest island at roughly 2 million square kilometers. The island's interior is covered by year-round ice sheets (Layberry & Bamber, 2001). The unglaciated coastal southern fjords of the island are characterized by a relatively restricted flora that forms plant communities shaped by the sharp environmental gradient between the colder and wetter coast and outer fjords and warmer and drier inner fjords (Böcher et al., 1968). Steep coastal mountains run parallel to the fjord coasts, creating another gradient of warm low, laying plains, stark mountain ridges, and higher altitude mountain valleys.

1.1.4 Norse Greenland settlement pattern

No formal towns or cities were founded in Norse Greenland, so the farm was the foundation of society (Jackson et al., 2018; Roussell, 1941). Norse farms utilized low-laying rolling plains between the coastal mountain ranges. Farms were primarily situated to exploit areas of pasture and concentrated towards the heads of the fjords, which experience a longer growing season owing to a drier continental climate (Ledger et al., 2014). Farms were also established further inland, such as in the Vatnahverfi district (Vebæk, 1992).

Main dwelling houses, or longhouses, were generally timber-framed structures clad with walls of turf for insulation (Roussell, 1941). The roofs were held up with thick poles that were likely either acquired via trade or found on the beach as driftwood (Guðmundsdóttir, 2022). Houses and byres may have had organic floors built of wood detritus, twigs, and straw set on soil or clay to act as insulation and carpeting, which was replaced semi-frequently (Buckland et al., 1994). The longhouses functioned as the home for the main family and were usually accompanied by a series of outbuildings. There is some variation in building layouts and the ancillary structures across farms (Roussell, 1941). Churches were rare and usually only appeared on high-status farms or the central farm in a network (Arneborg, 2008).

Stone constructed byres for overwintering livestock and lower-status community members who did not live in the main houses were common on farms as well as similar, more general, stone storage buildings (Roussell, 1941). Rarely, a farm may have contained a separate stone building to house a forge, which was used to rework traded metals and possibly even smelt bog iron (Roussell, 1941). This second claim is contentious as there is little evidence to say if smelting did or did not occur in Greenland (Buchwald, 2001; Vebæk, 1992).

1.1.5 Subsistence & seasonal round

In Greenland, each farm was self-sufficient in collecting foodstuffs (Arneborg, 2008). Norse Greenlandic subsistence was centered on transhumant pastoral agriculture in which livestock were rotated through various pastures at different points in the year (Albrethsen and Keller, 1986). Domesticates primarily comprised caprines (sheep and goats) and cattle that were kept for their primary (meat) and secondary (milk and wool) resources (McGovern, 1985; Arneborg, 2008). When domestic animals were moved to Outfield pastures in summer months, hay was raised in the Infield areas surrounding the farm before being cut and dried for overwintering animals (Ledger et al., 2014). Aside from cattle, sheep, and goats, the Norse also likely kept dogs for hunting and herding, as well as cats and horses. These latter animals were not eaten, so their remains are rare in zooarchaeological assemblages from middens (Nygaard, 2018).

In Greenland, the Norse likely managed the landscape in terms of the Infield-Outfield system, which was shared across the North Atlantic and Norway (Ledger et al., 2014; Øye, 2001; Sveinbjarnardóttir, 1991). The Infield comprised the farm and associated structures as well as the hay field, which was the primary source of hay cultivation for the overwintering of livestock (Ledger et al., 2014). The fertility of the Infield hayfield was likely maintained through manuring and, in some cases, irrigation (Buckland et al., 2009; Edwards & Schofield, 2013). The Outfield was the area beyond the immediate vicinity of the farm where animals were put out to pasture to graze during the summer months (Øye, 2005). Also situated within the Outfield were structures known as *sæters* or shielings (structures ancillary to the farm of the Infield) that were also essential to the transhumance system of pastoral agriculture (Albrethsen & Keller, 1986). Overwintering would occur at the farm buildings of the Infield, and in the spring and summer, communities would decentralize with some staying on the farm and others moving to shielings for activities like hunting, fishing, sealing, whaling, the walrus hunt, dairying and pasturing livestock (Ljunqvist, 2005; Madsen, 2019; Mainland & Haistead, 2005).

Research on terrestrial shielings has revealed some of the landscape usages by the Norse across Europe, Iceland, and Greenland (Arge et al., 2005; Brown et al., 2012; Ledger et al., 2013; Madsen, 2019; Sveinbjarnardóttir, 1991; Vickers & Sveinbjarnardóttir, 2013). Shielings were frequently placed to target poorly accessible patches of pasture and grass that could be grazed and possibly cropped. While the function of the main farm tended not to change much through time, the functions of the Outfield varied through time and space (Arneborg, 2008). Shielings were established in the Outfield's difficult-to-access valleys and uplands where the Norse could let their livestock find fodder for themselves without putting too much strain on the agricultural production of the main farm, a practice taken with them from Iceland and Norway (Brown et al., 2012). In Greenland, terrestrial shielings could also be situated for resource procurement or established in prime hunting locations (Dugmore et al., 2005; Jackson et al., 2018). Hay would also have been cropped at some shielings to supplement the resources of the Infield (Ledger et al., 2013). Dairying was a key task conducted at shielings and required substantial wood resources to process raw milk products from goats and cattle (Albrethsen & Keller, 1986).

1.2 Quaternary palaeoecology

1.2.1 Introduction

This project draws on the research traditions, methods, and theories of Quaternary palaeoecology. Quaternary palaeoecology can loosely be defined as a broad interdisciplinary suite of methods and theories well suited to reconstructing the changing environments of the Holocene (11,700 years ago to present) and the Pleistocene (2.6 million years ago to 11,700 years ago) (Birks & Birks, 2004). It is a framework at the interface of earth sciences, geography, and archaeology with a long-standing research tradition of studying human-environment interactions (Bell, 2005; Birks & Birks, 2004; Lowe & Walker, 2014). Quaternary environments are reconstructed by examining stratified accumulations of sediment commonly referred to as palaeoenvironmental archives (e.g., peats, soils, lake muds, etc.). The fundamental principle of palaeoecology is as follows: as palaeoenvironmental archives grow/accumulate, they incorporate ecofacts from the environment that reflect changes in that environment. By extracting and examining the ecofactual content (pollen, insects, plant macrofossils, diatoms, etc.) of these archives and interpreting them in relation to modern-day geomorphological and ecological processes, it is possible to make inferences about past environmental changes (Lowe & Walker, 2014).

Human groups influence the landscape they inhabit, and whether intentionally or not, they shape the ecologies of those environments (Boivin et al., 2016). If a group consistently interacts with the environment at different sites in a way that leaves similar signals, we can conceptualize this in terms of an "ecological footprint" or "palaeoenvironmental signal" (Dugmore et al., 2005). Humans and their niche construction are, in turn, influenced by their landscape and local changes in ecology or climate (O'Brien & Laland, 2012). Norse farmers generally made an immediate impact on the landscape throughout Greenland. While vital to their society's economy, defining and altering the land around them was not unique to the Norse farmers or even pastoral ways of life. Norse agriculturalists constructed their niche to survive and, in some cases, pushed the limits of their subsistence models, requiring Norse Greenlanders to further nuance their lifeway relative to their contemporaries in Norway and Iceland (Jackson et al., 2018). Hunter/fisher/gatherer societies likely influence their environment in more subtle ways that may be difficult to observe in the palaeoenvironmental record but likely still exist (Ledger et al., 2018).

1.2.2 Palynology

In the last couple of decades, a variety of palaeoecological approaches (e.g., palynology, palaeoentomology, archaeozoology) through the study of diverse palaeoenvironmental archives (e.g., midden deposits, anthrosols [human-amended soils], peat bogs and lakes), have refined our understanding of the environmental changes related to the Norse and their footprint in Greenland and the broader North Atlantic (Edwards & Schofield, 2013; Gauthier et al., 2010; Ledger et al., 2013, 2015; Schofield & Edwards, 2011; Schofield et al., 2013). Within the framework of Quaternary palaeoecology is the field of pollen analysis, or palynology, which I will be using in this project to investigate Norse landscapes and subsistence economies.

Palynology is the study of pollen grains in geologic or archaeological contexts. It is a method with over a century of theoretical and methodological history, addressing both fundamental and applied questions (Birks & Berglund, 2018; Birks & Birks, 2004; Faegri, 1989; Moore, 1978). Pollen grains recovered from archaeological contexts must first be prepared before they are counted. There is some variation in the process used to prepare samples, but for this thesis, the method was as follows. First, a collected archive is subsampled at sequential depths to control the stratigraphic and, therefore, temporal boundaries of each subsample. Subsamples are then treated by first cleaning the samples in a Sodium Hydroxide (NaOH) wash; solids are sieved out with a fine-grained mesh, and then an acetolysis heated bath is applied to remove the cellulose from the cell wall, aiding in later identification (Moore et al., 2001). Flotation in a centrifuge is then used to isolate the remaining plant material, including pollen grains, which is applied as a stain on glass slides, allowing viewing through a light microscope.

Pollen analysis is done by identifying the pollen grains through the light microscope by comparing key morphological characteristics of pollen grains to reference material until a statically significant total has been reached (500 TLP) (Moore, 1978). Pollen is primarily identified by the internal structure, suturing, and apertures within the cell wall, as well as by their size (Figure 1.2) (Moore, 1978). Interpretations of the statistical variance of pollen grains between different subsamples inform us of changes in landscape characteristics through time. The counting and identification of pollen grains from stratified contexts has provided wide-ranging insights into topics such as long-term vegetation change associated with glacial-interglacial cycles (Reille et al., 1998), changes in human-environment interaction like those arising from the Neolithic subsistence shift to agriculture (Iversen, 1941), and relatively short-lived episodes of human activity, such as that of Norse Greenland (Ledger et al., 2014). Regional research utilizing palynology has generated many new themes and ideas related to the environmental history of the Norse Greenlanders, which is summarized in the following section (Ledger et al., 2014, 2015, 2017; Massa et al., 2012; Schofield & Edwards, 2011).

1.2.3 Norse Greenland palynological research history

Early scholars working in Southern Greenland established the broad picture of Norse *landnám* and the settlement's history using palynology (Iversen, 1934). Johs. Iversen pioneered the study of pollen grains to examine archaeological questions and was the first to investigate Norse landscapes using this method (Edwards, 2021; Edwards et al., 2017). Paradigmatically, research of this period was focused on understanding the origins of cultural landscapes (Iversen, 1941), which is reflected in ideas about Norse Greenland environments. Iversen postulated the somewhat accepted model of ground fires used during *landnám* to clear vegetation and shape ecological successional processes within a landscape. His work also conceptualized and observed the stages that would follow *landnám*, such as a reduction in tree and shrub pollen, followed by or simultaneous to an increase in grass/weed pollen and microscopic charcoal.

Later, Bent Fredskild utilized a broader term interest in the palaeoevegetational history of Greenland. His thesis (1973) looked at a series of profiles from the Eastern Settlement covering the whole Holocene. Due to the enormous breath of time, research of this type tends to feature a poor chronological resolution of the Norse era. Despite this, Fredskild generally demonstrated similar patterns to Iversen, including grass increases and declining heath and shrubs. Fredskild's work also seemed to reinforce the idea of *landnám*-era burning (Fredskild & Humle, 1991) and occasionally characterized Greenland as a marginal landscape for the Norse way of life, primarily due to shorter growing seasons than that of Norway (Fredskild, 1988). During this era, ideas of environmental degradation leading to the abandonment or collapse of Norse Greenland gained popularity (see Diamond 2005 for more on this), although now it is more often accepted that the Norse moved on from Greenland for more nuanced reasons (Jackson et al., 2018).

The next significant advancement in our understanding of Norse Greenland cultural landscapes began in the 21st century, with a series of research projects undertaken by several palynologists working collaboratively in multidisciplinary projects. Significant insights have come from the consistent implementation of high-resolution palynology. Additionally, this work has been conducted with an explicit focus on exploiting the variability of Relative Source Area for Pollen (RSAPs: the area from which a depositional basin like a mire or lake receives input from pollen sources) from different depositional contexts alongside the analysis of multiple proxies found with pollen grains (Blockley et al., 2015; Edwards et al., 2008; Gauthier et al., 2010; Golding et al., 2011; Golding et al., 2015; Guillemot et al., 2015; Ledger et al., 2013, 2014, 2015, 2017; Massa et al., 2012; Schofield & Edwards, 2011; Schofield et al., 2008; Schofield et al., 2022). It has been demonstrated that samples used for palynological analysis show varying results if collected away from activity areas vs. nearby known activity areas due to the interactive nature humans have with their environment (Bell, 2005; Faegri, 1989; Jacobson & Bradshaw, 1981; Moore, 1978). The ecofacts necessary for interpretation (e.g., pollen and non-pollen indicators like microscopic charcoal and fungal spores) will reflect aspects of the archive. For example, the ecological succession of a lake drying out to peatland will likely feature increased sphagnum pollen through that period (Gearey & Chapman, 2023; Moore et al., 1991), or the grazing areas of herbivores may feature fungal spores indicative of their presence (van Geel et al., 2003). Palynological investigation done with this in mind can amplify the signal for human activity in different areas and allow for a more nuanced understanding of landscape use across a larger settlement area (Ledger et al., 2014, 2015). For example, specific settlement types, like shielings, have been investigated palynologically to understand their environmental context within the broader understanding of Norse Greenland landscapes (Ledger et al., 2013). Additionally, issues posed by previous generations of researchers, like the prevalence of large-scale ground clearing/burning, can be investigated site-by-site (Ledger et al., 2015).

With understanding specific sites rather than regional pollen signals in mind, some have typically targeted peat bogs in Greenland (Edwards, Schofield, et al., 2011; Ledger, 2013; Schofield & Edwards, 2011). Peat bogs often make a good source for investigating activity areas like an Infield, primarily due to their predictable growth rates and ability to amplify signals close to the deposit (Caseldine, 1981; Schofield et al., 2008). Additionally, the human occupation component of the peat sequence can be compared to earlier and later components. It can be seen as an internal control for change at a particular site (Moore et al., 1991). A potential drawback of targeting peat bogs near activity areas is that human activities, such as turf/sod cutting, may truncate archives (Ledger et al., 2014). In a scenario where peat has been modified or truncated, the relationships of plant communities through time will be obscured. However, analyzing such archives can still be useful and may lead to a greater understanding of human subsistence, settlement organization, and niche construction (Ledger et al., 2017).

Ledger et al. (2015) have demonstrated that targeting palaeoenvironmental archives near activity areas also reveals valuable information when used on plaggen soils or small ponds in Greenland. Edwards, Erlendsson and Schofield (2011) have also brought the analysis of coprophilous fungal spores to questions about land use and have highlighted a focus on chronology and targeting macrofossils for radiocarbon dating and age-depth Bayesian modeling. In general, research projects conducted in this way have moved beyond ideas of human impact on the environment, which tended to be the focus of earlier scholars, and began looking at Norse seasonality, land structure, and the small shifts in land use through time (Edwards, Schofield, et al., 2011; Edwards et al., 2008; Golding et al., 2011; Ledger et al., 2013, 2014, 2015, 2017; Schofield & Edwards, 2011; Schofield et al., 2008).

Broadly, a second modern methodology has been implemented by Gauthier et al. (2010), Massa et al. (2012), and Guillemot et al. (2015). They apply many of the archaeological questions discussed above but have also utilized the frameworks of Fredskild (1973) and others, including a focus on longer-term Holocene dynamics through a broader landscape lens. This team of French researchers deployed an explicitly multi-proxy approach focused on lakes, typically those with a large RSAP, in direct contrast to the work mentioned above (Gauthier et al., 2010; Guillemot et al., 2015). For example, results from diverse proxies such as stanols, diatoms, etc. (Gauthier et al., 2010; Guillemot et al., 2015; Massa et al., 2012) have been a focus of investigation. These inclusions allowed researchers to contribute to the study of the erosional history of southern Greenland. This topic has been popular at different times in regional discourse, especially regarding agricultural production (Massa et al., 2012).

1.3 Norse cultural landscapes

Some have considered Greenland, before the arrival of Norse settlers, to have been "pristine," which refers to the previous absence of humans practicing agriculture and a presumed lack of environmental impact by pre-Inuit peoples (e.g., Dugmore et al., 2005). It should be noted that this conceptualization is being challenged by research that illustrates how indigenous communities manage landscapes through active choices (i.e., ground fires and gardening, among other techniques) or may have unique palaeoenvironmental signatures due specific technologies (Lemus-Lauzon et al., 2016; Panagiotakopulu et al., 2020; Roy et al., 2012; Roy et al., 2015). Semantics aside, southern Greenland had previously never seen the level of intentional change brought on by the relatively light-touch agricultural systems of the Norse period (Edwards, Erlendsson, & Schofield, 2011; Schofield et al., 2013).

When the Norse settled in a new area, like most groups, they usually impacted the local environment through intentional or unconscious landscape modifications (Blockley et al., 2015; Schofield et al., 2013; Schofield et al., 2007). Some aspects of this, like a reduction in woodlands and an increase in grass, are ubiquitous through time and space to the first farmers of Northern Europe (Iversen, 1941). Human-induced deforestation began in Greenland, with Norse settlers shaping that environment to make it suitable for pastoral agriculture (Golding et al., 2015). Palynological analysis allows us to reconstruct vegetation change and thus see how Norse activity leaves traces, particularly in the *landnám* or settlement phase where palaeoenvironmental change is the starkest (Edwards et al., 2008; Schofield et al., 2008). The identification of Norse settlement is achieved through a suite of observations rather than single indicator species (Edwards, Erlendsson, & Schofield, 2011). Decreases in *Betula pubescens* (a copse-forming tree birch) and *Salix* (willow) pollen, for example, can be understood as resulting from Norse settlers clearing scrub and copse/woodland either manually, through grazing, or with controlled ground fires. The objective here is to increase rough pasture for domestic animals. Palynologically, this would be visible as increases in the grass and apophyte (plants that respond to human disturbance, commonly classified as weeds) pollen types that replaced the decreasing scrub (Iversen, 1934; Fredksild, 1973; Edwards et al., 2008). For example, *Rumex acetosella* (sheep's sorrel) is an apophyte associated with *landnám* in the Norse North Atlantic and was likely introduced to southern Greenland by Norse settlers, although it was probably indigenous to the location that became the Western Settlement (Edwards, Erlendsson, & Schofield, 2011; Fredskild, 1973).

Initially, at *landnám*, woodlands may have needed to be extensively cleared quickly to make more room for hayfields and expand pastures via burning, observable as a charcoal layer like that reported above Sandnes by Fredskild and Humle (1991) and other locations around the Western Settlement (Iversen, 1934). This was likely not a universal rule and what was likely more common was the use of hardy grazers such as sheep and goats to clear vegetation over some time (Edwards et al., 2011). The caprine and cattle manure would also have added nutrients to the soil and made space for plants the settlers wanted to target for hay cultivation (Buckland et al., 1994; Ross & Zutter, 2007). Palynology has shown that the Norse sometimes managed scrub woodland in their landscape as it was a valuable source of fuel for heating, cooking, and industry (Ledger et al., 2014; Schofield & Edwards, 2011).

In addition to pollen, a suite of associated proxies such as microscopic charcoal and fungal spores are crucial in reconstructing Norse activity. For example, burn layers represented by a layer of macroscopic charcoal in soil profiles are exceedingly rare (Fredskild & Humle, 1991), but microscopic charcoal is often present throughout a sedimentary sequence and can be related to activities such as local cookfires and forges (Schofield et al., 2013). Coprophilous fungal spores such as *Sporormiella*-type (HdV-113), which grows on the dung of grazing herbivores, are an excellent proxy for the presence of domestic animals and Norse activity (Schofield & Edwards, 2011). These indicators are assumed to be present most frequently in tune with Norse-associated herbivores (e.g., sheep, cows, and goats) because they grow on the substrate of herbivore species dung (Lee et al., 2022; van Geel et al., 2003). They can be assumed to be related to domesticates because they co-occur with other changes that are consistent with an agricultural landscape (Edwards et al., 2011; Schofield & Edwards, 2011). In some cases, *Sporormiella*-type spores could also be related to Norse-associated grazers manure being used to help fertilize the soils of farms (Buckland et al., 2009; Golding et al., 2015; Ledger et al., 2015).

In conclusion, identifying activity, particularly *landnám* activity, in Norse Greenland involves interpreting several lines of sometimes conflicting evidence and may require the explicit use of multiple working hypotheses (Ledger et al., 2017). The palynologists aims to construct coherent narratives of *landnám* and subsequent change through the interpretations of diachronic changes in palaeoenvironmental data. This is accomplished in this project by utilizing past palaeoenvironmental research and the interpretation of that research to identify previously observed patterns that constitute the palaeoenvironmental footprint of the Greenland Norse.

1.4 Research themes

This thesis is thematically focused on developing our understanding of Norse subsistence strategies in Greenland through palynology. It builds on a growing body of literature and is guided by the research questions and traditions previously implemented in the region, outlined in section 1.2.2. This research investigates the understudied Western Settlement and archives (sheep and goat dung) comparatively unexplored in the recent research history of the area. It is primarily concerned with understanding the cultural landscapes of Norse Greenland and the lifestyles and techniques implemented by the settlers to create and maintain this landscape. Specifically, I focus on utilizing multiple archives to develop nuanced ideas of the Norse cultural landscape across space and time. This guiding concept is structured by implementing three specific themes outlined in the sections below.

1.4.1 Seasonality and husbandry

A potential strength of palynology is the ability to investigate aspects of seasonality and mobility by targeting specific seasonal places (Bjune, 2000; Ledger et al., 2013). This idea is primarily explored through this research via caprine seasonality and husbandry in the transhumant agriculture of Greenland. The Infield-Outfield system is a subsistence strategy that relies on mobility across the landscape to seasonally beneficial areas. Summer was the optimal time for much of the resource procurement in Greenland, regardless of whether the focus of a settlement was hunting, growing hay for fodder, or a mix of both (Ljunqvist, 2005). At the farm, hay was grown during the summer to be cut and dried as a fodder source. Shielings were also occupied during the summer and tended to fill one of several roles: dairying, haymaking, full shielings, and marine resource procurement (Albrethsen & Keller, 1986; Madsen, 2019). Norse farmers would at least partially stall their domestics at the shielings for much of this time, and through replacing twig flooring, their feces would be collected by their handlers and deposited in middens (Buckland et al., 1994; Sveinbjarnardóttir, 1991). Conversely, the farm would be the likely home for domestics during the early spring, winter, and late fall, and feces recovered from middens at these sites likely reflect the husbandry strategies of the leaner, fodder-heavy months (Aðalsteinsson, 1991; Amorosi et al., 1998; McGovern, 1985). With this understanding in mind, the pollen content of coprolites has the potential to inform on seasonally specific husbandry strategies of mobile groups.

1.4.2 The palaeoenvironmental footprint of Norse activity areas

Although the palaeoenvironmental footprint of Norse activity areas has been investigated, an understanding of variation in the cultural landscapes maintained by Norse farmers can be further explored. This theme focuses on examining individual Norse sites through Quaternary palaeoecology and emphasizing the differences in subsistence strategies used across time and space. Many palynological archives are targeted for their presence in well-stratified soils, which can often allow for precise dating methods (age-depth models) that allow calendar dates to be assigned to observed environmental changes. This creates an avenue for comparing multiple sites to emphasize settlement variation through time. For example, the palaeoenvironmental footprint of high-status farms identified from historical sources can be compared to smaller, presumably lower-status farms and begin to inform on the impact these different levels of settlement had on the surrounding area (Buckland et al., 2009; Schofield & Edwards, 2011). The palaeoenvironmental data from Sandnes produced during this thesis will be compared to other archives to better understand Sandnes' unique environment as a Western Settlement high-status farm. Considering regional pollen data and data from the uplands of the site better illuminates the wider impacts of Sandnes and can potentially inform on the cultural landscape strategies utilized at the farm.

Although this theme primarily focuses on Sandnes and its development as a farm from *landnám* to abandonment, discussion of ecological footprints also allows an avenue for exploring known changes in the cultural landscape and how this relates to managing domestic herbivores. For example, birch populations around Norse settlements generally declined after *landnám*, likely resulting from intentional acts to increase pastures (Edwards et al., 2011). Complicating matters, birch in Greenland also experienced a further period of decline during and after the little age (Fredskild, 1973; Ledger, 2013). Identifying which plants were targeted by the Norse as a fodder source for caprines during ecological succession can help illuminate another angle of the Norse subsistence strategy during a potential period of stress, as birch was likely the premier leaf fodder source for caprines (Hejcman et al., 2016).

1.4.3 Chronology of farming cultural landscapes

The creation and maintenance of cultural landscapes by the medieval Norse in Greenland allowed for the successful implementation of transhumant pastoral agriculture in an arctic environment (McGovern, 1985). To understand this process through palynological methods, it is useful, although not mandatory, to establish a pre-*landnám* ecological 'baseline' to which subsequent changes linked to human action can be compared (Dugmore et al., 2005; Edwards et al., 2008). Following the palaeoenvironmental trail past *landnám* and later through time can inform on how adaptations were made to maintain cultural landscapes (Birks & Birks, 2004). Farming cultural landscapes were eventually replaced following the abandonment of the Norse settlements around the 14^{th}-15^{th} century. The chronology of Norse landscapes is valuable as a theme because the correlation between palaeoenvironments, human activity, and the potential collapse of a farming economy during the settlements' final stages are often cruxes of the research related to the Norse period in Greenland. Additionally, through the lens of chronology, potential avenues of adaptation and an often-presumed marginality of life in Greenland can be explored, as it is often thought that life in the settlements would have gotten increasingly bleak in later years (Diamond, 2005).

There are some common features to the creation and management of cultural landscapes in Greenland, like the reduction of tree pollen and increase of microscopic charcoal and Poaceae pollen, likely resulting from hayfields associated with *landnám* (Edwards et al., 2011; Edwards et al., 2008; Schofield et al., 2008). Not all sites contain these features, and there is variation; for example, the date of *landnám* and whether it involved a preemptive ground clearing burn varies from site to site, and around some sites, it appears like scrub resources were instead managed (Schofield & Edwards, 2011). Sandnes is currently understood to be an important site in the Western Settlement and the greater Greenland colony. The remains of domestic animals at Sandnes suggest farming and transhumant were a large part of the economy and became a larger part of the economy through time. The curation and cultivation of the cultural landscapes that supported those domestics are comparatively poorly understood, as is the chronology of farming cultural landscapes of the Western Settlement in general.

1.5 Research objectives

To investigate the themes listed above, two independent research projects were carried out with their own research objectives. Chapter two is a palynological examination of a series of caprine coprolites from middens in the Eastern and Western Settlement. Chapter three is an analysis of a stratified sedimentary sequence from the high-status Norse farm at Sandnes.

Chapter two addresses the following questions:

1. How does the pollen content of caprine coprolites recovered from middens in Norse Greenland differ through space and time?
2. Do they reveal valuable information regarding Norse husbandry strategies and cultural landscapes?

Chapter three addresses the following questions:

1. How do plant communities at Sandnes respond to Norse settlement, and what strategies are implemented by the Norse settlers to manage these cultural landscapes?
2. What does age-depth modeling of the Sandnes peat archive alongside pollen and non-pollen data reveal about the temporality of the settlement? When was *landnám* and abandonment?

1.6 Outline

This thesis is structured as a manuscript-style thesis with four chapters. The first chapter overviewed the cultural area and relevant palaeoenvironmental research in Greenland or affiliated with Norse cultures throughout the North Atlantic. Chapter two will examine caprine coprolites from three sites using palynology to determine foddering strategies through time and place. This is a somewhat novel approach to investigating Norse Greenland husbandry, and results indicate that Norse settlers utilized the various environments of Greenland to supply fodder. Chapter three comprises a palaeoenvironmental examination of a stratified sedimentary sequence from the high-status Western Settlement farm of Sandnes to evaluate the farm's changing cultural landscapes. The final chapter presents conclusions and perspectives on avenues for future study. Chapters two and three are structured as papers, and I intend to begin the publication process on both chapters as independent papers following the approval of this thesis with my advisor, Paul Ledger, as a co-author.

Chapter 2: Caprine husbandry practices across time and space in Norse Greenland

Abstract

The pollen content of domestic animal coprolites can be utilized to reconstruct past husbandry and foddering practices. This paper compares caprine coprolites from three sites associated with the medieval Norse settlements of Greenland. The coprolites cover a range of geographies and site types, including a centralized farm (V53d), and a possible shieling (V35), both from the Western Settlement as well as a moderate-sized farm (Ø171) from the Vatnahverfi region of the Eastern Settlement. In addition to this inter-site comparison, this study presents data of intra-site variability with multiple contexts (temporally distinct) data from Ø171 and V35, allowing a diachronic comparison of husbandry practices. Previous work on five caprine dung pellets from the Western Settlement farm of GUS identified macrofossil remains of downy birch, sedges and grasses. Pollen analysis of the same dung revealed high levels of *Betula nana*, *Salix* sp., Poaceae, and *Artemisia*, although this study counted only 516 pollen grains over five samples (well below the threshold of 500 total land pollen per sample that are required for a statistically robust analysis). This study finds similar but more nuanced patterns. *Betula pubescens* was used heavily as a fodder source at the Eastern Settlement site, while sedges and weeds seem more common in the Western Settlement ones. Comparisons from across Western Settlement sites show that there may also be some seasonally specific strategies, which may be reflections of locally available resources. Coprolites from the farm (V53d) featured lower shrub and weed counts and greater sedge content than the shieling (V35). The evidence also suggests there may be site-specific husbandry strategies and changes to these strategies over time. In general, pollen resulting from twig and leaf foddering seems to increase through time, perhaps indicating that Norse farmers continued to adapt their husbandry strategies to local environmental and broader socio-economic change late into the settlement.

2.1 Introduction

Greenland Norse subsistence was based on transhumant pastoral agriculture supplemented by resources from the hunting of marine and terrestrial mammals (Berglund, 1986; Jackson et al., 2018; McGovern, 1985). As part of the transhumant lifestyle, the Norse managed the landscape in terms of the Infield-Outfield system, variations of which were standard across the North Atlantic and Norway (Albrethsen & Keller, 1986). Evidence of Greenland Norse subsistence is preserved in different palaeoenvironmental archives that can be utilized to understand better land management practices (Edwards, Erlendsson, & Schofield, 2011; Edwards, Schofield, et al., 2011; Gauthier et al., 2010; Ledger et al., 2015). This chapter examines Norse substance strategies by examining a rarely utilized palaeoenvironmental archive in a Greenland context, caprine coprolites. The pollen content of 15 coprolites recovered from the midden assemblages of two Norse farms and one supposed Norse shieling have been analyzed to reveal some of the husbandry strategies related to sheep and goats.

Goats, sheep, and cattle were the primary domesticates on Norse farms, with the relative proportions of this suite of animals varying through time and place (Dugmore et al., 2012; McGovern, 1985). Caprines and cattle tend to be the most visible domestics in the faunal record, and therefore, it is assumed that they were relied on heavily for subsistence (Nygaard, 2018). The secondary milk and wool products were possibly even more important than the meat these animals would provide (Arneborg, 2008). Although it has not been examined extensively, there may have been a slight preference for sheep over goats in the earliest phases of settlement, which may have reversed in the later phases (Mainland & Haistead, 2005). Some authors have linked the end-period decrease in sheep to climatic pressure, sheep being the least hardy of the two species (McGovern et al., 2014). The preference for woody taxa as feed for goats is relevant to this study, as they can metabolize the material slightly more efficiently (Hejcman et al., 2016; McGovern et al., 2014).

Fodder and husbandry

The importance of fodder cannot be overstated in the North Atlantic, and fodder production often had political implications; for example, in Iceland, excess fodder was managed by chieftains to be handed out during lean times (Amorosi et al., 1998). Fodder is a broad category and includes cultivated hay, wild grasses, leaf, and twig from woody taxa, seaweed, sedge, and apophytes collected in various ways (Buckland & Panagiotakopulu, 2001). The Infield was critical to the production of fodder. It contained the house, other structures, and the hayfield (or *tun*). Hay production would likely begin in the early summer when animals would be moved to the pastures of the Outfield (Ledger et al, 2013; 2014). In Iceland, at the end of the summer, grasses from the Infield would be cut, turned and dried into hay in the field, with additional fodder from diverse plants being collected from the Outfield (Aðalsteinsson, 1991). Apophytes, such as *Ranunculus acris* (meadow buttercup), *Rumex acetosa* (sorrel), and some species of Caryophyllaceae (pinks) were likely intentionally harvested during the hay collection, but it is also possible that biodiverse hayfields resulted in the unintentional collection of weeds alongside hay (Amorosi et al., 1998; Ross & Zutter, 2007). Sedge may have been collected from wetlands, a practice recorded in Iceland (Amorosi et al., 1998). Leaf and twig foddering from woody taxa may have been selected in the summer and stored for future use (Hejcman et al., 2016; Ross & Zutter, 2007). Grasses generally have a higher nutritional value for caprines than leaf foddering, Although *Betula* spp. seemed to have sufficient nutritional value to support dairying and is the most nutritious of the leaf and twig foddering options of Greenland (Hejcman et al., 2016). To date, the implications of fodder regimes in Greenland have mostly been explored through site and landscape level palynology and can be seen as a reduction in shrub and health that was presumably being used as a fodder resource (Fredskild, 1988; Ledger et al., 2015; Schofield & Edwards, 2011).

In the seasonal round of Norse transhumant pastoral agriculture, domestic animals were constantly on the move to ensure that grazing did not adversely impact fodder production. Caprine husbandry was based on moving sheep and goats around the landscape throughout the year as part of the Infield-Outfield system. During spring, caprines would likely be released from the byres to graze around the farmstead on spring grass opportunistically and were probably fed a heath-heavy diet for additional support (Ross & Zutter, 2007). During this time, they would defecate in the fields, thereby contributing to the fertilization of the Infield. Dogs may also have been used to corral caprines, isolating their impact and ensuring they manured specific areas of the Infield. At some rare high-status church farms of the Eastern Settlement, it appears that a slightly different strategy was taken, and caprines and cattle would be set to graze with dykes that could keep the animals in beneficial areas (Krogh, 1967).

Beyond the Infield, much of the summer would have been spent in the Outfield at *sæters* or shielings (structures ancillary to the farm of the Infield, typically upland) (Albrethsen & Keller, 1986; Øye, 2005). Many animals would be taken to shielings where they may have been milked, traditionally by the women of the farm, who may have also stayed at the shielings during summer activities (Albrethsen & Keller, 1986; Nedkvitne, 2018). Caprines would feed on the available vegetation in these usually upland pastures so as not to exhaust the supply of hay at the main farms (Sveinbjarnardóttir, 1991). Many of these shielings would have barns or pens, and it is probable that animals were at least partially penned during summer milking (Roussell, 1941). During their time at shielings in the summer, domesticates would graze freely on Outfield pastures.

Palynological evidence from Ruin group Ø70, a shieling in Vatnahverfi, shows evidence of increased hay production in the latter half of the settlement, indicating that at some shielings, hay may also have been produced (Ledger et al., 2013). In the fall, the animals would return to the central farm, where they would stay through the winter (Øye, 2005) after the hay (and other vegetation) was cut (Albrethsen & Keller, 1986; Hejcman et al., 2016). The stubble was likely grazed and fertilized again briefly in the fall before adult caprines were housed in the byre over winter (Albrethsen & Keller, 1986; Amorosi et al., 1998; McGovern, 1985). During winter, cows were likely stalled for six months or more, with caprines probably partially stalled, and juveniles sometimes foraging for some leaf and twig winter grazing (Mainland, 2006). It can be assumed that caprines diet would be heavily supplemented by fodder during this coldest period, using the hay grown in the previous summer until supplies began running low again in the spring.

Caprine coprolites and seasonality

Sheep and goats would defecate in their byres, and then the byres and pens would be cleaned out with the refuse dumped onto a midden area some way away from the dwelling structures, adding to existing or creating new middens (Buckland, 2008; Buckland et al., 2009; Buckland et al., 1994). While cow manure was likely utilized as infield fertilizer, caprine pellets were less likely to be used in this way owing to their woodier composition (Ross & Zutter, 2007).

As part of the transhumant system, sites were occupied at predictable seasonal intervals throughout Norse Greenland (Albrethsen & Keller, 1986). Coprolites recovered from sites known to house caprines in the summer will presumably reflect summer husbandry strategies, and on the other hand winter sites should contain coprolites that demonstrate winter foddering (Amorosi et al., 1998; Sveinbjarnardóttir, 1991). Pollen content of coprolites have revealed spatial relationships between preferred feed at locations and seasonality among wild herbivores (Bjune, 2000), and applying those principles here could lead to a better understanding of Greenland Norse seasonality. Coprolites recovered from Infield (or the main farm) midden contexts are more likely to be proxies for late fall to early spring foddering and husbandry regimes, when animals were being overwintered at the farm (Albrethsen & Keller, 1986; Buckland, 2008; Ross & Zutter, 2007). Caprine pellets collected from shielings or *sæters* middens likely represent the summer fare and husbandry practices because this is the period they were likely to be at the satellite sites (Sveinbjarnardóttir, 1991).

Caprine coprolites from archaeological contexts have the potential to provide data about sheep and goat husbandry practices, especially around foddering (Moe, 1983; Ross & Zutter, 2007). To date, only a single study, from the Farm Beneath the Sand (GUS) in the Western Settlement, has examined the pollen content of caprine coprolites from a Norse context in Greenland. Pollen from heathland plants, shrubs, apophytes and grasses featured prominently in this study of five coprolites (Ross and Zutter, 2007). Unfortunately, this work suffers from pollen counts that do not reach thresholds of significance (cf. Moore et al 1991) and focused on a comparison of the differences between medieval Greenland and Iceland. Thus, the spatial and temporal differences within Greenland remain unexplored.

This paper examines fifteen caprine coprolites collected from three locations across Greenland: two from the Western Settlement (V53d and V35) and one from the Eastern Settlement (Tasilikulloq [O171]). In addition to this examination of inter-site variability, the samples from Tasilikulloq are derived from temporally distinct contexts within a stratified kitchen midden. Specifically, this paper asks: (i) how does the pollen content of coprolites recovered from the Eastern Settlement and Western Settlement differ both between and within these settlement locations? (ii) is there evidence of temporal differences in foddering strategies at Tasilikulloq? (iii) can coprolite data can help us understand seasonality as it relates to fodder procurement and the stalling of domestic animals in Norse Greenland?

2.2 Background

2.2.1 The studied farms

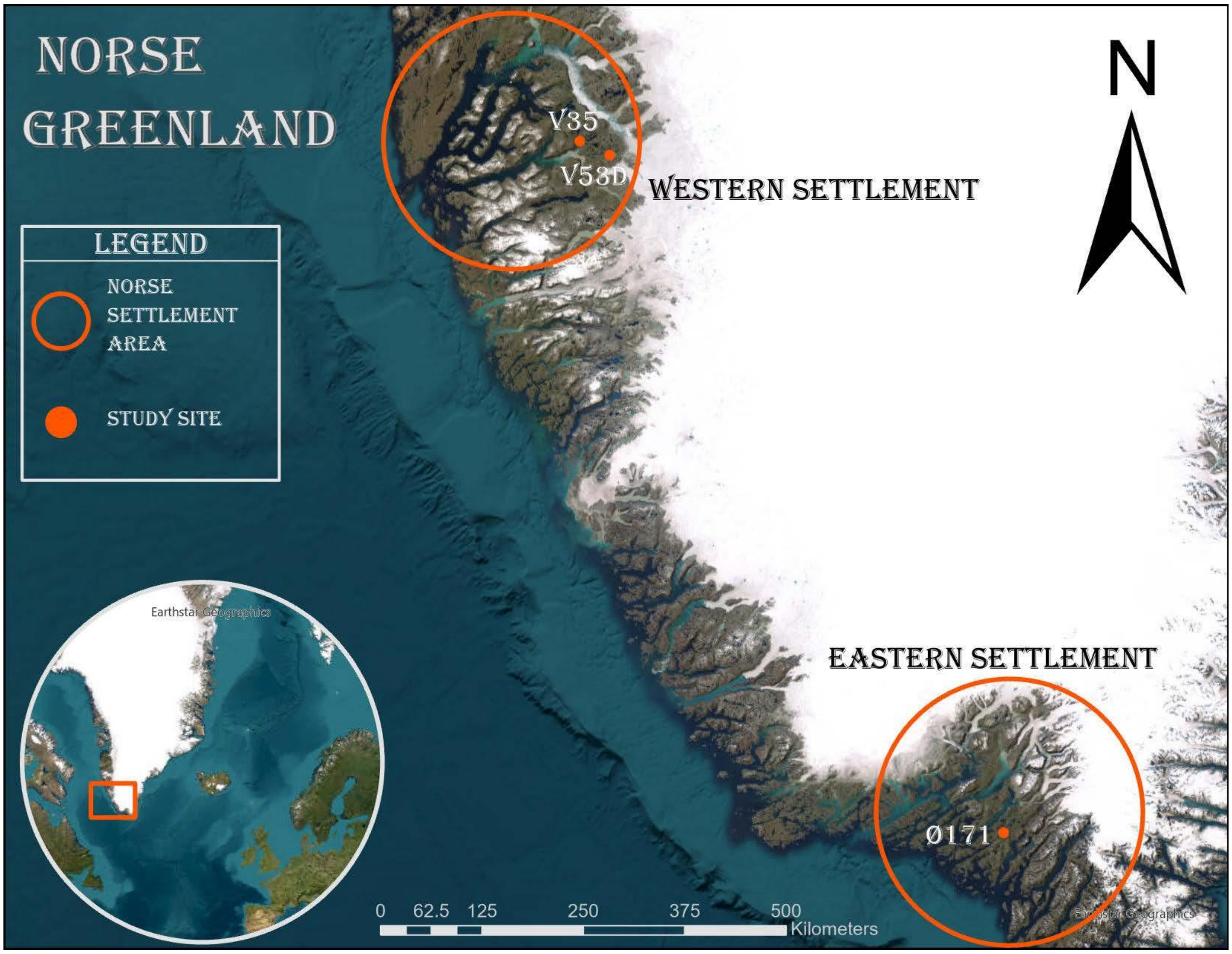

Figure 2.1: Satellite map of Norse Greenland. The sites studied in this chapter have been demarcated with dots, and the settlement areas have been marked with empty circles. In the bottom left inset map is the Norse Greenland settlement area in the North Atlantic.

Ø171

Tasilikulooq (Bruun no: Ø171) is a medium-sized Norse ruin group situated within Vatnahverfi, an inland region of the Eastern Settlement first identified and documented by Vebæk (1992) (Figure 2.1). The ruins comprise at least 11 structures, including a dwelling house, farm, pen (for sheep or horses), and a stable/barn. To the east and west of the ruins, the landscape rises relatively sharply to rocky outcrops characterized by *Salix glauca-Betula glandulosa* scrub.

Several contexts from the midden at Ø171 were dated by McGovern (unpublished) using bone, teeth, and birch twig material that were bagged and collected during excavation. The radiocarbon data suggests that the deposit may be somewhat mixed. Two samples from a basal layer of the midden (Context 11) were radiocarbon dated and returned calibrated age ranges in the early 11th century to mid-13th century: SUERC-45392(921 ± 45; cal. AD 1030-1215 [95.4%] and SUERC-45396(868 ± 45; cal. AD 1045-1265 [95.4%]. A further two radiocarbon assays from the more recent Context 2 are in conflict. SUERC-45397; 736 ± 45 provides a calibrated age range of AD 1215-1385 [95.4%], while SUERC-45398; 908 ± 45 provides a calibrated age range of cal. AD 1035-1220 [95.4] that is statistically indistinguishable from the data in Context 11.

Coprolites were recovered from midden context 2 and midden context 3. Ledger et al. (2017) examined a taphonomically complex, sedimentary archive within the Infield of the farm and determined that it may provide a snapshot of the closing centuries of the farm. The analyzed pollen profile from the farm featured high Poaceae counts (25%-60% TLP), relatively high sedge (20%-40% TLP), low heaths, trees, and shrubs (mostly <20% TLP), led by *Salix*, with several common herbaceous taxa including *Ranunculus* acris-type, Rosaceae (more common in the first half of the archive), *Thalictrum alpinum* (more common in the second half of the archive), *Potentilla*-type, Brassicaceae, and *Rumex* ssp. Disturbances in the archive, likely stemming from peat-cutting or other anthropogenic actions, made interpretations of the profile challenging (Ledger et al., 2017).

V53d

The Norse ruin group V53d is located in a spur in the Austmanadal valley, approximately 10 km east of the mouth of the river in the former Western Settlement. The site is classified as a centralized farm owing to the dwelling and other structures, including byres, a barn, storerooms, and a proposed bathhouse, being connected into one superstructure. The midden contained dung but was low in artifact density compared to other sites in the region. Although an attempt was made to record each context by photographing and illustrating it, the Knudsen et al. (2014) team reported that several upper layers were mixed during excavation. It was assumed by Knudsen et al. (2014) that Norse farmers would have relied heavily on the local willow scrub for animal fodder because of the apparent lack of well-drained patches of grass. Downslope of the dwelling lies the midden, creating a flat grass-covered bench.

A palynological study of the site by Schofield et al. (2022) presented two pollen diagrams deemed to represent the Infield and Outfield at V53d. They likely encompass pre-*landman* to the post-Norse period. The Infield featured high *Betula* (up to 60% pre-*landnám*), Poaceae (roughly 50%-80% TLP during the Norse period), low sedge (<20% TLP), with *Rumex acetosella*, *Artemisia*-type, and Lactuceae mostly making up the other herbaceous plants of the Norse period. Shrubs and heaths declined heavily at the Infield through the Norse period. The Outfield mainly consists of *Betula* ssp., *Salix,* and Ericaceae, with clear charcoal peaks associated with the Norse period (Schofield et al., 2022). The Infield and Outfield presented starkly different results, which is likely a testament to the smaller-scale nature of pastoral agriculture in the Western Settlement farms compared to Eastern Settlement counterparts. Age-depth modeling from the Outfield estimates that human activity began at the site in the interval of AD 870-1000 and ended in the interval of AD 1300-1470.

V35

The collection of ruins known as V35 is positioned at the far western edge of the expansive Lake Tummerallip Tasersua, located approximately 5 km north-northeast of Sandnes. The encompassing terrain lacks substantial areas of favorable pasture, as heath or willow scrub prevails across the vegetation, particularly in wetter and sheltered zones (Knudsen et al., 2014; Roussell, 1941). A small river/stream flows past the site towards Sandnes and Kapisillit. Five identifiable ruin structures include a dwelling house, probable byre, two sheds, a barn, a storehouse, and possibly a third sheep shed and accompanying midden. The site's midden was first excavated in 1981 by McGovern et al. (1981), who noted well-preserved bones, twig layers, and sheep/goat pellets. The site was revisited in 2012 when the ecofacts used for this paper were collected. At this time, the archaeological team determined that the site was likely not a small farmstead but instead, more likely, a satellite farm or shieling for Sandnes due to the "tiny" homefield and modest ruins (Knudsen et al., 2014).

The trench dug in 2012 accidentally overlapped McGovern et al.'s 1981 trench in the center, so half of the excavation was significantly disturbed context (Knudsen et al., 2014). Context four remained undisturbed and contained one caprine pellet (X06[04]). Context five contained several coprolites collected for pollen analysis as well as a charcoal layer, that in a few other locations have been associated with *landnám* in Norse Greenland (Iversen, 1934; Fredskild and Humle, 1991).

2.3 Methodology

2.3.1 Pollen & numerical analysis

Pollen samples were prepared using discipline standard NaOH, sieving, acetolysis, and flotation procedures from subsamples of coprolites (Moore et al., 1991; Nakagawa et al., 1998). *Lycopodium* tablets were added to enable the calculation of pollen and charcoal influx and concentration measurements (Stockmarr, 1971). Samples were suspended in silicone oil and mounted on slides following concentration procedures. Counting was undertaken using a Nikon E400 light microscope at ×400 magnification until a statistically significant sum of 500 total land pollen (TLP) was reached. Moore et al. (1991) reference photos were used to identify pollen and spores, while Bennett et al. (1994) was used for nomenclature. To differentiate between *B. pubescens* and *B. glandulosa*, grain size diameter measurements were taken with *B. glandulosa* defined as *Betula* <20 μm (Fredskild, 1973; Schofield & Edwards, 2011). Coprophilous spores, fungal spores that thrive on animal dung, were counted utilizing research by van Geel et al. (2003). Pollen preservation data was recorded and unidentifiable pollen appears in the diagram as "indeterminable." TILIA software was employed to construct pollen diagrams (Grimm, 1993).

2.3.2 Indeterminable/damaged pollen

Pollen is best preserved in waterlogged low pH environments (peat bogs, lakes, etc.) (Bunting & Tipping, 2000). One potential issue that arises with using suboptimal environmental archives is that pollen degrades at different rates due to the variation in thickness and resilience of their sporopollenin, or outer walls, meaning there is potential for a post-depositional or preservation bias within samples (Moore, 1978; Moore et al., 1991). Bunting and Tipping (2000) recommend that the indeterminable percentage be under 30% of TLP for reliable counting. Samples featuring above 30% indeterminable percentage are counted for this work, albeit considered with caution.

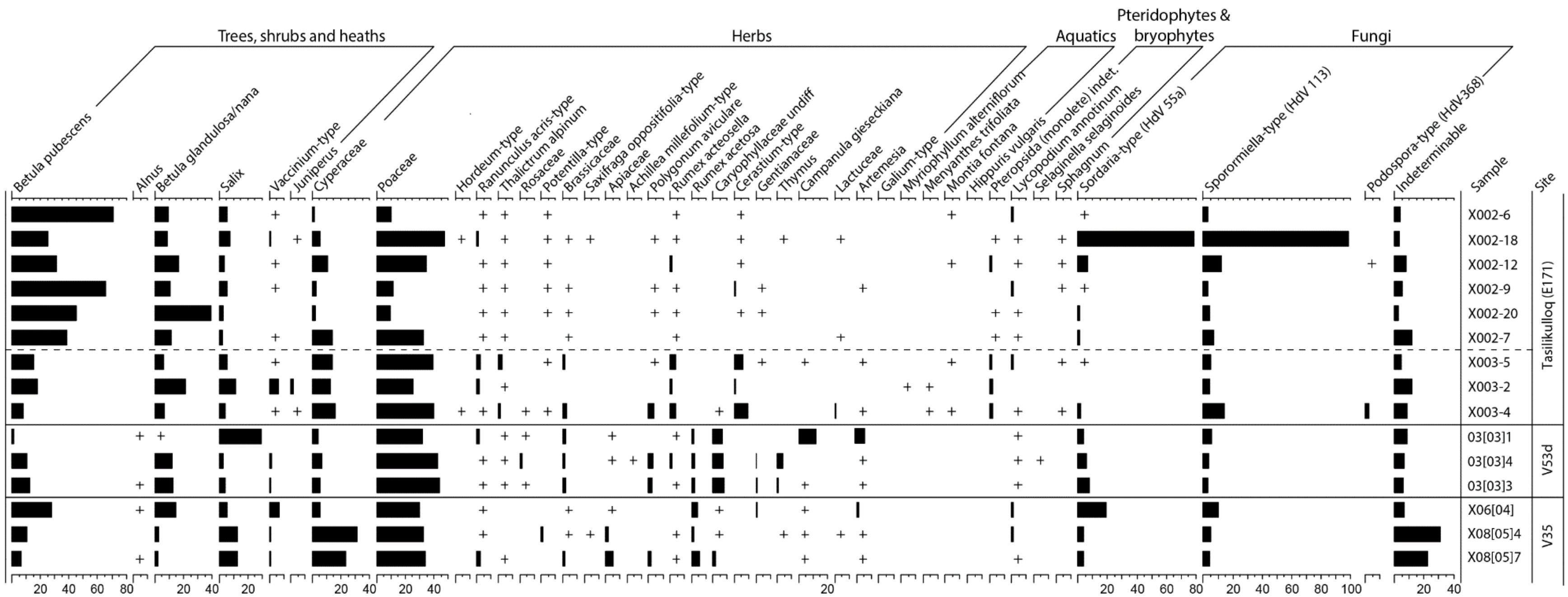

Figure 2.2: Percentage pollen and non-pollen palynomorph content of each of the caprine coprolites analyzed in this study (minimum sum = 500 TLP), + indicates <1% TLP. The second bracketed column on the right includes sample names, including the context they were recovered from if there was more than one context at a site. The dotted line breaks up the two contexts from Ø171. Context 2 is above the dotted line; Context 3 is below.

2.4 Results

2.4.1 Pollen results

Ø171

In total nine individual caprine coprolites were examined from Tasilikulooq. Three coprolites were recovered from Context 3, and six were recovered from Context 2 (Figure 3.1). Relative dating suggests that Context 3 coprolite pollen likely represents an earlier settlement phase, sometime after *landnám* (radiocarbon dating conducted on material from Context 11, a basal layer, returned calibrated dates from the 11th-13th centuries).

The samples recovered from midden Context 3 mostly contained *Betula ssp*. (15-39% TLP), *Salix* (4-12% TLP), Poaceae (25-40% TLP), and Cyperaceae (13-16% TLP). Other common taxa are *Vaccinium*-type (6% TLP in sample X003-5), *Rumex acetosella* (up to 4% TLP), and *Cerastium*-type (1-9% TLP). In fact, these three samples contain the highest percentages of *Cerastium*-type, *Rumex acetosella*, and *Thalictrum alpinum* (3% TLP) across all sites. This context features some of the lowest representations of woody taxa (trees, shrubs, and heaths) of the examined samples, a stark contrast to Context 2 of the same site. The samples from Context 3 feature more pollen from tree taxa (*Betula pubescens*), and their content is more varied when compared to those from Context 2. For instance, Cyperaceae was well represented in these pellet phases alongside the apophytes *Rumex acetosella*, *Polygonum aviculare*, Brassicaceae, and *Ranunculus acris*-type.

Context 2 from the Tasilikulooq midden comprises this study's most extensive set of samples from a single midden layer. In total, six samples were analyzed from the context and are accompanied by two radiocarbon dates returning calibrated ages of cal. AD 1215-1385 (SUERC-

45397; 736 ± 45) and cal. AD 1035-1220 (SUERC-45398; 908 ± 45). Regardless of the results of the absolute dating, Context 2 is stratigraphically below Context 3 and thus an older deposit that permits and examination of diachronic change at the Tasilikulooq. Unique to the coprolites from Context 2 are the relatively high percentages of pollen from woodland and scrub (*Betula pubescens*) and high counts of scrub and heath (*Betula glandulosa*), more than 40% and up to 80% in most of the coprolites. Three samples from Context 2 feature low Poaceae pollen counts (roughly 15% TLP), indicating these caprines were not receiving a grass-heavy fodder diet (Moe, 1983).

The samples from this context appear to show two general patterns in the pollen content. Three of the coprolites (X002-6, X002-9, and X002-20) are dominated by woodland and scrub pollen (80% TLP), with the second most common type being Poaceae at c. 10% TLP. Cyperaceae is consistently low (1%-3% TLP), as are other herbs. The second general grouping is still dominated by pollen from woodland/scrub (40%-50% TLP) but features more Poaceae (30-50% TLP) and more sedge (5%-15% TLP). Several context samples feature high spore counts, with X002-018 particularly prominent. Apophytes (weed and ruderal species that often thrive in disturbed soil and tend to proliferate around human activity) are more common among the Context 3 samples. They may be related to foddering and the collection of weeds alongside grasses from the Infield (Ross & Zutter, 2007).

V53d

It is entirely unclear what phase of Norse settlement is represented from the three V53d midden samples. Coprolites were recovered from a single context and are again characterized by high herbaceous taxa, with Poaceae representing the most significant portion. The three samples from

V53d contain some variation but have a general trend. All three samples contain approximately 70% TLP from herbaceous taxa and 30% TLP from trees, shrubs, and heaths. One sample contains a high amount of *Salix* sp*.,* while the other two include *Betula* ssp. Unique at V53d is a low Cyperaceae count (roughly 5% TLP) across the three samples. Several apophytes are relatively highly represented, including *Rumex acetosa* (2% TLP) and *Polygonum aviculare* (3% TLP). Also present are *Thymus* (4% TLP), *Caryophyllaceae* undifferentiated (8% TLP), *Artemisa* (6% TLP), and *Campanula gieseckiana* (11% TLP), which usually grow in heathland or herbslope communities (Böcher et al., 1968). V53d samples have a lower representation of scrub and heaths, although still present (approx. 20-30%TLP) and very few trees (*Betula pubescens* 1-13% TLP). Recent palynological research in the area demonstrated that the Infield associated with V53d had little pollen from Cyperaceae, trees, shrubs, and heaths with high pollen from Poaceae, and the potential Outfield had Cyperaceae and some woodland taxa but low pollen counts of Poaceae pollen (Schofield et al., 2022). The pollen makeup of the coprolites from this site reflects the plant community of the Infield rather than the Outfield, indicating that their fodder and some grazing were likely done around the farm.

V35

Context 5 at V35 most likely informs on the *landnám* period. There are no radiocarbon dates from this midden, but a burnt layer similar to the one found around the uplands of Sandnes (Fredskild & Humle, 1991) and the lack of cultural material discovered from midden Context 5 suggests this layer represents a localized *landnám*. At V35, pollen is generally characterized by a high representation of herbaceous taxa, notably Poaceae and Cyperaceae, although apophytes are still present across all the samples. Apophytes do not have one dominant taxon and counts of *Rumex* ssp., Brassicaceae, *Polygonum aviculare*, and *Ranunculus acris*-type vary by sample. V35 is unique due to its high representation of Cyperaceae pollen and has one of two samples analyzed for this research with a significant amount of *Vaccinium*-type heath (7% TLP).

Two samples were analyzed from midden Context 5, X08[05]4 and X08[05]7, and the pollen content is similar between the two samples. They feature some of the lowest pollen counts from woody taxa amongst all samples (23% and 27% TLP), with *Salix* being the most counted of the species. Pollen from Poaceae accounts for approximately 30% TLP amongst all the V35 samples. The two Context 5 samples feature high Cyperaceae (up to 32% TLP) and around 20-25% TLP from *Betula pubescens* and *Salix*. Notably, samples from Context 5 feature a large amount of indeterminable pollen counts (up to 30%). It is unclear exactly how the assemblage has been affected. However, it is important to note that this process may have selectively preserved more durable, thick-exine pollen types like *Caryophyllaceae* and *Brassicaceae* (Bunting & Tipping, 2000; Ledger, 2013). There is no clear evidence that any taxa are overly biased due to potential selective deterioration (in some contexts, different pollen types deteriorate at different rates, overly biasing the presence of the pollen types that deteriorate less easily).

A single sample was recovered from Context 4 at V35. Relative dating suggests this coprolite is more recent than Context 5 and has the potential to reveal husbandry and fodder strategies through time at the site. The context 4 sample differs significantly from the two V35 context 5 samples. Cyperaceae is not observed (5% TLP) at the frequency observed in the older samples. Also, *Betula* ssp. and *Vaccinium*-type pollen are much higher than in Context 5 (trees, shrubs, and heaths 56% TLP). It is worth noting that differences between contexts should not overly inform any interpretations on this site due to the small sample sizes.

2.5 Discussion

2.5.1 Exploring seasonal differences in caprine foddering strategies

It can be assumed that sheep and goats eating similar diets from the same landscape at the same point in the season will produce coprolites with similar pollen content, representing a mix of diet and pollen rain from the most prolific taxa in that season (Moe, 1983). Coprolites from the same species but originating from different seasons would contain different pollen assemblages (Bjune, 2000). The reverse logic should be that if a site can be determined to have been occupied in specific seasons, then the coprolites collected from that site will reflect the season in which the site was occupied. First, it must be determined when coprolites were deposited into byres and, by extension, the middens from which they were eventually excavated. Some general trends to note are that a higher relative pollen content, also known as pollen concentration, likely indicates summer due to increased pollen rain (Bjune, 2000), and coprolites with a dominant taxon usually indicate that taxa are a primary component of the domestics' fodder (Moe, 1983).

The caprines of the Greenland Norse were fed on either cut and dried fodder when stalled or would graze on the plant life available in their environment when partially stalled (meaning they were allowed out of the byre during the day to graze were put away in the evening). Even when partially stalled, the caprines likely returned to barns and stables overnight, where they would defecate on the ground. One potential contamination opportunity across samples is from the twig and grass floor coverings common across Greenland barns (Buckland et al., 1994). However, in general, pollen from caprine coprolites represents their food and diet at specific times of the year rather than the environmental signature of the place where they were stalled (Moe, 1983). This can be further mitigated by selecting material from the center of the pellet. The twig and grass floor covering is replaced every few seasons, and the old material (including the caprine coprolites identified in this study) is relocated to a midden somewhere in the Infield (Buckland et al., 1994). Therefore, the midden recovered caprine coprolites should reflect the fodder and husbandry strategies implemented at specific sites and, therefore, the seasons those sites would house caprines (Aðalsteinsson, 1991).

The midden at Ø171 (a farm) likely represents foddering strategies from the fall, winter, or spring, as it seems that caprines spent those seasons on the farm before going to shielings in the summer (Albrethsen & Keller, 1986; Sveinbjarnardóttir, 1991). The middens at V53d likely represent fall, winter, and spring foddering strategies for caprines for the same reasons, albeit from a longer winter season at the Western Settlement. V35 appears to be a shieling in the Sandnes area, so caprines pellets here should be from a different season representing a different phase in the subsistence strategy from the other two sites, perhaps late spring to early fall over the summer when caprines would be taken into the highlands to graze opportunistically (Albrethsen & Keller, 1986; Ljunqvist, 2005).

Different site types (shieling vs. farm) have been selected to compare seasonal strategies (Albrethsen & Keller, 1986). When comparing V35 to V53d, there is a clear difference in husbandry/foddering strategies. One of the samples from V35 contains a comparatively high amount of *Vaccinium*-type pollen and is slightly dominated by shrubs and heaths, which is a unique feature of that site amongst Western Settlement samples examined during this research. Coprolites from Western Settlement winter sites (GUS and V53d) featured a lower Cyperaceae content and higher apophyte content than coprolites recovered from summer sites (V35), with consistent grass and shrubs/heaths across both sites.

This may be because even haymaking shielings would likely not be managed as intensively as the tun, and while caprines were away from the main farm, they would be less likely to encounter the apophytes growing around the field (Øye, 2005). Instead, they may have replaced that component of their diet with wetland Cyperaceae that could be dried and used as a fodder source, a practice observed in Iceland (Amorosi, 1998). Pollen concentration was slightly higher at the Western Settlement shieling than at the centralized farm, following expectations of increased pollen concentration in pellets that are deposited during the summer (Moe, 1983). In fact, the seasonal increase in pollen concentration can also be observed in wild ungulates (Bjune, 2000), further lending to the interpretation of Knudsen et al. (2014) that the site functioned as a shieling, although originally classified as a small farm by Roussell (1936). To further explore the seasonal diet of caprines, more coprolites from shielings would need to be examined, but an initial interpretation fits our understanding from Iceland, where the fodder of the Outfield is much more opportunistic than the winter fair (Amorosi, 1998).

2.5.2 Eastern Settlement vs. Western Settlement

Nine caprine coprolite samples from a single Eastern Settlement site (Ø171) have been examined for microbotanical remains. Eleven samples from the Western Settlement, including those examined by Ross and Zutter (2007), have been examined from three sites (V53d, V35, and GUS). It is worth noting that the counted TLP sum in the GUS samples was very low (approximately 100 TLP per sample) (Ross and Zutter, 2007).

Poaceae pollen counts in coprolites are reasonably consistent between the two settlements. A few of the Tasilikulooq samples have much higher pollen concentrations (up to 630,349 grains/cm^3), indicating fodder may have been collected in the flowering period of many plants (Moe, 1983). The Western Settlement coprolites generally feature a much higher apophyte and other herbaceous plants as well as Cyperaceae content than Eastern Settlement sites, and it can be assumed that this reflects fodder strategies (i.e., diet) to some extent (Ross & Zutter, 2007). V35, V53d and GUS could be expected to reflect a slightly adapted subsistence model because the Western Settlement is known to have a shorter growing season, which introduces various environmental constraints (Barlow et al., 1997). *Rumex acetosella* is more common in coprolites from the Eastern Settlement, while *Rumex acetosa* is more common in coprolites from the Western Settlement, which unsurprisingly reflects known distributions of the two species (Böcher et al., 1968). The apophyte Rosaceae and herbslope taxa *Artemisa* appear in coprolites from the Western Settlement but not in coprolites from the Eastern Settlement, indicating that those species may have been growing alongside the collected hay at those respective settlements and may have been intentionally targeted (Moe, 1983).

A third of the coprolites from the Eastern Settlement feature very high *Betula* ssp. counts (70-85% TLP), which is not a trend seen from any of the Western Settlement sites. Two samples from GUS (Ross & Zutter, 2007) did contain roughly 60% TLP *Betula* ssp. However, none of the Western Settlement samples examined for this research had more than 40% TLP *Betula* ssp., and most had less than 30% TLP. Although it is possible that the high *Betula* ssp. content of the Eastern Settlement samples could be from pollen rain; it is unlikely because these plants are generally underrepresented in coprolites unless they were consumed during a period when the wind-pollinated plants are actively flowering (Moe, 1983). What is more likely is that *Betula* ssp. makes up a larger part of the diet of the Eastern Settlement caprines than of those in the Western Settlement, primarily through leaf and twig foddering conducted in winter and spring.

This trend is reversed when considering the other primary twig and leaf fodder source, *Salix* sp., which is more common amongst Western Settlement coprolites. Alternatively, this *Betula* ssp. vs. *Salix* sp. relationship may be indicative of the time period each coprolite was deposited. *Betula* ssp. may have started decreasing on the landscape as early as AD 1200 due to climate change (Dugmore et al., 2007). The sample from a presumed *landnám*-era deposit from the Western Settlement features the opposite trend where at V35, *Betula* ssp. is less common than *Salix* during the phase likely associated with *landnám.* Unfortunately, there is no radiocarbon data from the apparent burn layer, so its association with *landnám* cannot be confirmed. Due to the comparative lack of large *Betula pubescens* and other tree growth in the area (Böcher et al., 1968), Western Settlement farmers may have depended more on early spring weeds and sedges than in the Eastern Settlement and Iceland (Ross & Zutter, 2007). Sites from the Western Settlement feature a primarily herb-slope/grassland pollen make-up, with a comparatively lower contribution from woody taxa supplemented by some apophytes and sedges. Eastern Settlement Ø171 coprolites feature a similar profile, although there is a greater representation of pollen from the "ideal" foddering taxa such as Poaceae and *Betula pubescens*. The Western Settlement has long been considered the more marginal area of Norse Greenland (see Fredskild, 1988), and the caprine coprolites discussed here seem to indicate that hay fodder there might not have been quite as plentiful as at Eastern Settlement. Instead, Western Settlement farmers relied more on scrub-forming *Salix*, *Vaccinium*, and other select herbs, like *Cerastium*.

2.5.3 Diachronic and spatial husbandry strategies

At the Eastern Settlement site, Ø171, the older material (Context 3) tends to be much higher in the Poaceae and Cyperaceae content than the above context (Context 2), which is inversely proportional to the presence of trees and shrubs and, surprisingly, lack of apophytes (Ross & Zutter, 2007). Palaeoenvironmental data from Tasilikulooq featured decreasing contributions of pollen from scrub and woodland over time, with *Salix* being the most common taxon (Ledger et al., 2017). Conversely, in the coprolites studied here *Betula* ssp. dominate over *Salix*. A possible interpretation of the discrepancy is that the palaeoenvironmental data predates the environmental shift from predominately *Betula* ssp. to *Salix* sp. that could have begun as early as AD 1200 (Dugmore et al., 2007). The coprolites examined here then likely predate this shift, which the calibrated radiocarbon data SUERC-45398 (cal. AD 1035-1220; 908 ± 45 [±1σ]) supports. Alternatively, *Betula* ssp. could have been targeted over *Salix* sp. by Norse Greenlanders as a good fodder candidate that likely would have supported goat dairying (Hejcman et al., 2016).

It is worth noting that recent palynological investigations in the region report a general decline in heaths (Ledger et al., 2014). The greater reliance on heaths through time at this site could be seen as a reduction in the quality of agricultural production, forcing Greenlanders to rely on a potentially suboptimal resource for fodder. More likely, Ø171 samples from Context 2 represent different phases in the subsistence cycle or two unique husbandry strategies in the same season. As a farm, Ø171 was the stalling location for caprines in late fall, winter, and early spring. Presumably, cut hay was the preferred winter source of fodder, but one reason for the high *Betula* ssp. is that fodder could conceivably run low in the early spring when fresh-cut leaf and twig fodder would have to take over. A second possible explanation for some samples featuring much higher pollen from *Betula* ssp. was that they belonged to a subsect of the flock that ate a predominately leaf and twig diet while the rest continued eating primarily hay fodder. There is some evidence that juvenile caprines were only partially stalled in the winter and able to forage for leaf and twig sources from around the farm (Mainland, 2006). After eating a primarily foraged diet, predominantly *Betula* ssp., these animals would then be penned in byres. The coprolites examined in from Ø171 Context 2 that had higher *Betula* ssp. could have resulted from either scenario.

The pollen profiles of V53d and V35 are generally quite similar, although some slightly different patterns are apparent. V53d and V35 appear quite similar to the GUS samples examined by Ross and Zutter (2007) and provide an insight into husbandry strategies at small to medium farmsteads in the Western Settlement. Pollen assemblages in coprolites from V53d are higher in apophyte and herbslope taxa, while those from V35 are higher in Cyperaceae. 60% of the pollen from GUS caprine coprolites examined by Ross and Zutter (2007) were classified "Outfield/heathland,". Several coprolites from that study have above 60% TLP belonging to *Betula* sp., with *Sailx* sp. also being common (20% TLP in some samples). Of the six samples analyzed from the Western Settlement in this chapter, only one had a frequency of *Betula* ssp. over 30% TLP, while the others were between 8-26% TLP. The most common pollen assemblage in the coprolites from the Western Settlement sites are counts of approximately 30% TLP woody taxa (mostly *Betula* ssp. and *Salix* sp.) and 30-40% TLP Poaceae. In most coprolites from the Western Settlement, the final major component is either Cyperaceae (20-30% TLP) (V35 Context 5 coprolites) or Norse-associated apophytes and other herbslope taxa (15-30% TLP) (V53d coprolites). A third general pollen assemblage was noted in X06[04] (the only sample from Context 4 at V35). It may represent a different temporal range than other samples from V35, which is the most likely explanation for its unique composition. Sample X06[04] compares more favorably to several *Betula* sp. and *Salix* sp. dominated coprolites from GUS than to the other Western Settlement samples examined here. Perhaps unsurprisingly, the core suite of plants present in caprine coprolites is comparable across all three sites, but their distribution is variable between each context. In general, pollen content is much more similar within a single context (except for the high *Betula* from some Ø171 Context 2 samples), which indicates that each set of samples features a local husbandry strategy and demonstrates adaptability built into Norse transhumant agriculture.

2.6 Conclusion

The general pattern from all the pollen assemblages examined here primarily features evidence of leaf and twig foddering (20-80% TLP from woody taxa), where Poaceae, likely resulting from cut hay, also forms a significant portion of pollen assemblages (10-44% TLP). Although much more variable, likely because it may have been a suboptimal resource, Cyperaceae is also common (2-30 %TLP). As Cyperaceae (sedges) represents plants from various plant communities in Greenland, it should not be assumed that the same husbandry practices resulted in their presence in coprolites across all three sites. In some samples, pollen from Gentianaceae, *Campanula gieseckiana*, Caryophyllaceae undifferentiated, Apiaceae, *Rumex acetosa*, *Cerastium*-type, and *Artemisia* are also common (5-12% TLP) and may have been intentionally harvested for foddering, been selected for on the landscape by caprines when partially stalled or been incidentally collected alongside hay from diverse hayfields.

Beyond this, the pollen content of coprolites examined in this study differ in subtle ways that suggest spatially variable husbandry practices in the Norse Greenlandic settlements. At Ø171 of the Eastern Settlement, several coprolites (X002-6, X002-12, and 002-20) featured a pollen assemblage dominated by *Betula* ssp. and *Salix* (80-85% TLP), and this was a pattern not observed in the samples from Western Settlement sites. These samples likely represent either the partial stalling of juvenile caprines or the early spring fodder diet of caprines, indicating in either scenario that the preferred fodder choice, hay, had likely run low over the course of the winter. At V53d several herbslope plants were common alongside Poaceae and may represent the intentional selection of plants to bolster hay yields. V35 was likely a shieling and represents the opportunity to compare a summer site with a winter site from the Western Settlement. The most obvious difference is the high Cyperaceae in two samples from V35 (X08[05]7 and X08[05]4). A potential explanation for this phenomenon is that V35 likely did not have a prominent hayfield, so when caprines were being partially stalled over the summer at the site, they relied on Cyperaceae, likely in the form of wetland plants from the local mire that may have been harvested and dried.

The variation in signals across these sites, temporal ranges, and even individual samples is a testament to the flexibility of the Norse husbandry strategy in Greenland. While cattle were seen as the highest status livestock in this system, it is evident that plenty of care and attention was paid to maintaining caprine herds even when the assumed ideal food source (hay) was in predicable seasonal low points. This study captured some of the ways this system varied across Greenland. Still, there is potential to expand this line of inquiry to include more sites, preferably well-dated, to increase our understanding of Norse adaptability across the length of the Norse Greenland period. For example, some of the data reported here suggests that leaf and twig foddering was more important as a husbandry strategy in later periods. This study was the first attempt to synthesize multiple sites' coprolite pollen profiles to understand Norse husbandry and foddering strategies, and it revealed a perhaps unsurprisingly diverse suite of techniques that have long been discussed as ways caprines were managed in Greenland.

Chapter 3: Sandnes through time: palaeoenvironmental evidence from the ‘chieftain’s’ farm in the Western Settlement indicates a later, less intensive *landnám*

Abstract

The Norse *landnám* saw the creation of a cultural landscape in Greenland. This landscape was characterized by the clearance of scrub woodland to promote the expansion and development of natural grasslands to form hayfields and pastures, as well as the inadvertent introduction of a series of 'weeds' and the spread of a series of local plants responding to cultural activities (apophytes). This paper presents high-resolution pollen and associated proxy data (including non-pollen palynomorphs, microscopic charcoal, and loss-on-ignition) from Sandnes, a high-status (or chieftains) farm in the Western Settlement. The vegetation history of the hinterland of Sandnes, as recorded in a peat bog 1.5 km distant from the site, has previously illustrated possible evidence for ground fires, presumably to stimulate the growth of pasture somewhere between cal. AD 1030 to 1265, but limited impacts thereafter. This paper explores the site through a palaeoenvironmental archive located approximately 150 meters north of the end-period dwelling. The palaeoenvironmental change recorded in this mire with a small relevant source area for pollen (RSAP) should reflect localized palaeoenvironmental changes resulting from Norse activity. The results indicate a probable Norse *landnám* (initial settlement) by the beginning of local pollen assemblage zone (LPAZ) SAND-2a (cal. AD 1055-1175). Evidence of a cultivated landscape is not notable until LPAZ SAND-3, which begins somewhere in the interval cal. AD 1150-1245. During LPAZ SAND-4 (cal. AD 1280-1320), there was evidence of a short-lived soil amendment practice. Abandonment seemed to occur within a couple of decades, around AD 1300-1320. A possible interpretation is that within a couple of decades of the traditionally accepted date for *landnám* (AD 985), Sandnes began as a hunting community and stop-over point for long-distance voyages before, gradually, developing into a hay farm that was abandoned in the early 14th century.

3.1 Introduction

Norse settlers arrived in Greenland in the late 10th century (Krogh, 1967), establishing two settlements of interconnected farms (Nörlund, 1930; Nörlund & Stenberger, 1934). Known as the Eastern and Western Settlements, these communities are commonly thought to have been established simultaneously, with the Eastern Settlement likely abandoned around AD 1450 and the Western Settlement perhaps as much as a century earlier (Arneborg, 2008). Reasons for a probable earlier abandonment of the Western Settlement are contested, with explanations ranging from economic instability, environmental/climatic change, and competition with the southward migrating Inuit (Barlow et al., 1997; Buckland et al., 1996; Star et al., 2018).

Palynological research across Norse sites in Greenland has shown that there is often a clear and consistent palaeoenvironmental signal for Norse settlement (*landnám*) and their establishment of a cultural landscape focused on pastoral agriculture (Edwards, Erlendsson, & Schofield, 2011; Ledger et al., 2014). Norse landscapes in Greenland generally featured varying levels of woodland and scrub clearance accompanied by a rise in microscopic charcoal followed by increases in Poaceae, apophytes (plants that respond to human disturbance, commonly classified as weeds), and the introduction of some other ruderal plants (Schofield et al., 2013). Much of the earliest palaeoenvironmental research on Norse Greenland focused on the Western Settlement and was instrumental in characterizing these patterns (Fredskild, 1973; Iversen, 1934, 1954). Of particular note in more recent research has been the demonstration of the value of coprophilous fungi *Sporormiella*-type as a grazing indicator and proxy for domestic animals (Schofield & Edwards, 2011), the use of palaeoenvironmental data to generate detailed site chronologies (e.g., Ledger et al., 2013), and examination of resource use and activity areas (Schofield & Edwards, 2011; Ledger et al., 2014, 2015). More recent palynological research investigating Norse Greenland has concerned the larger Eastern Settlement to the south. Modern plant communities differ slightly between the two areas (Böcher et al., 1968), and it is fair to assume that there would have been differences during the Norse era as well. Some differences have been documented using palynology (Fredskild, 1973), but as the resolution of such studies is low, the cultural landscapes of the Western Settlement are comparatively poorly understood.

Previous palynological research has demonstrated that regional evidence of a palaeoenvironmental signature for farming was muted in the landscapes of the former Western Settlement (Fredskild, 1973; Iversen, 1954). While temperatures are comparable, the growing season of the Eastern Settlement was approximately seven months and only five in the fjords of the more northerly Western Settlement (Fredskild, 1988). Pasture productivity models implied that the Western Settlement may have been less productive in terms of the volume of hay produced, and shielings were limited to lower elevations (Christensen, 1991a, 1991b). Therefore, farming landscapes were likely more challenging to establish and maintain due to the shorter growing season.

Farmers in the Western Settlement likely adapted to shorter growing seasons by dedicating more space to storage, even on smaller farms, indicating that ample winter fodder storage was potentially more important in the Western Settlement than in the Eastern one (McGovern, 1992). Pasture productivity models suggest that Western Settlement farms would have faced increased vulnerability to temperature changes compared to their southern counterparts (Barlow et al., 1997). A gradual decrease in temperature and more intense year-to-year fluctuations seem to have been more common after AD 1250 (Barlow et al., 1997). The role changing environmental conditions played in land management, and the development of subsistence strategies in the Western Settlement farms, has been subject to speculation (Arneborg et al., 2012a). The Western Settlement may have been less productive from the perspective of pastoral agriculture, but it was well located to access valuable remote resource regions such as the *Norðsetur* (Ljunqvist, 2005). The resulting trade of high-value, low-bulk goods such as walrus and narwhal tusks, furs of exotic arctic animals, and, potentially, the occasional capture of live gyrfalcons and polar bears have all been highlighted as potential push factors in the establishment of a settlement in this part of the island (Arneborg, 2008; Frei et al., 2015). The Western Settlement was also an important location on the route to Markland and L'Anse aux Meadows, which were likely visited more often in the early years of the settlements (Nedkvitne, 2018).

To explore how the geography of the Western Settlement influenced the development of the farming landscapes, this paper presents data from Sandnes, a leading farm in the area (Figure 2.1). This study seeks to use pollen analysis, associated proxies, and radiocarbon dating to reconstruct palaeoenvironmental change at Sandnes to: (i) establish the timing and nature of *landnám*, (ii) determine the character of landscape use at Sandnes throughout the Norse period and how it compares with Eastern Settlement sites; (iii) use this data alongside age-depth modeling to examine the chronology of occupation at Sandnes. As a high-status church farm, Sandnes has often been assumed to be one of the first established and longest-lived farms of the Western Settlement. Therefore, establishing a chronology of the local cultural landscapes of Sandnes should lead to a better understanding of the development of the Western Settlement as a whole.

Figure 3.1: View to the south across the former Norse hayfield at Sandnes towards the archaeological remains. Note the dust storm on the horizon from katabatic winds blowing from the Greenland ice sheet and down the Austmannadalen valley. Sandnes is sheltered from these effects.

3.2 Background

3.2.1 Geography

The area of the former Western Settlement is in the Nuup Kangerluab and Ameralik-Ameralla fjord systems, where Nuuk, the modern capital of Greenland, is located. The fjord is characterized by a summer temperature gradient from a cooler, wetter maritime climate at the coast, to a warmer, drier, and more continental climate in the inner fjords (Iversen, 1954). Modern vegetation is dominated by willow scrub (*Salix glauca*) and *Betula nana* in the lowlands, while *Vaccinium uliginosum* and *Empetrum nigrum* are more common in the mountainous zones (Böcher et al., 1968; Iversen, 1954). Topographically, the area of the Western Settlement is more mountainous than the Eastern Settlement, with fewer low-laying plains favoured by Norse farmers (Christensen, 1991a). Sandnes, situated on an expansive, low-lying south-facing plain with an extensive relict hayfield and hinterland, is an exception to this pattern and an example of a productive low-lying plain. Dense willow scrub up to two meters high covers the archaeological remains at the site. Several authors have commented on Sandnes's unique and beneficial position within the Western Settlement and its immediate landscape (Christensen, 1991b; McGovern et al., 1996; Roussell, 1936). Notably, Spring vegetation (owing to the southerly aspect of the site) has been observed to arrive up to three weeks earlier than other Norse sites around the Tumeralik area (McGovern et al., 1996).

3.2.2 Study Site

Sandnes was a large high-status ‘chieftains’ church farm with at least two phases of Norse construction, including an end-period house built upon the foundation of an earlier dwelling (Roussell, 1936). During the end period before abandonment, there were two large byres, a probable smithy or storage building, a large dwelling, a churchyard wall, a cemetery, and one of two known stone-constructed churches in the region (Anavik V7 is the other) (Brunn, 1917; Roussell, 1941). The main-dwelling structure is well known as being the type-site for Roussell’s longhouse, a construction style he thought was indicative of late Greenland Norse construction (Roussell, 1941). A more recent interpretation highlights the similarities between Sandnes’ longhouse and those typical of construction in Norway, potentially indicating a continued cultural connectedness with the farmers' ancestral home until the final phase of the settlement (Høegsberg, 2009).

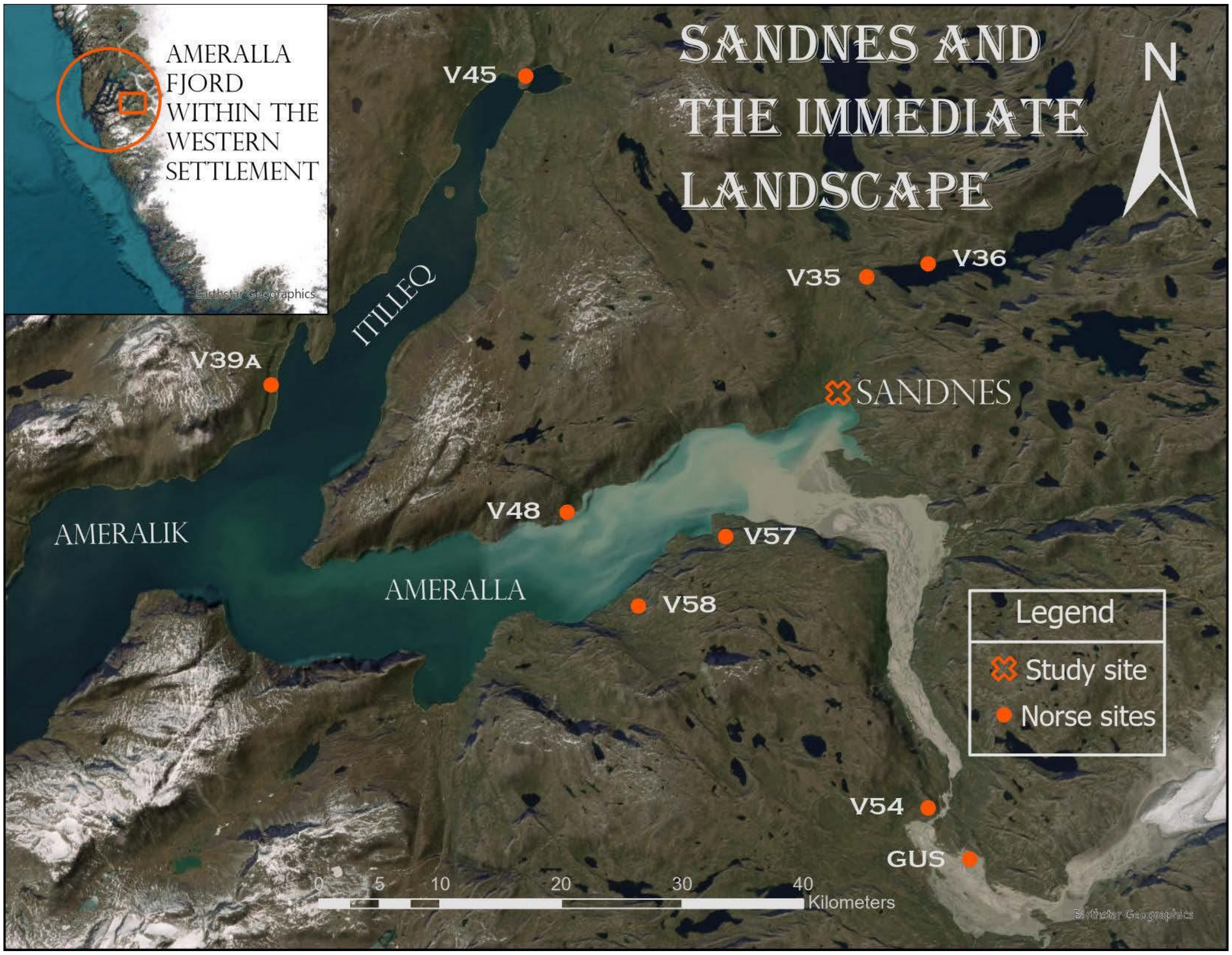

Figure 3.2: Satellite map of Sandnes within the Ameralla Fjord branch. The upper left inset map is the location of the Ameralla Fjord branch within the Western Settlement. Several Norse ruins near Sandnes are also shown.

The geographical aspect of Sandnes is south-facing, sheltered from winds off the Greenlandic ice sheet, and contains an extensive hay field (Figure 3.1, Figure 3.2), suggesting this was a choice settlement location. Indeed, this geographical aspect, along with the size and scale of the archaeological remains at the site and its mention in historical manuscripts, make it likely that Sandnes was one of the earliest *landnám*-era farms of the Western Settlement (McGovern et al., 1996; Seaver, 1996). Previous palaeoenvironmental and archaeological work at Sandnes confirmed the importance of this site by investigating the abundance of animal products indicative of high-status (walrus, caribou, and cows) and one of the two stone-built churches of the Western Settlement (Roussell, 1936). Additionally, a chronological framework for activity at the site and its hinterlands indicated settlement in the late 11th century and abandonment by the mid-14th century (Fredskild & Humle, 1991; McGovern et al., 1996).

3.2.3 Archaeology

The earliest known report of archaeological remains/ruins that are thought to reference Sandnes date to the early 18th century (Knudsen et al., 2014). Little detail is provided about the condition of the site, and there was no systematic survey. Throughout the 19th century, further authors (recorded in the reports and diaries of Dutch administrators and travelers) apparently visited and mentioned the site several times (Knudsen et al., 2014).

Archaeological Investigations: 1903-1932

The first archaeological fieldwork conducted at the site was undertaken by Daniel Bruun in 1903. He recorded the location of 6 or 7 ruins and deeply stratified middens (Brunn 1917). The National Museum of Denmark later spearheaded a large-scale excavation project at Sandnes headed by Niels Nørlund and assisted by Aage Roussel in 1930 and 1932. The team meticulously emptied rooms and trenched along the outside walls to determine the extent of the ruins, and they also excavated parts of a midden.

Recovery Project: 1984

The first environmental archaeology undertaken at Sandnes dates from the 1980s and stemmed from a collaboration between Hunter College and the National Museum and Archives of Greenland. The main thrust of this work was the excavation and analysis of faunal remains from the large well-stratified midden at the site and the examination of several ruins. Radiocarbon assays on a variety of marine and terrestrial faunal remains returned calibrated dates at 95.4% probability that ranged from the early 11th century through to the late 14th century (Figure 3.3). None of the materials tested produced what could be interpreted as a 'classic' *landnám* that encompassed the historically accepted date of AD 985. The oldest calibrated age range came from a cattle bone (K-4600; 930±65; cal. AD 995 to 1225), with other pieces of cattle bone returning similar ranges (K4597; 900±65; cal. AD 1025 to 1260 and K4599; 910±65; cal. AD 1020 to 1260). These data were interpreted to indicate *landnám* at around cal. AD 1025 followed by an economic shift in site activity in the interval cal. AD 1150-1200. Pigs, cattle, and seals became less important while walruses, goats, and caribou increased in representation at this boundary. This was followed by some site reconfiguration c. cal. AD 1200-1250, where several buildings were moved before final abandonment by AD 1325. Fredskild and Humle (1991) also investigated a pollen sequence from an upland mire roughly 1.5 km north of the ruins. This study, at a relatively low-temporal resolution of analysis, identified very little evidence of environmental change. The most notable finding was that a 0.3 cm band of charcoal seemingly confirming Iversen's (1934) observation of a charcoal layer at Anavik (V7) being indicative of widespread ground fires at *landnám* (Fredskild and Hulme 1991). A radiocarbon assay on fragments of charcoal from this burn layer (K-4569; 890±70; cal. AD 1030 to 1265) also postdates the traditionally accepted date for Norse *landnám* in Greenland.

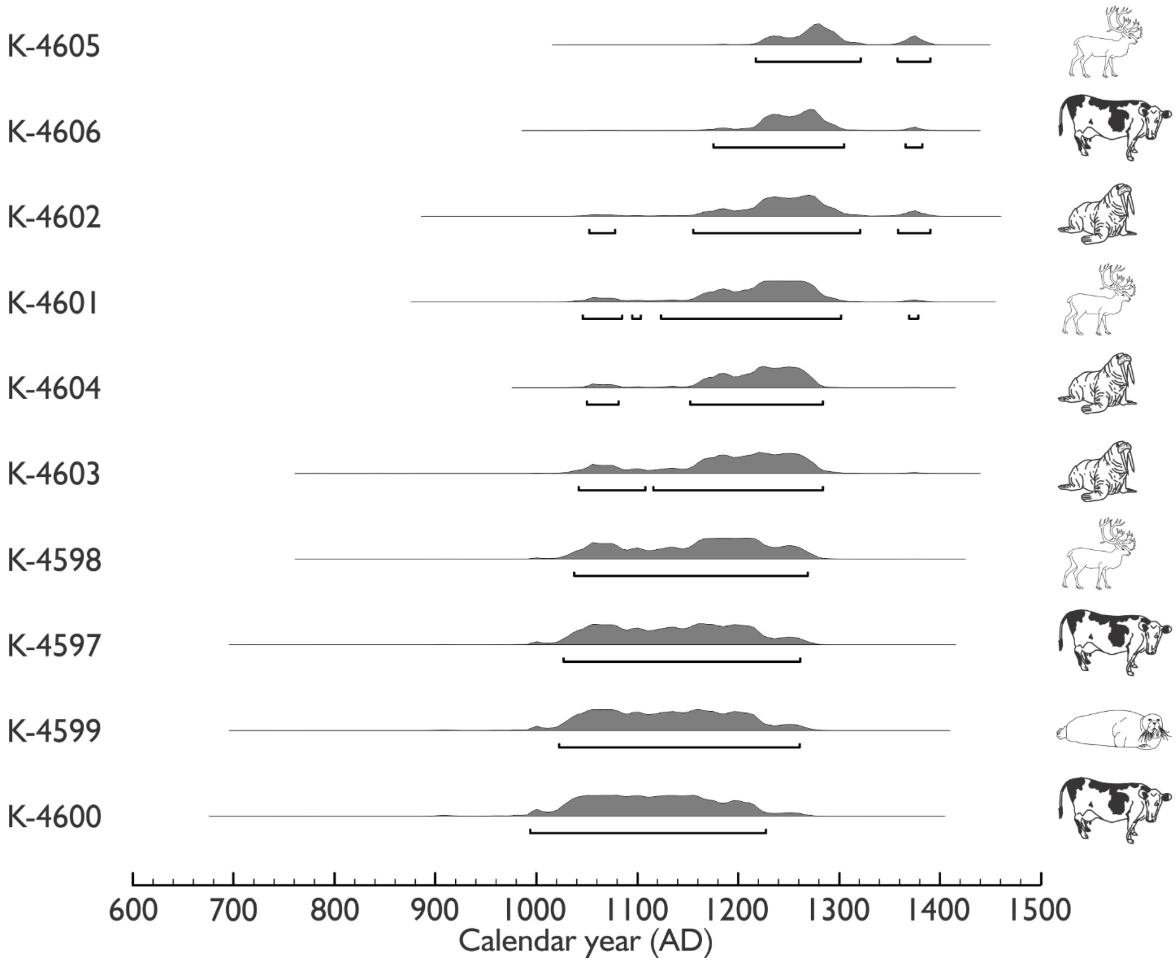

Figure 3.3: Multiplot showing calibrated age ranges (95.4% probability) of radiocarbon assays run on animal bones recovered from the F I Midden area at Sandnes (V51), originally presented in McGovern et al. (1996). The data has been re-calibrated in OxCal v.4.4.4 (Bronk Ramsay, 2021) r;5 using atmospheric data from Reimer et al. (2020). The laboratory codes of each assay is presented on the left of the diagram and on the right a cartoon animal depicts the species dated.

3.3 Methodology

3.3.1 Fieldwork and Sampling

Fieldwork was undertaken in August 2012 by Paul Ledger, who identified peaty deposits in a small mire c. 150 m northeast of the main dwelling structure (Knudsen et al., 2014). A 60 x 60 cm square trench was cut into these deposits to a depth of approximately 58 cm. The deposit was sampled from ground level to 50 cm (centimeters below surface) using a 10 x 50 x 10 cm monolith tin. The sample was extracted from the face of the trench and wrapped in plastic before being transferred to the University of Aberdeen. The monolith sample was stored at 4 °C at the University of Aberdeen until summer 2022, when it was sub-sampled at contiguous 1 cm intervals before being shipped to Memorial University, St. John's, for analysis. Loss-on-ignition (LOI) was measured following combustion at 550°C for three hours to measure the organic content of the archive through time (Bengtsson & Enell, 1986).

3.3.2 Pollen & numerical analysis

Pollen samples were prepared using standard NaOH, sieving, acetolysis, and flotation procedures (Moore et al., 1991; Nakagawa et al., 1998). *Lycopodium* tablets were used to calculate pollen and charcoal influx and concentration measurements (Stockmarr, 1971). Samples were suspended in silicone oil and then mounted on slides. Counting was undertaken using a Nikon E400 light microscope at ×400 magnification until a minimum sum of 500 total land pollen (TLP) had been reached. Moore et al. (1991) was used to identify pollen and spores, while (Bennett et al., 1994) was used for nomenclature. To differentiate between *B. pubescens* and *B. glandulosa*, grain size diameter measurements were taken (Fredskild, 1973; Schofield & Edwards, 2011), with *B. glandulosa* defined as *Betula* pollen measuring <20 µm. Spores of coprophilous fungi, that thrive on the dung of grazing herbivores, were counted utilizing descriptions and type designations by van Geel et al. (2003). Pollen preservation data was recorded for all indeterminable pollen grains (i.e., those that could not be identified owing to post-depositional taphonomic processes). Indeterminable grains were recorded as either corroded, degraded, broken, or folded following Cushing (1967) and are expressed in the pollen diagram as a percentage of total land pollen (TLP). The software TILIA was employed to construct pollen diagrams with local pollen assemblage zones (LPAZs) defined using CONISS following the square root transformation of percentage data (Grimm, 1987; 1993).

3.3.3 Charcoal counts

Microscopic charcoal was counted throughout the sequence using the point count method (Clark, 1982). The reticle of the microscope's eyepiece was employed for 22 reference points at unique viewpoints and every instance where charcoal touched a reference point is counted. Four hundred unique viewpoints were used, creating 8800 reference points. 8800 reference points were applied to achieve a <5% error in charcoal estimates. Techniques for determining pollen concentrations were used to calculate charcoal concentrations (Swain, 1978). Additionally, charcoal-to-pollen (C:P) ratios were calculated to check whether charcoal abundances changed due to sedimentation effects (Patterson et al., 1987).

3.3.4 Radiocarbon dating and age-depth modeling

Sediment samples were placed in beakers in a weak (2%) solution of NaOH and heated in a water bath to 60°C to aid in the disaggregation of the sediment matrix. After ten minutes, the samples were passed through a 125 µm sieve and extensively washed to remove humic acids and fine detritus. Samples were then suspended in water and examined under a low-power microscope. Seeds and twigs were identified primarily using reference material held at the PEAT laboratory in the Department of Archaeology at Memorial University. Eight samples were submitted to the Lalonde AMS facility in Ottawa and two to Beta Analytic, Miami, Florida, for analysis. Radiocarbon results were calibrated using the IntCal20 calibration curve (Reimer et al., 2020), and Bayesian Age-depth modeling of radiocarbon data was undertaken using the R-based script BACON (Blaauw & Christen, 2011).

3.4 Results

3.4.1 Lithostratigraphy and depositional environment

The Sandnes monolith sample comprises three distinct lithological divisions. From the bottom of the trench at 58 cm to 33 cm, the sequence consists of a grey-brown, slightly organic silty sand with rare rootlets and degraded mosses. Above this, from 33 cm to 25 cm, there is a more organic substrate comprised of dark brown to black moderately humified peat, with organic material being rootlets and sedge stems, larger woody debris, and occasional large charcoal fragments. At 31 cm, the sediment featured darker brown to brown moderately humified peat with rootlets, sedge stems, birch twigs, *Vaccinium* leaves, and other plant material. From 25 cm to the surface, the archive comprises orange-brown, poorly humified *sphagnum* peat with occasional sedges and ericaceous rootlets. LOI confirms the lithostratigraphic interpretations and suggests little organic material in the matrix at 50 cm, followed by several short-lived organic material spikes before a gradual increase in organic material from 35-25 cm. This indicates that between 35 cm and 25 cm, the archive either began increasing in organic makeup slowly or, more likely, that organic material was added to an inorganic soil. This is obvious because of the pieces of charcoal and small twigs throughout the 35-25 cm range. Organic material might have had some mixing with the surface consisting of sandy material, so LOI appears to climb steadily (35-30 cm). The rest of the sequence registers a similar minerogenic makeup as other mires in southern Greenland (Ledger et al., 2014, 2015; Schofield et al., 2022).

3.4.2 Age-depth models and radiocarbon dates

Ten radiocarbon dates between the depths of 10 and 47 cm form the chronology of the sequence. The measurements were undertaken exclusively on plant macrofossils and present a conformable sequence without evidence for age-depth reversals (Table 3.1). The samples analyzed were from terrestrial plant macrofossils in all but two cases. The first, from 25 to 26 cm, was a sample of seeds from the emergent aquatic plant *Montia fontana* (UOC-20292; 669±12). A sample of terrestrial macrofossils comprising *Betula* and *Vaccinium* leaves and twigs (UOC-20291; 696±12) was also submitted for dating from this depth to examine the potential for a freshwater reservoir effect similar to that which has been noted elsewhere in southern Greenland (Edwards, Erlendsson, & Schofield, 2011). The two samples returned near identical calibrated ages (Figure 3.4, Table 3.1), suggesting no age offset exists between terrestrial and emergent aquatic plants in this environment, and the calibrated dates are indistinguishable. This anecdotal observation was confirmed using the *Test Sample Significance'* function in CALIB 8.2, which returned a T value of 2.5, well below the test statistic value of 3.8, indicating that the samples are indistinguishable at 95.4% probability (Stuiver et al., 2024) The basal measurement from 45-47 cm (Beta-657529; 910 ± 30) was also undertaken on macrofossils of an emergent aquatic plant, in this case *Carex* seeds. The calibrated age of this sample is AD 1040-1215, indicating that the analyzed sequence likely encompasses up to 1000 calendar years.

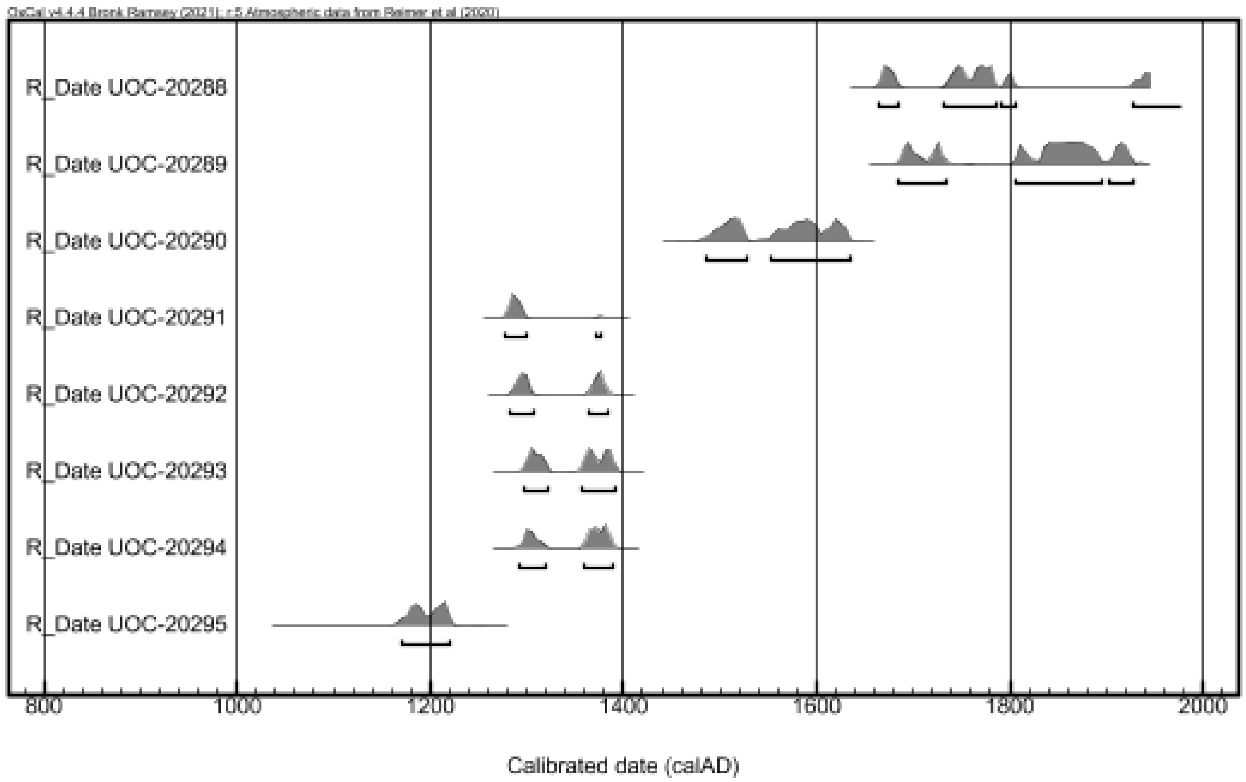

Figure 3.4: Multiplot of calibrated radiocarbon data from Sandnes. Data was calibrated using OxCal v4.4 using the INTCAL20 radiocarbon calibration curve.

Depth (cm)	Lab code	Material	^{14}C yr BP (±1σ)	cal. AD (95.4% probability)	δ13C (‰)
10.0-11.0	UOC-20288	*Sphagnum* leaves and stems	184 ± 12	AD 1665-1950	NR
14.0-15.0	UOC-20289	*Sphagnum* leaves	127 ± 12	AD 1685-1930	NR
19.0-21.0	UOC-20290	*Sphagnum* leaves and stems, and *Vaccinium* sp. leaves, wood, and bark	341 ± 12	AD 1485-1635	NR
25.0-26.0	UOC-20291	Leaves, stems, and bark (cf. *Vaccinium* sp. and *Betula nana*)	696 ± 12	AD 1275-1375	NR
25.0-26.0	UOC-20292	*Montia fontana* seeds	669 ± 12	AD 1285-1385	NR
30.5-31.0	UOC-20293	*Betula* twig	639 ± 13	AD 1300-1390	NR
34.0-35.0	UOC-20294	*Betula* twig	649 ± 12	AD 1295-1390	NR
35.0-37.0	UOC-20295	Stems, leaves, and bark (cf. *Vaccinium* sp.)	858 ± 12	AD 1170-1220	NR
41.0-42.0	Beta-657528	Bark and twigs (cf *Betula*)	850 ± 30	AD 1055-1265	-26.1
45.0-47.0	Beta-657529	*Carex* sp. seeds	910 ± 30	AD 1040-1215	-26.9

Table 3.1: radiocarbon data from the Sandnes profile.

A closer inspection of the dates indicates that although there is no evidence for age-depth reversals, there are indications of a period of rapid accumulation between the depths of 35 and 24 cm. Four samples from this depth range were submitted for radiocarbon dating, and each returned a nearly identical calibrated age range spanning the late 13th to late 14th centuries, although they are statistically indistinguishable at 95.4% probability (e.g., Stuiver et al., 2024). The sediment from these levels is rich in macroscopic charcoal remains (≤5mm) and may indicate an allochthonous source for the sediments. These deposits could potentially have been eroded elsewhere in the catchment and redeposited in their location, or more likely, they may represent redeposited houses or byre floors (Buckland et al., 1994). Elsewhere in Norse Greenland, similar deposits have been observed near Norse farms and interpreted as sweepings from hearths and byre/house floors that were deliberately spread in an attempt to improve soil fertility (Ledger et al., 2015)

A series of three age-depth models were constructed and tested for the Sandnes profile using all the available radiocarbon data except UOC-20292, the duplicate measurement on *Montia fontana* seeds from 25-26 cm, which was not included due to being statistically indistinguishable from UOC-20291 (Table 3.1). The main differences in the models related to the placement of a slump (a hiatus in the temporal progression of the age-depth model) to accommodate the possibility of a significant proportion of the profile arising from a dump of material from byres or house floors. Each age-depth model was run to extrapolate the ages of the archive past the basal radiocarbon dates generated from material collected at 45-47 cm. The most significant differences in modeling results were between Sandnes_v1 and Sandes_v2 & v3, those which included slumps. All modeling results are in broad agreement, indicating the analyzed portion of the Sandnes profile likely post-dates in the mid-9th century and, at the latest, ends in the 18th/19th centuries. Sandnes_v2 was adopted as the preferred model for the remainder of this paper, as it included a slump from 34-24 cm (for which there is clear stratigraphic evidence) (Figure 3.5).

Model name	Acc. shape	Acc. mean	Mem. strength	Mem. mean	Slump depths (cm)
Sandnes_v1	1.5	20	10	0.5	NA
Sandnes_v2	3	22	10	0.5	34 to 24
Sandnes_v3	3	22	10	0.5	35 to 25

Table 3.2 Comparison of the priors used in the age-depth modeling experiments.

Depth (cm)	LPAZ	Sandnes_v1			Sandnes_v2			Sandnes_v3		
		Earliest	Median	Latest	Earliest	Median	Latest	Earliest	Median	Latest
15	Top of analyzed sequence	1665	1700	1875	1665	1695	1740	1665	1700	1805
19	SAND-5a/5b boundary	1525	1595	1670	1525	1570	1650	1530	1605	1665
24	SAND-4/5a boundary	1335	1375	1395	1280	1300	1320	1275	1295	1335
34/35	SAND-3/4 boundary	1270	1305	1340	1280	1300	1320	1275	1295	1345
39	SAND-2b/3 boundary	1120	1205	1255	1150	1200	1245	1110	1195	1270
41	SAND-2a/2b boundary	1070	1175	1230	1125	1175	1215	1055	1165	1240
45	SAND-1/2a boundary	1045	1130	1200	1055	1115	1175	1030	1110	1190
50	Base of analyzed sequence	865	1045	1155	900	1015	1120	860	1030	1150

Table 3.3: Comparison of the variability in 95.4% probability and median age estimates of different age-depth models for selected bio-stratigraphic events of interest in the Sandnes profile.

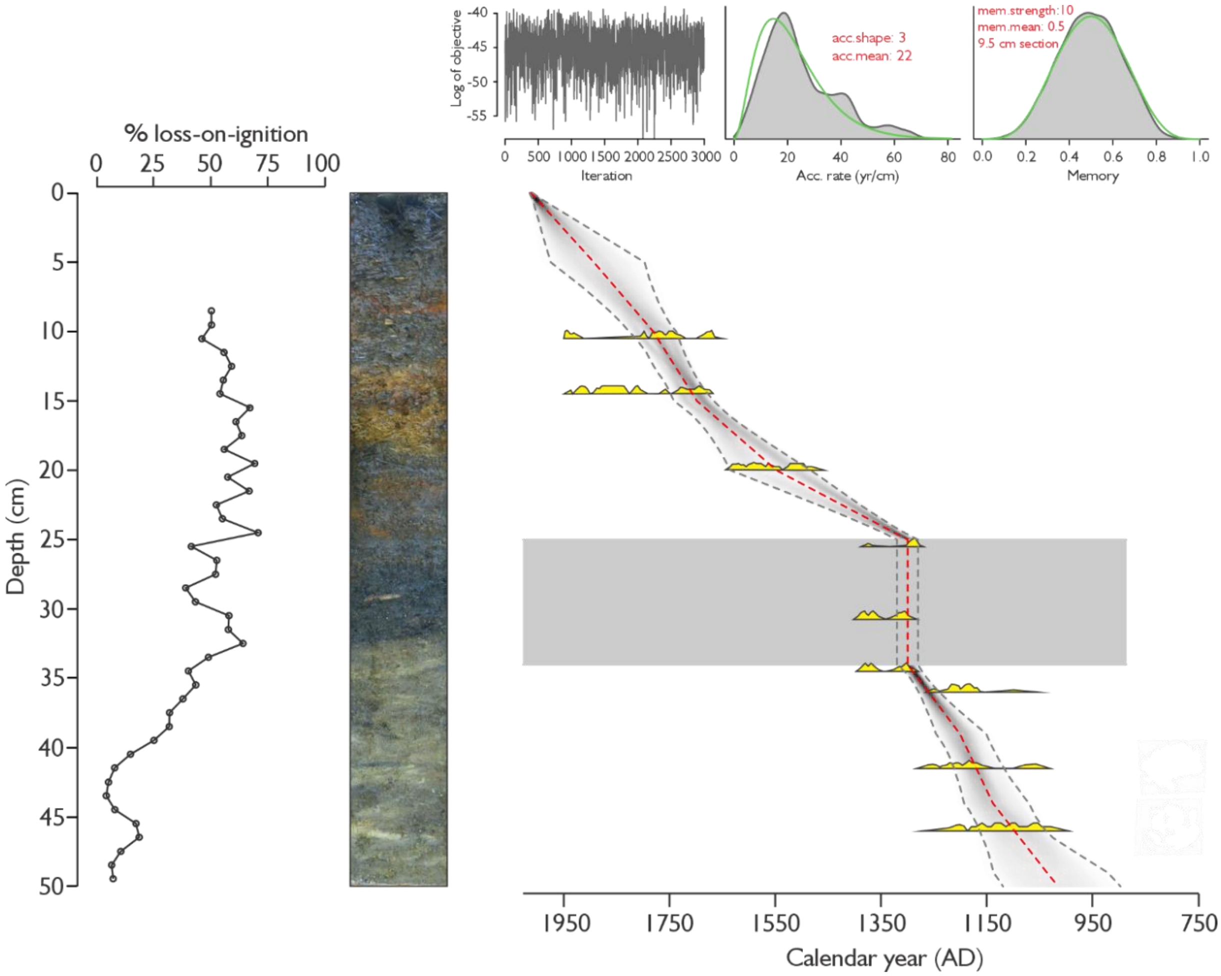

Figure 3.5: From left to right is loss-on-ignition data, the image of the examined profile, and the adopted age-depth model Sandnes_v2. The slump is illustrated by the grey rectangle.

3.4.3 Pollen and multi-proxy analysis (Fungal spores, LOI, and charcoal)

The pre-landnám baseline? (LPAZs SAND-1)

Local pollen assemblage zone (LPAZ) SAND-1 opens in the interval cal. AD 900-1120 and conceivably reflects the *landnám* period. The median date for the beginning of this zone (cal. AD 1015) is within a few decades of AD 985, the traditionally accepted date associated with the initial Norse settlement led by Eric the Red (Seaver, 2010). This zone has no clear dominant taxon, although pollen from trees, shrubs, and heaths consistently comprised more than 50% TLP (Figure 3.6). *Salix* is steady (c. 10-12% TLP), and *Betula pubescens* (c. 14% TLP) is slightly more common than *Betula glandulosa* (c. 12% TLP) at this stage, although *Betula glandulosa* trends upwards and becomes the most common species in the zone (c. 34% TLP). Pollen from Ericaceae is briefly common but is otherwise not dominant (c. 5-10% TLP). Herbaceous pollen comprises c. 33-52% TLP, and the fern *Lycopodium annotinum* spores are steady at c. 8% TLP, suggesting a substantial heathland at the site (Böcher et al., 1968). The herbaceous component comprises Poaceae (c. 8-13% TLP), Cyperaceae (c. 12-24% TLP), and *Rumex acetosa* (c. 4-8% TLP), while several other herbslope taxa (Caryophyllaceae and Apiaceae) and apophytes (*Rumex acetosella* and Lactuceae) are continuous but in lower percentages (c. <1-2% TLP). Non-pollen palynomorphs (NPPs) such as *Sordaria*-type (c. 1% TLP) and a single *Sporormiella*-type spore (rare) possibly indicate the presence of decaying organic matter or dung (cf. van Geel et al., 2003).

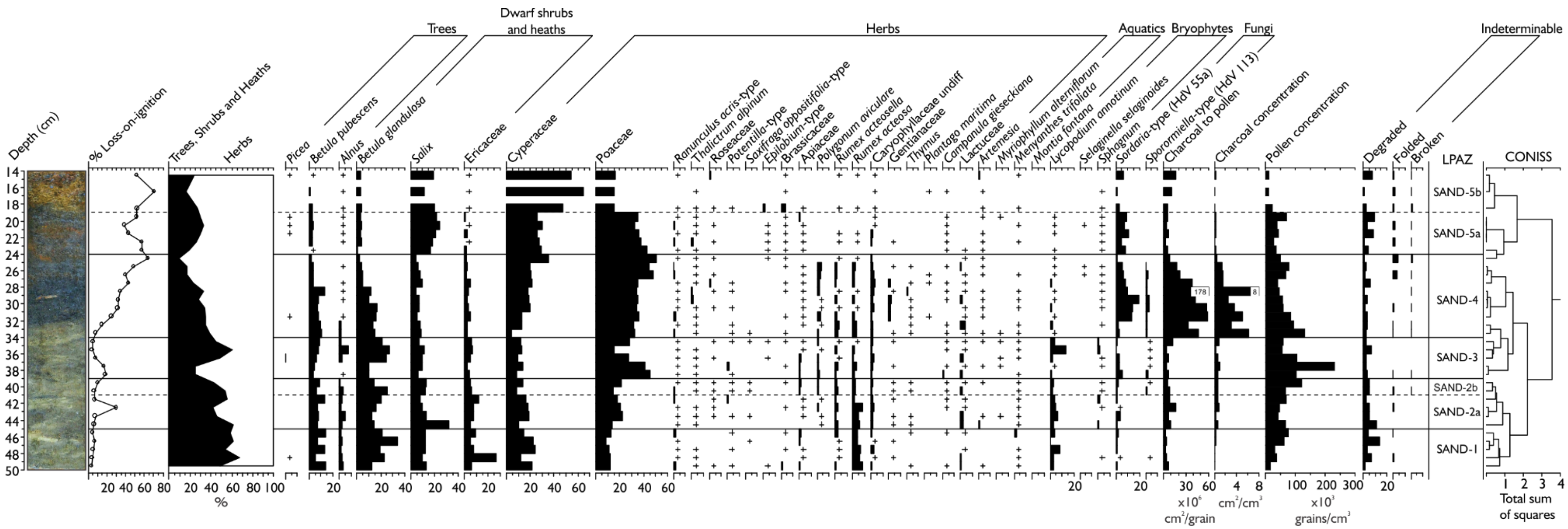

Figure 3.6: Percentage pollen and spore diagram for the analyzed portion of the Sandnes profile between 50 and 14 cm displaying selected taxa (minimum sum = 500 TLP). Also shown is a photograph of the lithology, loss-on-ignition, microscopic charcoal, and pollen concentration. + indicates < 1% TLP.

In many respects, this zone's pollen assemblage elements compare favorably with pre-*landnám* environments elsewhere in the Western Settlement (Iversen, 1934; Schofield et al., 2022). For example, low Poaceae and comparatively high woodland and shrub percentages and little microscopic charcoal deposition (c. .1 cm^2cm^{-3}) (cf. Schofield et al., 2022) are common features of pre-*landnám* elsewhere in the Settlement.

Contrary to the general lack of evidence for human activity in this zone, there is the presence of *Rumex acetosella* (rare to 1% TLP) from the base of the zone, which is a Norse introduction and marker of Norse presence in the Eastern Settlement (Schofield et al., 2013). While non-native to the area around the Eastern Settlement, this species is thought to be a native element of the flora of the Western Settlement region (Fredskild, 1973). A single *Sporormiella*-type spore was found between 48 and 49 cm. This zone does not contain the features characteristic of a Norse farming economy and predates any Norse-associated cultural landscape. It only has minor elements possibly related to human activity (i.e., trampling) that could have equally resulted from erosion or activity by grazing caribou. A possible scenario is that there may have been low-impact activities like camping and hunting in the area occurring during this pollen zone, although there is no conclusive evidence of human activity, and the *Sporormiella*-type spore can result from the grazing of wild herbivores.

Activity area and regional landnám (LPAZs SAND-2a) localized landnám (LPAZs SAND-2b)

LPAZ SAND-2a (opens cal. AD 1055-1175) differs little from the previous zone. Trees, shrubs, and heath continue to dominate the landscape (c. 42-61% TLP), although herbaceous taxa are occasionally more common (c. 39-58% TLP). The zone opens with shrub coverage, which seems to have slightly declined from SAND-1 but recovered again before SAND-2b. *Betula pubescens* (c. 7-12%) continues to be replaced by *Betula glandulosa* (c. 12-20% TLP). *Alnus* is more prevalent than in the previous zone (c. 3%-5% TLP). This zone is marked mainly by the first appearance of *Polygonum aviculare* (knotgrass), a Norse introduced species, in sample 44-45 cm, and Poaceae becoming more frequent than Cyperaceae. Poaceae peaks at 22% TLP in this zone, while Cyperaceae is between 10-19% TLP. Apophytic taxa, although already present at SAND-1, continue to increase alongside the introduction of *Polygonum aviculare*. Particularly common are *Rumex acetosa* (c. 1-9%), *Rumex acetosella* (c. 1-3%), Caryophyllaceae (c. 1-3%) and Lactuceae (c. 1-2%). Ferns remain relatively common in this zone (c. 3-6%), and *Sphagnum* is present for the first time (c. 1-2%). Charcoal concentrations gradually rise from the beginning of the zones and include two relative spikes (0.7 and 0.8 cm^2cm^{-3}) that are most pronounced in the charcoal-to-pollen ratio (C:P). The LOI data indicates the deposit is gradually becoming more organic (approx. 4-6% LOI), although the predominant component remains minerogenic. These zones likely represent a herbslope community with slightly more growth from wetland plants, potentially around the river with a modern mire (Böcher et al., 1968).

This zone contains the first probable sign of a Norse signature. However, the signal is weak and, when compared with farms from the Eastern Settlement, seems unlikely to represent haymaking and the presence of livestock in the area around Sandnes (Edwards, Erlendsson, & Schofield, 2011; Lee et al., 2022). General but gradual increases in microscopic charcoal are similar to the early stages of Norse settlement elsewhere in the Western Settlement (Iversen, 1954). Additionally, the grass/sedge relationship is more similar to what was observed in the Outfield rather than Infield at Austmannadalen during the early Norse-period (Schofield et al., 2022). The signature seen could be linked to increased trampling/disturbance influencing the *Betula* species and grass/sedge relationship. The zone does lack the characteristic *Sporormiella*-type spores associated with *landnám* in the Eastern Settlement. Therefore, it is uncertain if domestic animals were present at this stage (Edwards, Erlendsson, & Schofield, 2011). The most likely interpretation of this pollen zone is that it represents a regional *Landnám* signature where most of the pollen that is related to Norse farming was likely non-local in origin (Ledger et al., 2013). *Polygonum aviculare* is a Norse-introduced species to the Western Settlement, and its presence, although also possibly non-local, indicates that Sandnes was visited by Norse settlers, perhaps in a short-term hunting or camping capacity (Schofield et al., 2013).

SAND-2b (opens cal. AD 1125-1215) is a short pollen subzone that continues the trends already observed in SAND-2a. This assemblage probably still represents a simple herbslope community (cf. Böcher 1968). However, there are the first signs of a growing grass and weed community with *Sporormiella*-type spores, which comfortably fits an interpretation of the beginnings of a Norse farming economy (Schofield & Edwards, 2011). Pollen from trees, shrubs, and heaths are prominent at the zone's opening before declining (c. 54-43% TLP). This subzone is designated largely owing to a shift in the prevalence of weedy taxa (*Rumex acetosa* falls while *Polygonum aviculare* increases) and the first consistent presence of spores of the fungi *Sporormiella*-type. The latter's presence is significant as they are an obligate coprophile (van Geel et al., 2003) and likely reflect herbivores associated with Norse farmers (Lee et al., 2022; Schofield & Edwards, 2011). Charcoal is steady from SAND-2a and higher than SAND-1. A minor increase in the LOI (10.39%) starts a short shift to slightly more organic soil for 3 cm. The interpretation that this zone represents the early stages of a developing farming community is further strengthened by identifying several grains of Norse-introduced *Polygonum aviculare* (Schofield & Edwards, 2011).

Intensification of hayfields (LPAZs SAND-3)

SAND-3 (opens cal. AD 1150-1245) is a pollen zone again featuring significant fluctuations in taxa. The first evidence of drastically reduced counts of pollen from trees, shrubs, and heath is the most notable. These pollen types initially decline to approximately 25% TLP, briefly recovering to c. 61% TLP before decreasing to 45% TLP at the end of the zone. Poaceae increases in line with the reduction of shrubs, peaking at c. 45% TLP at the zone's opening, but it declines back to c. 25% TLP by the end of the zone. These short-lived increases in Poaceae pollen coincide with increasing pollen concentrations and could be interpreted as an increase in hay production from the nearby farm (Schofield & Edwards, 2011). *Sporormiella*-type begins the zone at c. 2% and becomes rare. There are no significant changes in charcoal concentration. The archive is slightly more organic at the opening of the zone (18% LOI) but trends towards a sandier deposit for the last time at the end of the zone (<10% LOI). The pollen record compares favorably to Western Settlement Norse sites where hay cropping was likely conducted (Iversen, 1954; Schofield et al., 2022). However, it does seem somewhat reduced in intensity compared to other Eastern Settlement high-status farms (Schofield & Edwards, 2011). The only other analyzed pollen archive originating from a localized RSAP associated with an archaeological site in the Western Settlement features high grass counts (45-80% TLP) through the Norse period at the Infield but is much more muted (approx. 10% TLP) in the Outfield (Schofield et al., 2022).

Anthrosol (LPAZ 4)

SAND-4 (opens cal. 1280-1320) most likely represents an anthrosol (human-modified soil). Four radiocarbon dates in general agreement were generated from 34-25 cm organic material. Nearly identical radiocarbon dates from the samples fall into the range of cal. AD 1275-1390. This corresponds to a sharp lithographic shift from sand and silts to an organic dark brown to black moderately humified peat with larger woody debris, occasional large charcoal fragments, and, most convincingly, a sharp increase in *Sporormiella*-type spores. Other authors associate these features with manuring regimes in Norse Greenland (c.f. Ledger et al. 2015). The two most likely interpretations of this sequence are that either a dump of byre material resulted in the accumulation of the sequence from 34-25 cm or that multiple smaller dumps occurred over a relatively short period, resulting in an anthrosol that still received some input from the environment.

The pollen and non-pollen palynomorph assemblage of SAND-4 features a number of subtle changes. Nevertheless, it is challenging to interpret what has been added through human action and what has been incorporated through anemophilous deposition (pollen deposition through natural environmental processes such as pollen rain). The pollen assemblage is generally suggestive of a landscape where pollen from woodland scrub and heath is dominant before being superseded by herbaceous taxa, notably grasses, during the latter part of the zone (c. 51% TLP). The scrub and woodland pollen components comprise *Betula* ssp., which dominates the initial part of SAND-4 before receding. *Alnus* is present at the opening of the zone before becoming rare. *Salix* is consistent at around 8-12 % TLP and becomes the most common shrub species as *Betula* declines, a pattern that remains consistent for the remainder of the archive. This evidence for the replacement of *Betula* scrub and woodland by *Salix* is a commonality with other palaeoenvironmental archives from across southern Greenland during the post-medieval warm period (Fredskild, 1973; Ledger, 2013). Charcoal concentration is by far the highest in the sequence through the middle section of this zone (up to 8.2 cm^2cm^{-3}), although it tapers significantly on both the lower and upper edges. The most likely interpretation of these ecofacts is that they were generated elsewhere, mostly likely a mix of cattle byre floor deposits consisting of dung and twig and leaf flooring (Buckland et al., 2009; Buckland et al., 1994; Ledger et al., 2015). At some point, this flooring was cleaned out and deposited in areas where Norse farmers wanted to promote hay growth for future cropping. It is unclear if this was an attempt to increase a previously unexploited area or increase the productivity of an area already dedicated to hay cultivation.

Abandonment and Post-Norse (LPAZ 5a & 5b)

The final LPAZ is divided into two subzones: LPAZ 5a (opens cal. AD 1280-1320) and 5b (opens cal. AD 1525-1650). Poaceae declines throughout SAND-5a (c. 35-40% TLP). Cyperaceae is consistently higher than in the last pollen zone (c. 30% TLP). Shrubs recover slightly in this zone, led by *Salix* (c. 24% TLP). Weedy taxa are less prominent than in previous zones, notably featuring a decrease in apophytes like *Polygonum aviculare*, *Rumex* ssp., and Lactuceae. The most common taxa are Apiaceae (c. rare -1 % TLP), Caryophyllaceae (c. rare -2% TLP), *Thalictrum alpinum* (c. rare -1% TLP), and *Ranunculus acris*-type (c. rare -1% TLP). LPAZ 5a is the first zone since LPAZ 2b without *Sporormiella-type,* signifying the absence of grazing animals near the former farm. *Sphagnum* and *Lycopodium annotinum* are still present but are rare. Charcoal decreases from the end of the last zone to levels comparable to the pre-*landnám* environment with continued minor charcoal peaks (c. .35 cm^2cm^{-3}), potentially indicating cookfires from a comparatively subtle human presence, perhaps the Inuit caribou hunters known to have used the area (McGovern et al., 1996). The lithology and pollen content (Cyperaceae and *Sphagnum*) of SAND-5a suggests that this zone represents the development of a mire/peat growth and paludification of a formerly dryland surface. Peat is the undecayed or partially decayed remains of plants that grow at relatively consistent rates in waterlogged or wetland environments (Gearey & Chapman, 2023). Presumably, this signifies the end of the soil amendment regime of SAND-4, and alongside recovering shrubs, the absence of *Sporormiella*-type spores and a major reduction in charcoal all suggest this pollen zone represents the plant community after Norse abandonment. Notably, relic hayfields are likely still a prominent landscape feature. Copses of willow shrub and sedge grow without the pressure that Norse farms usually have on woodland, all aspects of a broadly similar pattern to what was observed in Austmannadalen (Schofield et al., 2022).

In SAND-5b (opens cal. AD 1525-1650), there is no longer evidence for relic hay fields (a strong hay signature without other farming characteristics like *Sporormiella*). Rather than being replaced by shrubs, they are replaced by sedges (c. 65% TLP). Species usually considered Norse apophytes are mostly unrepresented, apart from Brassicaceae (c. rare to 3 % TLP). *Chamanerion angustifolium* (Fireweed) increases to its highest percentage in the diagram (c. 2% TLP). *Salix* continues to dominates the woodland and scrub component of the pollen assemblage. Charcoal is mostly as low as observed in the pre-*landnám* environment, and there are no other apparent indicators of occasional use at the site. The plant community here compares favorably with a sub-arctic steppe with localized mires, probably growing in the stream margins with an occasional copse of willow shrubs or full scrub (Böcher et al., 1968). A modern Inuit hunting site is reported in the area, but the impact from such sites is likely too ephemeral to consistently see palynologically (Ledger, 2018).

3.5 Discussion

3.5.1 The timing and character of *landnám*

The radiocarbon-based Bayesian age-depth model for the sequence indicates that the base of the sequence dates from the interval AD 900-1120, encompassing the traditionally accepted AD 985 date for *landnám* (Figure 3.7). Low levels of microscopic charcoal deposition dwarf shrubs/heaths and grasses from the base of the sequence are comparable with pre-*landnám* levels elsewhere in the Western Settlement and more widely in Greenland (Schofield et al., 2007; 2022). The effective absence of *Sporormiell*a-type and the absence of Norse-introduced plants, such as *Polygonum aviculare*, support this conclusion. All available pollen and non-pollen data suggest that the basal samples of the analyzed portion of the Sandnes profile pre-date *landnám*.

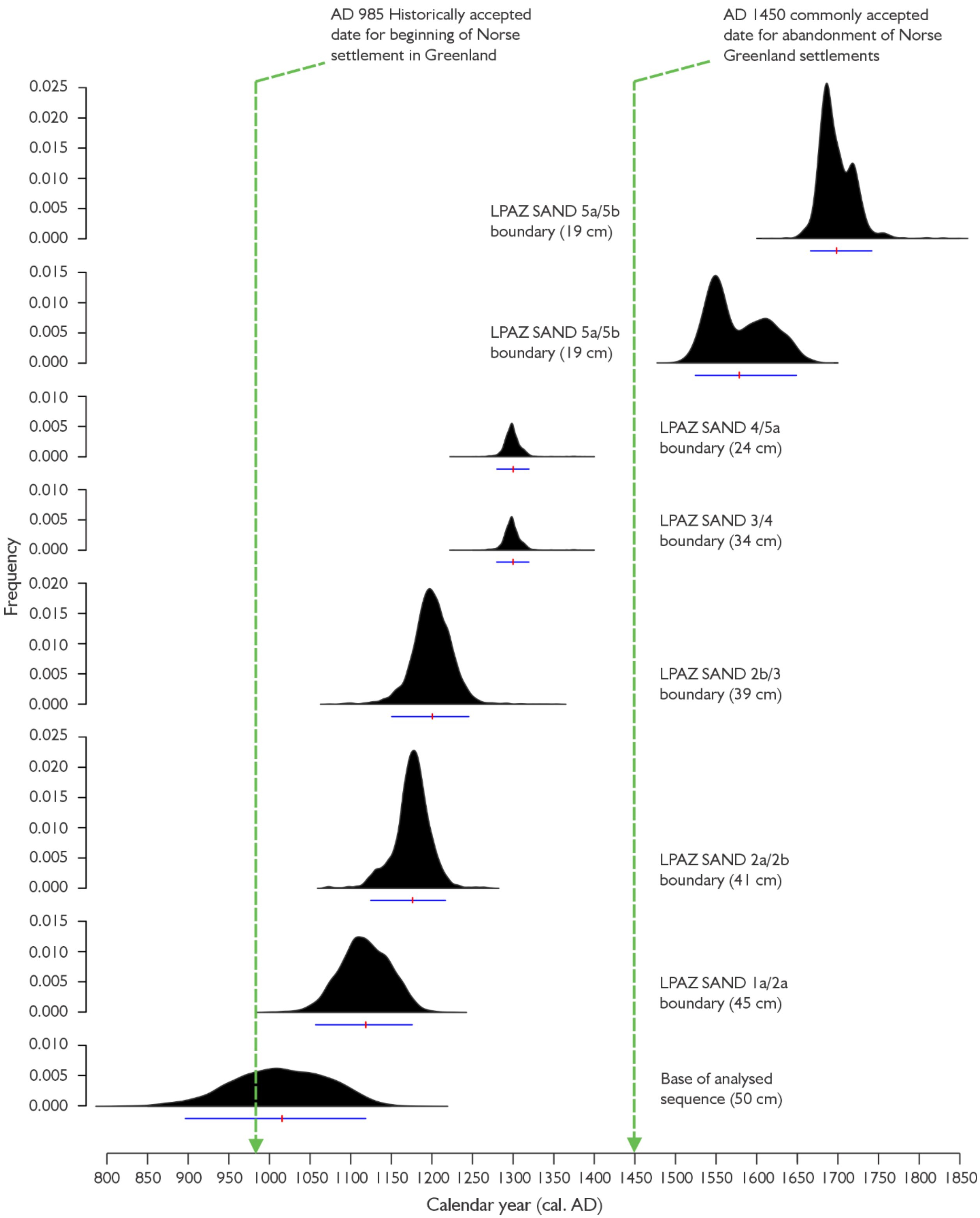

Figure 3.7: Age estimates for key points in the palaeoenvironmental record at Sandnes. Estimates were produced from the age-depth model Sandnes_v2 using the *Bacon.hist* command. The blue lines beneath each

histogram represent the 95.4% probability and the red vertical checks indicate the median of the distribution. The biostratigraphic event in question is noted to the right of the age estimate. In addition, two green dashed lines indicate the historically suggested dates for Norse settlement and abandonment in Greenland.

The first evidence of Norse settlers at Sandnes occurs at the boundary between LPAZs SAND-1/2a (opens in cal. AD 1055-1175). Pollen from the Norse-introduced *Polygonum aviculare* appears for the first time in the record, and there is consistent representation from Norse-associated apophytes such as *Rumex* ssp. and Brassicaceae (Schofield et al., 2013). There is also a slight rise in microscopic charcoal at this boundary that may be indicative of fires for heating and cooking alongside a decline in *Salix*. Many of the other elements that form a palaeoenvironmental signature for localized *landnám* elsewhere in Greenland are absent. The muted *landnám* signal is likely indicative of the regional *landnám* signal before a localized *landnám* at Sandnes (Ledger et al., 2013; Schofield & Edwards, 2011). Although Poaceae increases and *Salix* decreases through SAND-2a, it is not at an intensity that suggests the curation of hayfields (40-80% TLP is Poaceae for Infield at V53d (Schofield et al., 2022). It is not until the beginning of SAND-2b (dating to the interval cal. AD 1125- 1215) that *Sporormiella*-type spores, which can be indicative of livestock, are consistently present (van Geel, 2003). Palaeoenvironmental evidence recovered from an upland fen 1.5 km north of Sandnes reaches a similar, albeit less precise, conclusion. A radiocarbon date on charcoal (K-4569; 890 ± 70) from a 3mm-thick 'burn layer,' posited as resulting from the burning of scrub vegetation to stimulate the spread of grasslands for pasture and hayfields, indicates the *landnám* in the interval cal. AD 1030-1265 (Fredskild and Humle, 1991).

Radiocarbon data from middens on the archaeological site itself also produce similar findings. The calibrated age ranges of two radiocarbon assays on animal bone from the base of the

Sandnes midden (K-4597; 900±65 and K-4598; 870±65) respectively produce calibrated age ranges of cal. AD 1025 to 1260 and cal. AD 1035-1270. Notably, McGovern et al. (1996) adopted the early part of this range. They presented a table indicating that the first phase of a Norse presence began in AD 1025, which was deducted from radiocarbon data using faunal specimens (K4597 and K4598) excavated from the basal levels of Sandnes kitchen middens (Figure 3.3). The archaeofauna data confirms that the earliest phase at Sandnes had the most significant relative representation of hunted taxa, primarily seal and caribou, although domestics were still present. The basal midden layers had dung and the remains of domestics as well as the remains of hunted taxa. These results fit with the palaeoenvironmental interpretations presented here.

Sandnes likely began as a farm with a significant reliance on hunted taxa to supplement Norse dietary needs, and a farming cultural landscape was therefore not necessary until an economic shift that later prioritized domestics. Over this development, more domestics were brought to the site, and cultural landscapes were established and maintained. *Landnám* at Sandnes should, therefore, be understood as having undergone a nuanced development and settlement pattern. A muted signal for cultural landscapes (SAND-2a) represents a regional *landnám* and possibly Sandnes' use as an activity area, although clearly not as a farming settlement. Later, cultural landscapes developed due to more intensive and widespread hay-making and grazing alongside a major economic shift at the farm. This is obvious in the LPAZ SAND-2b, which opens AD 1125-1215 and coincides with archaeofaunal/economic developments from AD 1150-1200 reported in McGovern et al. (1996).

3.5.2 The character of landscape use at Sandnes

The first Norse settlers used the surrounding area by the SAND-1/2a border (AD 1055-1175), perhaps slightly earlier. By the SAND-2a/2b border (AD 1125-1215), there is a localized *landnám*, and some evidence suggests that the process of creating farming cultural landscapes had begun by the end of the zone. Pollen assemblages zone SAND-3 (opens AD 1150-1245) has the signature of a hayfield, indicating farming had been developed. To summarize, these key aspects of Norse cultural landscapes are the introduction of new Norse-associated taxa, reduction in trees/shrubs/heaths, increase in Poaceae and apophytes, increase in microscopic charcoal counts, and an increase in herbivore-associated spores, e.g., *Sporormiella*-type (Edwards, Erlendsson, & Schofield, 2011). The development of a farming cultural landscape at Sandnes can be observed in stages. There are clear markers of intensification by AD 1055-1175 (increased charcoal and introduction of *Polygonum aviculare*), followed by more herbivore presence by AD 1125-1215 (consistent *Sporormiella*-type spores), and finally, the development of a hayfield by AD 1150-1245 (increase in Poaceae pollen concentration and declines in tree, shrub, and heath).

As part of this developing farming community, it is possible that the upland area was burned to clear the natural coverage and encourage the growth of grasses, ultimately expanding the infield productive area or making a second upland farm, a practice observed in the Eastern Settlement (Ledger et al., 2013). Similar to that found in Sandnes' uplands (Fredskild & Humle, 1991), a charcoal layer was observed in the V35 midden, another possible indication that the process of burning may have been more common in the area around the former Western Settlement than the Eastern Settlement (Fredskild & Humle, 1991; Iversen, 1934; Knudsen et al., 2014). Landscape clearance by burning may have been somewhat successful because Fredskild and Humle (1991) observed a single spike in Poaceae representation at 17cm in their study. Unfortunately, the study was undertaken with a low resolution (cm gap between samples), and few radiocarbon dates were collected. Therefore, the data makes it hard to ascertain much about this short-lived rise in productivity from their sequence. The observed increase in Poaceae pollen deposition in LPAZ SAND-3/4 here does present similarities to these observations from further inland, which may be coherent with this evidence for broader landscape management.

Archaeofaunal evidence generally agrees that domestics, and therefore the importance of farming, increased in the century following the initial settlement at Sandnes. McGovern et al., (1996) noted that a significant economic shift occurred in which cattle, pigs, and caprines became more prevalent while hunted animals (other than walrus) became less important around AD 1200. Following the economic shifts, there was significant site reorganization in which several buildings were moved around AD 1250, potentially linked to rising sea levels that seem to have been occurring locally (Borreggine et al., 2023).

Soil amendment

Radiocarbon data, the profile lithology and the pollen assemblages from SAND-4 indicate this zone comprises a rapid period of allochthonous deposition. The most likely scenarios are that: (i) the material was deposited by human action in several events over a relatively short period; (ii) the material was deposited by human action in a single event, or (iii) the material became included in the archive through natural forces. A series of statistically indistinguishable radiocarbon dates leads to the most likely hypothesis scenario (ii) as the explanation for this deposit. The deposit probably resulted from intentional field management strategies involving the cleaning out of byres in the spring and depositing the manure and other household detritus (spoiled hay, twig beds, etc.) onto the field (Buckland et al., 1994; Golding et al., 2015; Ledger et al., 2015). This observation confirms those made at sites in the Eastern Settlement that indicate intentional soil amendment with manure (Ledger et al., 2015).

Soil amendment was likely a concerted attempt to expand the hayfields of the Infield. In LPAZ SAND-4, the coprophilous fungi *Sporormiella*-type content is significantly increased from SAND-3, and they are consistently represented throughout this zone. Similarly high spore counts and charcoal have been identified in several sites across Greenland, and these were linked to the manuring regimes of the Norse, who used waste from houses and byres, spreading the dung across the Infield (e.g., Ledger et al., 2015). Soil amendment dates to sometime in the interval of cal. AD 1280-1320 at the location where the archive was recovered, although it could have occurred earlier in other areas around the Infield. There is a potentially interesting correlation between manuring, the movement of several buildings, and the period of cooler weather post-AD 1250. One possible interpretation of the data is that Norse settlers may have begun soil amendment and adjusted their farming strategy to adapt to this cooler, supposedly less productive period.

3.5.3 Timing and character of abandonment

Palaeoenvironmental evidence for the abandonment of Sandnes can be traced to the boundary between LPAZs SAND-4/5a. This boundary dates to the interval cal. AD 1280-1320. The starkest evidence for abandonment at this point in the record is the return to pre-*landnám* baseline charcoal concentrations and the immediate and consistent lack of *Sporormiella*-type spores (Gauthier et al., 2010; Ledger et al., 2013). In addition to these changes is an increased representation of Cyperaceae and dwarf shrubs and heaths, the most prominent of which is *Salix*.

Other aspects of the Norse cultural landscape remain after the farmers, apparent departure. Notably, although the hayfield has been abandoned, there is still increased Poaceae beyond what was previously in the Pre-Norse signature, similar to what was seen at V53d (Schofield et al., 2022). Charcoal concentrations return to what has been determined to be an environmental baseline at the border of SAND-4 and SAND-5a (AD 1280-1320). In SAND-5b (AD 1525-1650), Poaceae is replaced largely by Cyperaceae and *Sphagnum*, which is likely evidence for the expansion of the mire and growth of peatlands (Böcher et al., 1968).

Norse presence seems absent, or at least severely muted by SAND-5, and the slumped placement in age-depth model v_2 occurs at the intervals cal. AD 1280-1320 seems to suggest an earlier potential abandonment than what may have been expected at Sandnes (Arneborg et al., 2012b; Barlow et al., 1997). Although potentially inconsistent with historical narratives and some radiocarbon dating conducted at 1-sigma, this date is consistent with the radiocarbon dates from the zooarchaeological remains at 2-sigma, which date the final midden phase to AD 1250-1325 (McGovern et al., 1996). It is difficult to impossible to discern if this was a quickly occurring shift (i.e. abrupt abandonment) or prolonged due to the potential taphonomic disturbances caused by human activity associated with manuring during the SAND-4/5a boundary. Relative dating suggests abandonment would have immediately followed manuring, while age-depth model v_2 suggests that abandonment could have happened up to a generation or two after the soil amendment event(s). The soil began paludification as early as SAND-5a, likely due to the addition of organic matter, which held more water than sand (Adderley & Simpson, 2006).

3.6 Conclusion

This research provided new data regarding the development, management, and abandonment of the cultural landscape surrounding a chiefly farm of the Western Settlement. Notably, it appears that Sandnes was settled later and with a less intensive farming footprint than what may have been expected for a high-status site. The first evidence of Norse presence occurs around the SAND-1/2a boundary, dated to the interval of cal. AD 1055-1175, and is much later than historical references to *landnám* (AD 985). This muted signal may be indicative of a regional *landnám* signal, although the continuous presence of *Polygonum aviculare* suggests that the site was probably visited by Norse settlers, albeit with little to no evidence of haymaking until the interval of AD 1150-1245 (SAND-3). Previous research, while lacking precision in estimating the time of events, is in agreement with the data presented here, with Sandnes likely occupied somewhere from the mid-11th century onwards. Nevertheless, the muted nature of the palaeoenvironmental data presented here opens the potential for considering alternative settlement models. For instance, Sandnes may have begun with hunting, trading, and exploratory voyages in mind, before transitioning to a farming-focused economy in the early to the mid-12th century.

Palaeoenvironmental evidence of a Norse pastoral farming cultural landscape emerges over several generations as seen in the subtle changes from SAND-2a (AD 1055-1175) through to SAND-3 (1150 to 1245). Such an interpretation would be concordant with previous research that established hunting was likely most important in the *landnám*-era and was gradually superseded by farming from c. AD 1150-1200. Evidence for a soil amendment regime that occurred during SAND-4 indicates that past assumptions concerning the favorability of Sandnes as a location for pastoral farming may have been overstated, and the settlers instead had to work to improve the farming conditions around Sandnes. Environmentally deterministic modeling and an archaeology comprising a church, multiple large buildings, and an extensive modern-day hayfield have often led to the assumption of a rich farming landscape that may have been equal to parts of the Eastern Settlement. The palynological data presented here, including a late and muted farming footprint, does not support this and brings into question the site-level cultural landscapes of the Western Settlement.

The abandonment of Sandnes appears to have occurred in the interval AD 1280-1320, immediately following soil amendment strategies. Environmental factors cannot be completely ruled out as motivation for abandonment as a response to gradually cooler temperatures and increased storminess post-AD 1250. Adaptations like the soil amendment described in this chapter occurred during this cooler period where it appears pastoral agriculture may have been more marginal. Abandonment occurring relatively soon after attempts at improving the soil quality is, at the very least, an interesting coincidence. It is worth noting that SAND-5a contains a signature similar to what other authors have described as a relict hayfield, which indicates the farmers would still have been able to produce some fodder post-1250 AD, although determining the productivity of these relict hayfields is difficult. Although the exact conditions of the abandonment of cultural landscapes at Sandnes are unclear, the early date could be an indication that the chiefly farm's political and cultural importance may have waned in the final decades of the Western Settlement.

Chapter 4: Concluding remarks and future direction

4.1 Introduction

This thesis presented new palaeoenvironmental data from Sandnes (V51) and coprolite pollen profiles from Tasilikulooq (Ø171), Austmannadal (V53d), and Tummmerallip Tasersua (V35). It has added to the understanding of Norse Greenland subsistence strategies implemented by Norse settlers in a new arctic environment. This chapter presents a conclusion to this manuscript-style thesis. I will highlight how this research can contribute to larger questions regarding Norse Greenland. I close this thesis by offering suggestions for future regional research.

4.2 Coprolites as a tool for investigating husbandry strategies, seasonality, and landscapes

In Chapter 2, the pollen and non-pollen proxy data from fifteen caprine coprolites was presented. Previous research has demonstrated that in different circumstances, coprolites reveal valuable information regarding the diets of caprines as well as some details of the landscape from which their food is acquired (Moe, 1983). This line of research had previously been relatively unexplored in a Norse Greenland context. The data presented in this thesis has begun to characterize the plant diets of caprines in Greenland using archaeological evidence, while previous understandings of the foddering strategies in Greenland had mostly been extrapolated from historical comparisons of Iceland and Norway (Amorosi et al., 1998). This research has further shown that the analysis of coprolites from well-dated archaeological contexts can demonstrate the diachronic aspects of seasonality, landscape, and foddering sources amongst domestic animals.

Amongst the samples analyzed for chapter two, there was consistent evidence of foddering, and therefore husbandry and subsistence, throughout all the individual samples. For example, leaf and twig foddering was apparent, and pollen likely stemming from this practice was found in every coprolite. Common taxa likely related to this practice were *Betula pubescens*, *Betula glandulosa*, *Salix*, and *Vaccinium*-type. Additionally, pollen from Poaceae was found in every sample, either resulting from caprines grazing during the day and returning to byres at night, or being fed dry hay as a fodder source while being kept in byres during the winter. Less common were other herbslope taxa like *Artemesia* and *Campanula gieseckiana*, which likely were part of the diverse hayfields and heathlands (Böcher et al., 1968). Several apophytes like *Rumex* ssp., *Polygonum aviculare*, and *Ranunculus acris*-type were common and may have been intentionally selected for (Amorosi et al., 1998; Ross & Zutter, 2007). Cyperaceae featured prominently in some coprolites, although this was not true for every sample. The minor variation between samples was insightful because it appears that dispersals of these core taxon clustered by site and temporal context, indicating that coprolites could be a valuable tool for determining variation in husbandry strategies amongst a dispersed population of agriculturalists, like those in Norse Greenland.

Although coprolites are a relatively unexplored palaeoenvironmental archive in the study of Norse Greenland, this research has demonstrated their potential usefulness and viability in investigating the variability of husbandry strategies. This has most obviously been accomplished by highlighting the role of leaf and twig foddering, which was evident by pollen counts likely related to this subsistence strategy being up to 87% of the TLP for some samples recovered from Ø171, while only roughly 30% of the TLP assemblage from the three coprolites recovered from V53d. This variability indicates that the strategy was not uniform across Norse Greenland, being a larger part of caprine husbandry strategies at different times and places. The prevalence of husbandry strategies, like twig and leaf foddering, can indirectly tell us things about the landscapes as well. For example, the prevalence of *Betula* ssp. vs. *Salix* sp. may give an indication about the local scrub communities that Norse settlers were harvesting for spring fodder.

Seasonality and mobility have previously been investigated through the palynological analysis of coprolites belonging to wild ungulates (Bjune, 2000). This same methodology can be applied in archaeological contexts to explore the seasonality of husbandry strategies. This is partly possible by first understanding the seasonal round of the culture in question. In Greenland, the Norse settlers practiced transhumant agriculture based on an Infield/Outfield system, where animals would be taken to upland pastures in the summer to graze and be milked, amongst other subsistence activities (Aðalsteinsson, 1991). Therefore, coprolites recovered from the Outfield represent summer feed, while coprolites recovered from the Infield represent the feed throughout the rest of the year. Following this logic, this research highlighted some differences in the summer and winter strategies of the Western Settlement. Particularly Cyperaceae and *Betula* ssp. appeared more prominently from the Outfield, indicating that those plants were a more important part of the caprine diet during summer.

4.3 Chronology of Western Settlement cultural landscapes

Landnám

Several aspects of the Western Settlement were crucial to life in the Eastern Settlement. More generally, the Western Settlement's proximity to the Norðsetur was likely vital to the function of Greenland's economy (Ljunqvist, 2005; Seaver, 1996; Star et al., 2018). The area supplied several trade commodities like walrus ivory, gyrfalcons, and polar bears, ensuring regular contact with the wider Norse world (Frei et al., 2015). The Western Settlement likely also functioned as a starting or stopover point for long-distance voyaging to the coasts of Markland (Labrador) and, by extension, L'Anse aux Meadows (Seaver, 1996). The route to eastern North America likely went through the Western Settlement due to the dangers of traveling the open ocean, and Norse settlers may have followed the West Greenland Current (WGC) north along Greenland's western coast instead (Ingstad & Ingstad, 1985; Ljunqvist, 2005). New data suggests that the Norse were in L'Anse aux Meadows by AD 1021 (Kuitems et al., 2022), and therefore, it is quite likely that the area that became the Western Settlement was in use by this date, at least as a coastal camp. This tells little of the development of cultural landscapes, and therefore farming, of the Western Settlement, though. In Chapter Three, I presented new data regarding the development of cultural landscapes from Sandnes, a leading farm in the Western Settlement.

Historical sources and modern readings of those sources have long assumed that Sandnes was: (i) likely settled quite early and (ii) was important early in the life of the Western Settlement (Berglund, 1986, McGovern et al.,1996; Roussell, 1936; 1941). Archaeology agrees that Sandnes was important from quite early in its life, but not necessarily that it was settled early. For example, the faunal remains at Sandnes indicate that the walrus trade had some connection to Sandnes even in the earliest midden phase (McGovern et al., 1996). Additionally, Sandnes housed one of two Western Settlement stone churches, indicating that Sandnes likely functioned as the political and ecclesiastical leader of 25-30 neighboring farms (Roussell, 1936; 1941). Therefore, it is surprising that there is no palaeoenvironmental evidence for Norse presence at Sandes until the interval cal. AD 1055-1175 (SAND-2a), identified by the presence of *Polygon aviculare* (Norse-introduced plant to the Western Settlement) and an increase in other weeds like *Rumex* ssp. and Brassicaceae. The results from this study also indicate that farming was likely not as important at Sandnes early in the site's history, with few indicators until cal. AD 1125-1215 (SAND-2b). It is not until cal. AD 1150-1245 (SAND-3) that a cultural landscape has clearly been established around Sandnes. The charcoal layer from the uplands at Sandnes that Fredskild and Humle (1991) associate with *landnám* date to cal. AD 1030-1265 and correlates well with a small charcoal-to-pollen ratio spike before SAND-2b. The ephemeral paleoenvironmental evidence of Norse presence in SAND-2a (opens in interval cal. AD 1055-1175) likely represents a regional *landnám*, indicating that some farming cultural landscapes may have been established in the area at this time.

A lack of well-dated, high-resolution palaeoenvironmental studies from Norse archaeological sites in the Western Settlement makes it difficult to ascertain if Sandnes was an outlier in its late establishment of cultural landscapes or if the pattern was more widespread. The only other high-resolution palaeoenvironmental data with a robust chronology from a Norse archaeological site in the Western Settlement is from the Outfield at V53d, where cultural landscapes seemed to be established at the BAu-2a/2b boundary, dated to roughly the interval of cal. AD 870-1000 (Schofield et al., 2022). Although lacking in palaeoenvironmental resolution and radiocarbon data, early research using lake cores in the Western Settlement indicated that farming there was less intensive than in the Eastern Settlement (Iversen, 1954). Although the initial importance of farming in the Western Settlement is not yet clear, there is still evidence of Norse presence not long after AD 985. Radiocarbon data of other archaeological data from the region suggests a *landnám* in the Western Settlement in the early 11th century at some sites, with others not appearing occupied until later (Arneborg et al., 2012b). A possible interpretation of this limited data is that in the Western Settlement, some farms may have been established in the decades following *landnám* (AD 985), but the development of widespread cultural landscapes did not occur for up to several centuries, if at all. Some sites, like Sandnes, may have initially functioned in more of a leadership role and as resource extraction/distribution centers before transitioning to dedicated farming sites later.

Abandonment and ecological succession

The abandonment of the Western Settlement intersects several prominent research questions of historians and archaeologists pertaining to Norse Greenland. For example, the role of climate change/environmental degradation (Barlow et al., 1997; Diamond, 2005; Dugmore et al., 2012), potential Inuit contact and warfare (Nedkvitne, 2018), and the historicity of manuscripts related to Greenland (e.g. Seaver, 1996; 2010). Historical sources are often used alongside archaeology to date the abandonment of the Western Settlement. Ivar Bardarson, a cleric sent to Greenland, reports that at least some Western Settlement was abandoned with sheep grazing on top of ruins as early as 1342 and definitely by 1355 (Nedkvitne, 2018). Two assumptions that I think are fair to make regarding this narrative are that (a) Bardarson likely did not explore the entire settlement; therefore, some sites could still have been occupied by Norsemen at this time; (b) there is no indication from the source that abandonment could not have happened even earlier than 1342. While it might be assumed that the presence of still-living domestic animals would indicate that he must have arrived soon after abandonment, this is not necessarily the case. In some parts of the former Western Settlement, herds of feral sheep have been supported since the 1930's (Mainland, 2006). Therefore, although Bardarson's account is interesting and affords some historical context to the archaeology of the area, it does not prove a historical analogy for the patterns of ecological succession following abandonment across the region. Archaeological evidence for the abandonment of Western Settlement indicates that although it was likely inhabited until at least the early 14th century, evidence beyond this point is less clear, with few sites featuring clear evidence of occupation into the second half of the 14th century (Arneborg et al., 2012b).

I have suggested above that perhaps the lack of farming is further evidence that the Western Settlement was not founded purely to expand pastureland. An alternative that makes sense is that the Settlement was founded with some resource extraction (walrus ivory) in mind. Further, the life cycle of the Western Settlement overlaps very closely with the boom-and-bust walrus trade, and it is hard not to see the chronological parallels (the last shipment of walrus ivory from Greenland dates to AD 1327) (Frei et al., 2015; Keller, 2010; Star et al., 2018). The abandonment of lifeways and settlement areas is often a complicated mix of factors, commonly explained as system collapse theory (Tainter, 2000). In Norse Greenland's context, the relationship between abandonment and the failure of the walrus trade and a particularly stressful climatic period is still murky. Additionally, it is well established that climatic factors like increased storminess, more sea ice, rising sea levels, cooler summers, and increased erosion are all potential factors in the decision to abandon the established cultural landscapes of the Western Settlement (Barlow et al., 1997; Berglund, 1986).

It is unclear if the Western Settlement was abandoned quickly, in one fell swoop, or more slowly over a prolonged period. Due to the small sample size, understanding the Western Settlements, site-level ecological succession from farming cultural landscapes to *Salix glauca-Betula nana* scrub woodland is again difficult (Böcher et al., 1968). The palaeoenvironmental data presented here indicates that the culturally managed landscapes of Sandnes were abandoned somewhere between AD 1280-1320. At the Outfield of V53d charcoal returns to pre-*landnám* levels, suggesting abandonment, in the interval of cal. AD 1300-1470 (Schofield et al., 2022). This indicates that farming might have continued on at V53d longer than at Sandnes. More, preferably diverse sites, from the Western Settlement should be investigated through palynology to better inform on the chronology and character of Norse abandonment and ecological succession of Western Settlement landscapes. Further, well-dated and high-resolution archives recovered from lakes in the region may better illuminate the timing of more widespread farming practices.

4.4 Future research suggestions

Further investigation into the coprolite pollen content of Norse domesticates should continue to reveal the husbandry and foddering strategies of the Norse. There remains the potential to identify site-specific husbandry strategies by analyzing coprolites. For example, it was common in southern Iceland to cut large swaths of wetland sedges and dry them for fodder use (Amorosi et al., 1998). Some sites in Greenland may represent similar resource specializations that have yet to be investigated. It has often been said that the Norse adapted little during the latter half of the Settlement's life, which has been considered to have played a role in their abandonment of the island (Diamond, 2005; Jackson et al., 2018). This research potentially revealed one way that the Norse adapted through time: switching their livestock's diet to have a woodier composition. In my opinion, Norse settlers in Greenland demonstrated remarkable resiliency and adaptability to many potentially detrimental factors before finally relinquishing their last farmsteads on the island in the mid-15^{th} century.

The timing and effects of *landnám* are relatively poorly understood from the Western Settlement, while the Eastern Settlement features several regional pollen studies (Gauthier et al., 2010; Ledger et al., 2014; Massa et al., 2012) and activity area investigations (Edwards et al., 2010; Ledger et al., 2013, 2014) undertaken with high-resolution supported by robust chronologies. Many assumptions are made regarding the development of the Western Settlement, especially regarding timing and cultural landscape, from just a few sites (Fredskild & Humle, 1991; Schofield et al., 2022). More well-dated, high-resolution palynology conducted in conjunction with Norse settlements in the Western Settlement could help determine if the region may have begun with somewhat stunted *landnám* and add further credence to postulated theories (Frei et al., 2015) regarding push and pull factors that led to the founding of the Greenland settlement.

References

Aðalsteinsson, S. (1991). Sheep in early Icelandic agriculture. *Acta Archaeologica*, *61*, 285-291.

Adderley, W. P., & Simpson, I. A. (2006). Soils and palaeo-climate based evidence for irrigation requirements in Norse Greenland. *Journal of Archaeological Science*, *33*(12), 1666-1679.

Albrethsen, S., & Keller, C. (1986). The use of the Saeter in Medieval Norse farming in Greenland. *Arctic Anthropology*, *23*, 91-107.

Aldred, O. (2008). Unfamiliar Landscapes: Infields, Outfields, Boundaries and Landscapes in Iceland. V Recent Approaches to the Archaeology of Land Allotment, ur. Adrian M. Chadwick, 299–321. In: Oxford: Archaeopress.

Amorosi, T., Buckland, P. C., Edwards, K. J., Mainland, I., McGovern, T. H., Sadler, J. P., & Skidmore, P. (1998). They did not Live by Grass Alone: the Politics and Palaeoecology of Animal Fodder in the North Atlantic Region. *Environmental Archaeology*, *1*, 41-54.

Arge, S. V., Sveinbjarnardottir, G., Edwards, K. J., & Buckland, P. C. (2005). Viking and Medieval Settlement in the Faroes: People, Place and Environment. *Human ecology : an interdisciplinary journal*, *33*(5), 597-620.

Arneborg, J. (2008). The Norse Settlements in Greenland. In *The Viking World*. Routledge.

Arneborg, J., Lynnerup, N., & Heinemeier, J. (2012a). Human Diet and Subsistence Patterns in Norse Greenland AD C.980—AD c. 1450: Archaeological interpretations. *Journal of the North Atlantic*, *2012*(sp3), 119-133.

Arneborg, J., Lynnerup, N., Heinemeier, J., Møhl, J., Rud, N., & Sveinbjornardóttir, E. (2012b). Norse Greenland Dietary Economy ca. AD 980-ca. AD 1450: Introduction. *Journal of the North Atlantic*, 1-39.

Barlow, L. K., Sadler, J. P., Ogilvie, A. E. J., Buckland, P. C., Amorosi, T., Ingimundarson, J. H., Skidmore, P., Dugmore, A. J., & McGovern, T. H. (1997). Interdisciplinary investigations of the end of the Norse Western Settlement in Greenland. *The Holocene*, *7*, 10.

Barrett, J. H. (2008). What caused the Viking age. *Antiquity*, *82*, 15.

Bell, M. (2005). *Late Quaternary environmental change: physical and human perspectives* (2nd ed.). Prentice Hall.

Benediktsson, J. (1968). *Islensk fornrit I — Islendingabok, Landnelmabok*. Hi 6 islenska fomritafelag.

Bengtsson, J., & Enell, M. (1986). Chemical analysis. In *Handbook of Holocene Palaeoecology and Palaeohydrology* (pp. 423-454). John Wiley and Sons.

Bennett, K. D., Whittington, G., & Edwards, K. J. (1994). Recent plant morphological changes and pollen morphology in the British Isles. *Quaternary Newsletter*, *73*, 1-6.

Berglund, J. (1986). The Decline of the Norse Settlements in Greenland. *Arctic Anthropology*, *23*(1/2), 109-135.

Birks, H. J. B., & Berglund, B. E. (2018). One hundred years of Quaternary pollen analysis 1916–2016. *Vegetation History and Archaeobotany*, *27*(2), 271-309.

Birks, H. J. B., & Birks, H. H. (2004). *Quaternary Palaeoecology*. Blackburn Press.

Bjune, A. E. (2000). Pollen analysis of faeces as a method of demonstrating seasonal variations in the diet of Svalbard reindeer (Rangifer tarandus platyrhynchus). *Polar Research*, *19*, 183-192.

Blaauw, M., & Christen, J. A. (2011). Flexible paleoclimate age-depth models using an autoregressive gamma process. *Bayesian Analysis*, *6*, 457-474.

Blockley, S. P. E., Edwards, K. J., Schofield, J. E., Pyne-O'Donnell, S. D. F., Jensen, B. J. L., Matthews, I. P., Cook, G. T., Wallace, K. L., & Froese, D. (2015). First evidence of cryptotephra in palaeoenvironmental records associated with Norse occupation sites in Greenland. *Quaternary Geochronology*, *27*, 145-157.

Böcher, T. W., Holmen, K., & Jakobsen, K. (1968). *The Flora of Greenland*. Hasse & Son.

Boivin, N., Zeder, M. A., Fuller, D. Q., Crowther, A., Larson, G., Erlandson, J. M., Denham, T., & Petraglia, M. D. (2016). Ecological consequences of human niche construction: examining long-term anthropogenic shaping of global species distributions. Proceedings of the National Academy of Science of the United States of America,

Borreggine, M., Latychev, K., Coulson, S., Powell, E., Mitrovica, J., Milne, G., & Alley, R. (2023). Sea-level rise in Southwest Greenland as a contributor to Viking abandonment. *Earth, Atmospheric, and Planetary Sciences*, *120*, 1-7.

Brown, J. L., Simpson, I. A., Morrison, S. J. L., Adderley, W. P., Tisdall, E., & Vésteinsson, O. (2012). Shieling Areas: Historical Grazing Pressures and Landscape Responses in Northern Iceland. *Human ecology : an interdisciplinary journal*, *40*(1), 81-99.

Brunn, D. (1917). Oversigt over Nordboruiner I Godthaab- og Frederikshaab-Distrikter. *Meddelelser om Grønland*, *56*, 57-147.

Buchwald, V. F. (2001). Ancient iron and slags in Greenland. *Meddelelser om Grønland*, *26*, 74.

Buckland, P. C., & Panagiotakopulu, E. (2001). Archaeology and the palaeoecology of the Norse Atlantic Islands: a review. Viking and Norse in the North Atlantic. Proceedings of the 14th Viking Congress, Tórshavn,

Buckland, P. C. (2008). The North Atlantic farm: an environmental view. In S. Brink & N. Price (Eds.), *The Viking World* (pp. 598-603). Routledge.

Buckland, P. C., Amorosi, T., Barlow, L. K., Mayewski, P., McGovern, T. H., Ogilvie, A. E. J., & Skidmore, P. (1996). Climate change, bioarchaeology, and the end of Norse Greenland. *Antiquity*, *70*, 88-96.

Buckland, P. C., Edwards, K. J., Panagiotakopulu, E., & Schofield, J. E. (2009). Palaeoecological and historical evidence for manuring and irrigation at Gardar (Igaliku), Norse Eastern Settlement, Greenland. *The Holocene*, *19*(1), 105-116.

Buckland, P. C., McGovern, T. H., & Skidmore, P. (1994). Twig layers floors and middens. Recent palaeoecological research in the Western Settlement. 12.

Bunting, M. J., & Tipping, R. (2000). Sorting the dross from data: possible indicators of post depositional assemblage biasing in archaeological palynology. In G. Bailey, N. Winder, & R. Charles (Eds.), *Human Ecodynamics* (pp. 63-69). Oxbow books.

Caseldine, C. J. (1981). Surface pollen studies across Bankhead Moss, Fife, Scotland. *Journal of Biogeography*, *8*(1), 18.

Christensen, K. M. B. (1991a). Aspects of the Norse Economy in the Western Settlement of Greenland. *Acta Archaeologica*, *61*.

Christensen, K. M. B. (1991b). Land use and resource exploitation in the Norse western settlement in Greenland. *Acta Borealia*, *8*(1), 29-39.

Clark, R. L. (1982). Point count estimation of charcoal in pollen preparations and thin sections of sediments. *Pollen et spores*, *24*, 523-535.

Cushing, E. J. (1967). Evidence for differential pollen preservation in late Quaternary sediments in Minnesota. In E. J. C. H. E. Wright (Ed.), *Quaternary Palaeoecology* (pp. 59-88). Yale University Press.

Diamond, J. (2005). *Collapse: How Societies Choose to Fail or Survive* (1st edition ed.). Penguin.

Dugmore, A. J., Church, M. J., Buckland, P. C., Edwards, K. J., Lawson, I., McGovern, T. H., Panagiotakopulu, E., Simpson, I. A., Skidmore, P., & Sveinbjarnardóttir, G. (2005). The Norse landnám on the North Atlantic islands: an environmental impact assessment. *The Polar Record*, *41*(1), 21-37.

Dugmore, A. J., Keller, C., & McGovern, T. H. (2007). Norse Greenland Settlement: Reflections on Climate Change, Trade, and the Contrasting Fates or Human Settlements in the North Atlantic Islands. *Arctic Anthropology*, *44*(1), 12-36.

Dugmore, A. J., McGovern, T. H., Vésteinsson, O., Arneborg, J., Streeter, R., & Keller, C. (2012). Cultural adaptation, compounding vulnerabilities and conjunctures in Norse Greenland. *Proceedings of the National Academy of Sciences*, *109*(10), 3658-3663.

Edwards, K. J. (2021). Marginalia in the 'bible'of pollen analysis: Gunnar Erdtman and the annotations of a displeased 'evangelist'. *Review of Palaeobotany and Palynology*, *295*, 104538.

Edwards, K. J., E., S. J., & J., A. (2010). Was Erik the Red's Brattahlið located at Qinngua? A dissenting view. *Viking and Medieval Scandinavia*, *6*, 83-99.

Edwards, K. J., Erlendsson, E., & Schofield, E. J. (2011). *Is there a Norse "footprint" in North Atlantic Pollen Records* Viking settlements and society: papers from the Sixteenth Viking Congress, Reykjavík and Reykholt.

Edwards, K. J., Schofield, E. J., Kirby, J. R., & Cook, G. T. (2011). Problematic but promising poinds? Palaeoenvironmental evidence from the Norse Eastern Settlement of Greenland. *Journal of Quaternary Science*, *26*(8), 11.

Edwards, K. J., & Schofield, J. E. (2013). Investigation of proposed Norse irrigation channels and dams at Garðar/Igaliku, Greenland. *Water History*, *5*(1), 71-92.

Edwards, K. J., Schofield, J. E., & Mauquoy, D. (2008). High resolution paleoenvironmental and chronological investigations of Norse *landnám* at Tasiusaq, Eastern Settlement, Greenland. *Quaternary Research*, *69*(1), 1-15.

Edwards, K. J., Fyfe, R. M., & Jackson, S. T. (2017). The first 100 years of pollen analysis. *Nature Plants*, *3*(2), 1-4.

Enghoff, I. B. (2003). *Hunting, fishing and animal husbandry at the Farm Beneath The Sand, Western Greenland.* (Vol. Man & Society).

Faegri, K. (1989). *Textbook of pollen analysis* (4th / by Knut Faegri, Peter Emil Kaland, and Knut Krzywinski. ed.). Wiley.

Friđriksson, A., & Vésteinsson, O. (2003). Creating a past: a historiography of the settlement of Iceland. In *Contact, continuity, and collapse: The Norse colonization of the North Atlantic* (pp. 139-161).

Fredskild, B. (1973). Studies in the vegetational history of Greenland. *Meddelelser om Grønland*, *198*, 245.

Fredskild, B. (1988). Agriculture in a marginal area – South Greenland from the Norse landnám (985 AD) to present (1985 AD). In H. H. Birks, H. J. B. Birks, P. E. Kaland, & D. Moe (Eds.), *The Cultural Landscape: past, present & future* (pp. 12). Cambridge University Press.

Fredskild, B., & Humle, L. (1991). Plant remains from the Norse farm Sandnes in the Western Settlement, Greenland. *Acta Borealia*, *1*, 12.

Frei, K. M., Coutu, A. N., Smiarowski, K., Harrison, R., Madsen, C. K., Arneborg, J., Frei, R., Guðmundsson, G., Sindbæk, S. M., Woollett, J., Hartman, S., Hicks, M., & McGovern, T. H. (2015). Was it for walrus? Viking Age settlement and medieval walrus ivory trade in Iceland and Greenland. *World Archaeology*, *47*(3), 439-466.

Gauthier, E., Bichet, V., Massa, C., Petit, C., Vannière, B., & Hervé, R. (2010). Pollen and non-pollen palynomorph evidence of medieval farming activities in southwestern Greenland. *Vegetation History and Archaeobotany*, *19*(5-6), 427-438.

Gearey, B., & Chapman, H. (2023). *An Introduction to Peatland Archaeology and Palaeoenvironments*. Oxbow Books.

Golding, K. A., Simpson, I. A., Schofield, J. E., & Edwards, K. J. (2011). Norse–Inuit interaction and landscape change in southern Greenland? A geochronological, Pedological, and Palynological investigation. *Geoarchaeology*, *26*(3), 315–345.

Golding, K. A., Simpson, I. A., Wilson, C. A., Lowe, E. C., Schofield, J. E., & Edwards, K. J. (2015). Europeanization of Sub-Arctic Environments: Perspectives from Norse Greenland's Outer Fjords. *Human Ecology*, *43*(1), 61–77.

Grimm, E. C. (1987). CONISS: A FORTRAN 77 program for stratigraphically constrained cluster analysis by the method of incremental sum of squares. *Comuters and Geoscience*, *pp. 13*, 13–35.

Grimm, E. C. (1993). *TILIA: a program for analysis and display*. In Illinois State Museum.

Guðmundsdóttir, L. (2022). The Utilisation of Native Woodland in Norse Greenland. *Environmental Archaeology*, *0*(0), 1-17.

Guðmundsson, G. (1996). Gathering and processing of lyme-grass (Elymus arenarius L.) in Iceland: an ethnohistorical account. *Vegetation History and Archaeobotany*, *5*, 13-23.

Guillemot, T., Bichet, V., Simonneau, A., Rius, D., Massa, C., Gauthier, E., Richard, H., & Magny, M. (2015). *Impact of Holocene climate variability on lacustrine records and human settlements in South Greenland* [preprint].

Hejcman, M., Hejcmanova, P., Pavlu, V., & Thorhallsdottir, A. G. (2016). Forage quality of leaf fodder from the main wood species in Iceland and its potential use for livestock in the past and present. *Grass and forage science*, *71*, 649-658.

Hem Eriksen, M., Pedersen, U., Rundberget, B., Axelsen, I., & Lund Berg, H. (2014). *Viking Worlds: Things, Spaces and Movement*. Oxbow Books, Limited.

Henriksen, P. S. (2012). Agriculture on the edge: the first find of cereals in Norse Greenland. *Northern Worlds challenges and solutions*, 3.

Høegsberg, S. M. (2009). Continuity and change: the dwellings of the Greenland Norse. *Journal of the North Atlantic*, *2*, 19.

Ingstad, A. S., & Ingstad, H. (1985). *The Norse Discovery of America: The historical background and the evidence of the Norse settlement discovered in Newfoundland* (Vol. 2). Oxford University Press, USA.

Iversen, J. (1934). Moorgeologische Untersuchengen auf Gronland. *Meddeleser fra Dansk Geologisk Forening*, *8*, 5.

Iversen, J. (1941). Landnam i Danmarks Stenalder. En pollenanalytisk Undersøgelse over det første Landbrugs Indvirkning paa Vegetationsudviklingen. *Danmarks Geologiske Undersøgelse II. Række*, *66*, 1–68.

Iversen, J. (1954). Über die Korrelationen zwischen den Pflanzenarten in einem grönländischen Talgebiet. *Oikos*, *5–6*, 238–246.

Jackson, R., Arneborg, J., Dugmore, A., Madsen, C., McGovern, T., Smiarowski, K., & Streeter, R. (2018). Disequilibrium, Adaptation, and the Norse Settlement of Greenland. *Human ecology : an interdisciplinary journal*, *46*(5), 665–684.

Jacobson, G. L., & Bradshaw, R. H. W. (1981). The Selection of Sites for Paleovegetational Studies1. *Quaternary Research*, *16*(1), 80–96.

Keller, C. (2010). Furs, Fish, and Ivory: Medieval Norsemen at the Arctic Fringe. *Journal of the North Atlantic*, *3*(1), 1–23.

Knudsen, P., Madsen, C., Toft, P., Matthiesen, H., Hollensen, J., Kroon, A., Moller, A., Pedersen, M., Allentoft, M., Meldgaard, M., Ledger, P. Lennert, A., Moller, K., & Lynge, P. (2014). *Field report for the pilot project "People of All Times"*.

Krogh, K. (1967). *Viking Greenland : with a supplement of saga texts*. National Museum.

Layberry, R. L., & Bamber, J. L. (2001). A new ice thickness and bed data set for the Greenland ice sheet: 2. Relationship between dynamics and basal topography. *Journal of Geophysical Research: Atmospheres*, *106*(D24)

Ledger, P. (2013). *Norse landnám and its impact on the vegetation of Vatnahverfi, Eastern Settlement, Greenland*

Ledger, P. M., Edwards, K. J., & Schofield, J. E. (2013). Shieling activity in the Norse Eastern Settlement: Palaeoenvironment of the 'Mountain Farm', Vatnahverfi, Greenland. *The Holocene*, *23*(6), 810–822.

Ledger, P. M., Edwards, K. J., & Schofield, J. E. (2014). A multiple profile approach to the palynological reconstruction of Norse landscapes in Greenland's Eastern Settlement. *Quaternary Research*, *82*(1), 22–37.

Ledger, P. M., Edwards, K. J., & Schofield, J. E. (2015). Taphonomy or signal sensitivity in palaeoecological investigations of Norse landnám in Vatnahverfi, southern Greenland? *Boreas*, *44*(1), 197-215.

Ledger, P. M., Edwards, K. J., & Schofield, J. E. (2017). Competing hypotheses, ordination and pollen preservation: Landscape impacts of Norse landnám in southern Greenland. *Review of Palaeobotany and Palynology*, *pp. 236*, 1–11.

Ledger, P. M., Forbes, V., Masson-Maclean, E., Hillerdal, C., Hamilton, W. D., McManus-Fry, E., Jorge, A., Britton, K., & Knecht, R. A. (2018). THREE GENERATIONS UNDER ONE ROOF? BAYESIAN MODELING OF RADIOCARBON DATA FROM NUNALLEQ, YUKON-KUSKOKWIM DELTA, ALASKA. *American Antiquity*, *83*(3), 505–524.

Lee, C., van Geel, B., & Gosling, W. (2022). On the Use of Spores of Coprophilous Fungi Preserved in Sediments to Indicate Past Herbivore Presence. *Quaternary*, *5*(30), 23.

Lemus-Lauzon, I., Bhiry, N. & Woollett, J. (2016) Assessing the effects of climate change and land use on northern Labrador forest stands based on paleoecological data. *Quaternary Research.*

Ljunqvist, F. C. (2005). The Significance of Remote Resource Regions for Norse Greenland.

Lowe, J. J., & Walker, M. J. C. (2014). *Reconstructing Quaternary Environments* (Vol. 2nd ed). Routledge.

Lynnerup, N. (2014). Endperiod Demographics of the Greenland Norse. *Journal of the North Atlantic*, *2014*(sp7), pp. 18–24.

Madsen, C. K. (2019). Marine Shielings in Medieval Norse Greenland. *Arctic Anthropology*, *56*(1), 119-159.

Mainland, I. (2006). Pastures lost? A dental microwear study of ovicaprine diet and managment in Norse Greenland. *Journal of Archaeological Science*, *33*, 238-252.

Mainland, I., & Haistead, P. (2005). The Economics of Sheep and Goat Husbandry in Norse Greenland. *Arctic Anthropology*, *42*(1), 103-120.

Massa, C., Bichet, V., Gauthier, É., Perren, B. B., Mathieu, O., Petit, C., Monna, F., Giraudeau, J., Losno, R., & Richard, H. (2012). A 2500 year record of natural and anthropogenic soil erosion in South Greenland. *Quaternary Science Reviews*, *32*, 119-130.

McGovern, T., Harrison, R., & Smiarowski, K. (2014). Sorting Sheep and Goats in Medieval Iceland and Greenland Local Subsistence, Climate Change, or World System Impacts? *Publications and Research*.

McGovern, T.H. (1981). Itilleq, Kapisilik, Godthåbsfjorden. Unpublished field report.

McGovern, T. H. (1985). Contributions to the palaeoeconomy of Norse Greenland. *Acta Archaeologica*, *pp. 54*, 49.

McGovern, T. H. (1992). Bones, buildings and boundaries: paleoeconomic approaches to Norse Greenland. In C. Morris & D. J. Rackham (Eds.), *Norse and Later Settlement and Subsistence in the North Atlantic* (pp. 167-186). University of Glasgow.

McGovern, T. H., Amorosi, T., Perdikaris, S., & Woollett, J. (1996). Vertebrate Zooarchaeology of Sandnes V51: Economic Change at a Chieftain's Farm in West Greenland. *Arctic Anthropology*, *33*(2), 94–121.

Moe, D. (1983). Palynology of sheep's faeces: relationship between pollen content, diet and local pollen rain. *Grana*, *22*(2), 105-113.

Mooney, D. E., Guðmundsdóttir, L., Pinta, É., & Alm, T. (2023). Timber as a Marine Resource: Exploitation of Arctic Driftwood in the North Atlantic. *International Journal of Wood Culture*, *-1*(aop), pp. 1–41.

Moore, P. D. (1978). *An illustrated guide to pollen analysis*. Wiley.

Moore, P. D., Webb, J. A., & Collinson, M. E. (1991). *Pollen Analysis* (2nd ed.). Blackwell Science.

Nakagawa, T., Brugiapaglia, E., Digerfelt, G., Reille, M., J.L., D. B., & Yasuda, Y. (1998). Dense-media separation as a more efficient pollen extraction method for use with organic sediment/deposit samples: comparison with the conventional method. *Boreas*, *27*, 15-24.

Nedkvitne, A. (2018). *Norse Greenland: Viking Peasants in the Arctic*. Routledge.

Nelson, D. E., Lynnerup, N., & Arneborg, J. (2012). A First Isotopic Dietary Study of the Greenlandic Thule Culture. *Journal of the North Atlantic*, *2012*(sp3), 51-64.

Nörlund, P. (1930). Norse ruins at Gardar. *Meddelelser om Grønland*, *76*, 171.

Nörlund, P., & Stenberger, M. (1934). Researches into Norse culture in Greenland. Brattahlid. *Meddelelser om Grønland*, *88*, 145.

Nygaard, G. (2018). Dairy Farmers and Seal Hunters: Subsistence on a Norse Farm in the Eastern Settlement, Greenland. *Journal of the North Atlantic*, *pp. 37*, 80.

O'Brien, M. J., & Laland, K. N. (2012). Genes, Culture, and Agriculture: An Example of Human Niche Construction. *Current Anthropology*, *53*(4), 434–470.

Øye, I. (2001). Technology, land use and transformations in Scandinavian landscapes, c. 800-1300 AD. In.

Øye, I. (2005). "Utmark" The Outfield as Industry and Ideology in the Iron Age and the Middle Ages. Viking and Norse in the North Atlantic. Select papers from Proceedings of the Fourteenth Viking Congress, Tórshavn, Tórshavn, Faroe Islands.

Panagiotakopulu, E., Schofield, E. J., Vickers, K., Edwards, K. J., & Buckland, P. C. (2020). Thule Inuit environmental impacts on Kangeq, southwest Greenland. *Quaternary International*, *pp.* 176–190.

Patterson, W. A., Edwards, K. J., & Maguire, D. J. (1987). Microscopic charcoal as a fossil indicator of fire. *Quaternary Science Reviews*, *6*, 3–23.

Price, N. (2011). *The Viking World (S. Brink, Ed.).* Routledge.

Reille, M., Andrieu, V., De Beaulieu, J., Guenet, P., & Goeury, P. (1998). A long pollen record from Lac du Bouchet, Massif Central, France: for the period ca. 325 to 100 ka BP (MIS 9c to MIS 5e). *Quaternary Science Reviews*, *17*, 1107-1123.

Reimer, P. J., Austin, W. E. N., Bard, E., Bayliss, A., Blackwel, P. G., Bronk Ramsey, C., Butzin, M., Cheng, H., Edwards, R. L., Friedrich, M., Grootes, P. G., Guilderson, T. P., Hajdas, I., Heaton, T. J., Hogg, A. G., Hughen, K. A., Kromer, B., Manning, S. W., Muscheler, R., . . . Talamo, S. (2020). The IntCal20 Northern Hemisphere radiocarbon calibration curve (0–55 cal kBP). *Radiocarbon*, *62*.

Ross, J. M., & Zutter, C. (2007). Comparing Norse Animal Husbandry Practices: Paleoethnobotanical Analyses from Iceland and Greenland. *Arctic anthropology*, *44*(1), 62-86.

Roussell, A. (1936). Sandnes and the neighbouring farms. *Meddelelser om Grønland*, *88*, 74-81.

Roussell, A. (1941). Farms and churches of the medieval Norse settlement in Greenland. *Meddelelser om Grønland*, *89*, 347.

Roy, N., Bhiry, N., & Woollett, J. (2012). Environmental change and terrestrial resource use by the Thule and Inuit of Labrador, Canada. *Geoarchaeology*, *27*(1), 18–33.

Roy, N., Woollett, J. & Bhiry, N. (2015) Paleoecological perspectives on landscape history and anthropogenic impacts at Uivak Point, Labrador, since AD 1400. *The Holocene* 1742-1755.

Schofield, J. E., & Edwards, K. J. (2011). Grazing impacts and woodland management in Eriksfjord: Betula, coprophilous fungi and the Norse settlement of Greenland. *Vegetation History and Archaeobotany*, *20*(3), 181-197.

Schofield, J. E., Edwards, K. J., & Christensen, C. (2008). Environmental impacts around the time of Norse landnám in the Qorlortoq valley, Eastern Settlement, Greenland. *Journal of Archaeological Science*, *35*(6), 1643-1657.

Schofield, J. E., Edwards, K. J., Erlendsson, E., & Ledger, P. M. (2013). Palynology supports ‘Old Norse’ introductions to the flora of Greenland. *Journal of Biogeography*, *40*(6), 1119-1130.

Schofield, J. E., Edwards, K. J., & McMullen, J. A. (2007). Modern Pollen-Vegetation Relationships in Subarctic Southern Greenland and the Interpretation of Fossil Pollen Data from the Norse landnám. *Journal of Biogeography*, *34*(3), 473-488.

Schofield, J. E., Pearce, D. M., Mair, D. W. F., Rea, B. R., Lea, J. M., Kamenos, N. A., Schoenrock, K. M., Barr, I. D., & Edwards, K. J. (2022). Pushing the Limits: Palynological Investigations at the Margin of the Greenland Ice Sheet in the Norse Western Settlement. *Environmental Archaeology*, *27*(2), 228-242.

Seaver, K. (1996). *The Frozen Echo: Greenland and the Exploration of North America, ca. A.D. 1000-1500*. Stanford University Press.

Seaver, K. (2010). *The Last Vikings*. I.B. Tauris.

Star, B., Barrett, J. H., Gondek, A. T., & Boessenkool, S. (2018). Ancient DNA reveals the chronology of walrus ivory trade from Norse Greenland. 9.

Stockmarr, J. (1971). Tablets with spores used in absolute pollen analysis. *Pollen et spores*, *13*, 615-621.

Stuiver, M., Reimer, P.J., and Reimer, R. 2024 CALIB version 8.2. http://calib.qub.ac.uk/calib/ (last accessed 28 January 2024)

Sveinbjarnardóttir, G. (1991). Shielings in Iceland: an archaeological and historical survey. *Acta Archaeologica*, *61*, 73-96.

Swain, A. M. (1978). Environmental changes during the past 2000 years in north-central Wisconsin: analysis of pollen, charcoal and seeds from varved lake sediments. *Quaternary Research*, *10*, 55–68.

Tainter, J. A. (2000). Problem Solving: Complexity, History, Sustainability. *Population and environment*, *22*(1), 3-41.

van Geel, B., Buurman, J., Brinkkemper, O., Schelvis, J., Aptroot, A., van Reenen, G., & Hakbijl, T. (2003). Environmental reconstruction of a Roman Period settlement site in Uitgeest (The Netherlands), with special reference to coprophilous fungi. *Journal of Archaeological Science*, *30*, 10.

Vebæk, C. L. (1992). Vatnahverfi: An inland district of the Eastern settlement in Greenland. *Meddelelser om Grønland*, *Man & Society*(Man & Society), 247.

Vickers, K., & Sveinbjarnardóttir, G. (2013). Insect invaders, seasonality and transhumant pastoralism in the Icelandic shieling economy. *Journal of environmental archaeology*, *18*, 165-177.