Environmental exploitation by humans following the settlement of eastern Iceland: Contribution of archaeobotanical data

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Figure on front cover: Examples of macro-botanical remains retrieved from archaeological contexts of the site Fjörður, eastern Iceland. Taken through a binocular microscope. Photograph by Snædís Sunna Thorlacius.

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Abstract

The topic of discussion in this thesis is the pre- and post-settlement environment of eastern Iceland, human exploitation of it and its consequences. Materials used are pre-existing publications on macro- and micro-botanical remains retrieved from both archaeological and natural contexts in eastern Iceland along with new archaeobotanical data from the archaeological site of Fjörður, Seyðisfjörður. The aim is to get a comprehensive image of the environment and vegetation in the area and to estimate the scope of human exploitation of it, with special emphasis on domestic use, livestock and cultivation. The results show that most of the sites seem to have been unforested prior to the settlement and characterised by heathland and grassland. Due to this fact the environmental effect of human arrival in the area was not as dramatic as in other more forested parts of the country. The most common influence of the settlement was replacement of taxa that are preferred by grazers by more grazing tolerant taxa and an introduction of anthropogenic indicators. A decrease in woodland was also observed where relevant, as well as increased soil erosion. Evidence of grazing was detected in almost all of the sites, along with anthropogenic fertilization and heathland expansion and exploitation. Insects and fungi reliant on domestic animals were also present in some of the sites. Driftwood seems to have been the most common wood used for construction and local wood most common as fuel. Peat and animal dung were also used as fuel which suggests a versatile fuel utilisation strategy. Cereal pollen was only found at three sites and a barley seed found in Fjörður seems to be the first cereal macrofossil found in an archaeological context in eastern Iceland. Cereal seeds have been found in many archaeological sites in other parts of the island and cultivation suggested for some of them. A possible explanation for the lack of evidence of arable agriculture in eastern Iceland is the lack of archaeological, environmental and archaeobotanical research in this part of the country, especially in environments suitable for cereal cultivation.

1. Introduction

1.1 Icelandic environment

Iceland is famous for its treeless landscape such as black sand beaches, mountains, lava fields, waterfalls and geysers. But the Icelandic landscape is ever-evolving and has changed drastically through the millennia. Iceland is an island located in the middle of the North Atlantic Ocean (see Figure 1) between the continents of North-America and Europe (Denk et al., 2011, p. 1). The island was formed by volcanic eruptions produced by a mantle plume at the boundaries of the North American and the Eurasian plates (Denk et al., 2011, p. 17). The plate boundary is spreading, causing the oldest parts of the country being at the eastern and western edges and the youngest part in the centre, where frequent volcanic eruptions occur (Denk et al., 2011, pp. 16–18). Iceland's oldest exposed rocks at the northwestern edge of the country, formed about 15 million years ago (Kristjansson et al., 2003, p. 992). Iceland is mountainous with an average altitude of 500 metres above sea level and the highest peak at above 2100 metres. The biggest lowland regions of the country are in the south where the coast is sandy and smooth but most of the rest of the country, especially in the northwest and east, has an irregular coast characterised by fjords cut into rocky landscape with small lowland areas at the valley bottoms (M. Á. Einarsson, 1984, p. 673).

Figure 1: Geographical location of Iceland. Iceland is located on the Mid-Atlantic ridge which separates the North American and Eurasian plates. The ridge can be seen on the sea bed southwest and northeast of the island. Created with Google Earth (https://earth.google.com/web).

Iceland has a maritime climate with cool summers and mild winters (M. Á. Einarsson, 1984, p. 680) and can be categorized as cold-temperate oceanic (Denk et al., 2011, p. 4). Iceland is located at a border between cold and warm ocean currents with the North Atlantic Drift from the south and the East Greenland Current from the north. As seen on Figure 2, a branch of the North Atlantic Drift called the Irminger Current encircles the south, west and north coasts of Iceland but a branch of the East Greenland Current called the East Icelandic Current flows south along the eastern coast (Eggertsson, 1993, p. 15; M. Á. Einarsson, 1984, p. 675). During the 9th-13th centuries AD there seem to have been unusually warm climatic conditions in the North Atlantic which resulted in the period being called the Medieval Warm Period (Hughes & Diaz, 1994, p. 111; Ogilvie et al., 2000, p. 43). A cooling followed the Medieval Warm Period called the Little Ice Age but it has been considered beginning in the 13th up to the 16th century and lasted until the 19th/20th century (Ogilvie & Jónsson, 2001, pp. 11–12).

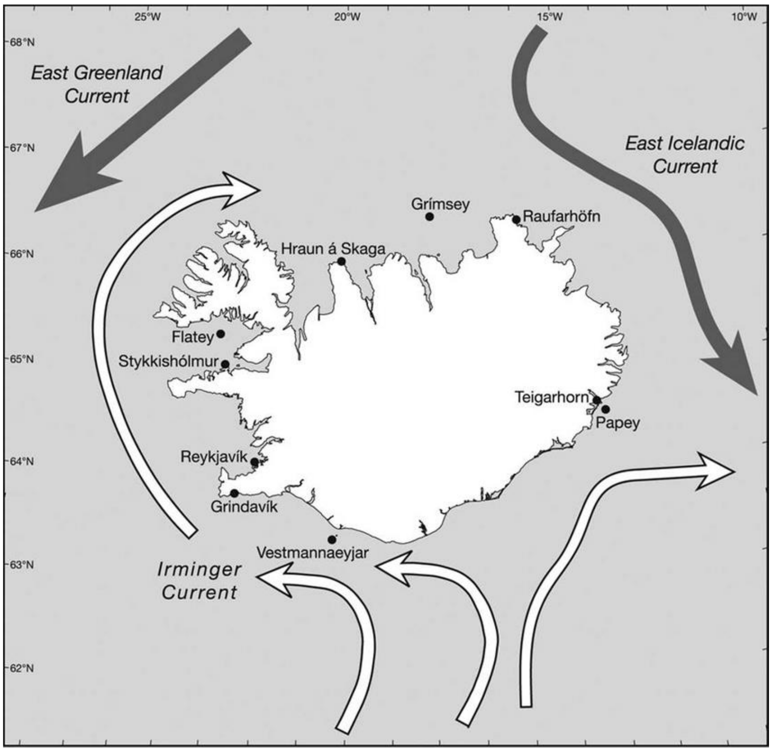

Figure 2: The main ocean currents around Iceland. The Irminger Current from the south and the East Greenland Current and East Icelandic Current from the north. From "Icelandic Coastal Sea Surface Temperature Records Constructed: Putting the Pulse on Air–Sea–Climate Interactions in the Northern North Atlantic. Part I: Comparison with HadISST1 Open-Ocean Surface Temperatures and Preliminary Analysis of Long-Term Patterns and Anomalies of SSTs around Iceland" by E. Hanna, T. Jónsson, J. Ólafsson and H. Valdimarsson, 2006, Journal of Climate 19(21), p. 5653. (https://doi.org/10.1175/JCLI3933.1).

The only native land mammal in Iceland is the arctic fox (P. C. Buckland et al., 2008, p. 174; Denk et al., 2011, p. 10; Smith, 1995, p. 323) but many marine mammals such as whales, dolphins and seals are common around the island (Denk et al., 2011, p. 12). Once in a while a polar bear or a walrus wanders from Greenland to Iceland (Denk et al., 2011, pp. 10, 12; Smith, 1995, p. 323). Hundreds of species of birds are present in Iceland both migratory and nesting (Denk et al., 2011, p. 11; Smith, 1995, p. 323). There are hundreds of species of fish in the sea around Iceland and a few in freshwater rivers and lakes (Denk et al., 2011, p. 12; Smith, 1995, p. 323). Two mammal species have been introduced by man in the past centuries; reindeer were imported in the 18th century (Thórisson, 1984, p. 22) and mink was introduced in the early 20th century (Bonesi & Palazon, 2007, p. 472). The reindeer only survived in the east part of the country and currently inhabit the Eastfjords and highland plateaus in eastern Iceland (Thórisson, 1984, p. 26).

The oldest botanical remains found in sedimentary rocks in the northwest part of the country are ca. 15 million years old (Grímsson et al., 2007, p. 181; Denk et al., 2011, p. 23). The first plants to inhabit Iceland probably came from both North America in the west and Europe in the east (Grímsson et al., 2007, p. 212). Some of the earliest taxa have a limited dispersal radius which suggests that Iceland was connected via a land bridge or a chain of islands to the continents during the first succession of plants, which then became isolated when Iceland became an island (Grímsson et al., 2007, pp. 216–217). When the Icelandic flora is compared with neighbouring countries it is obvious that it is poor in, and even lacks some taxa. For example no spruce nor pine is native to Iceland on the contrary to other countries on similar latitudes, which can perhaps be explained by the distance from the island to mainlands, resulting in only long-range taxa being capable of reaching it (Kristinsson et al., 2019, p. 48; Alsos et al., 2021, pp. 11–13).

The landscapes before the human settlement of Iceland have appeared to be more diverse than previously thought and the vegetation seems to have been ever-changing, even before the settlement (Erlendsson, 2007, p. 268). A decades long debate has been ongoing about if the modern Icelandic taxa survived the Last Glacial Maximum or arrived post-glaciation (Alsos et al., 2021; Brochmann et al., 2003; Hallsdóttir & Caseldine, 2005; Rundgren & Ingólfsson, 1999). The most recent results demonstrate that high arctic taxa might have survived the Last Glacial Maximum but boreal taxa immigrated post-glacially (Alsos et al., 2021, p. 10). When Iceland became ice-free following deglaciation, *Betula* and other plants colonized the newly exposed landscape, most likely dispersed by wind, sea ice, driftwood and birds (Geirsdóttir et al., 2020, p. 9; Rundgren & Ingólfsson, 1999, p. 394). According to ancient sedimentary DNA research on the oldest known lacustrine sedimentary records of Iceland, more than 80% of the recorded taxa had arrived before the Holocene Thermal Maximum (Alsos et al., 2021, p. 15).

The by far most species-rich plant families in Iceland are Cyperaceae and Poaceae but other species-rich families are Caryophyllaceae, Rosaceae and Asteraceae (Denk et al., 2011, pp. 8–9). The only woodland forming species in Iceland are *Betula pubescens* (downy birch) and its subspecies *Betula pubescens* ssp. *tortuosa* (mountain birch) (Eddudóttir et al., 2016, p. 715). Birch woodland established itself in the most favourable areas, such as lowlands and valleys, during the Late Boreal and Early Atlantic Chronozones (Hallsdóttir & Caseldine, 2005, p. 319). Scattered within birch woods are other tree species such as *Sorbus aucuparia*, *Populus* *tremula* and *Salix phylicifolia* (Denk et al., 2011, p. 9). The only native conifer species in Iceland is *Juniperus communis* (Denk et al., 2011, p. 7; Kristinsson et al., 2019, pp. 115–116).

According to a long-term potential vegetation cover model based on pollen from sites in Southwestern and Northern Iceland (see Figure 3), the potential maximum vegetation cover of the country during the Holocene Thermal Maximum may have been about 60%, including more than 10% birch forest cover (Ólafsdóttir et al., 2001, p. 207). On the other hand, shortly after the turn of the last millennium, around 45% of the country had higher than 50% vegetation cover and could therefore be considered vegetated. It could be divided into grass heath and dwarf-shrub heath as 25%, moss heath 10%, mires 8% and woodland and cultivated land both 1% (Hallsdóttir & Caseldine, 2005, p. 321).

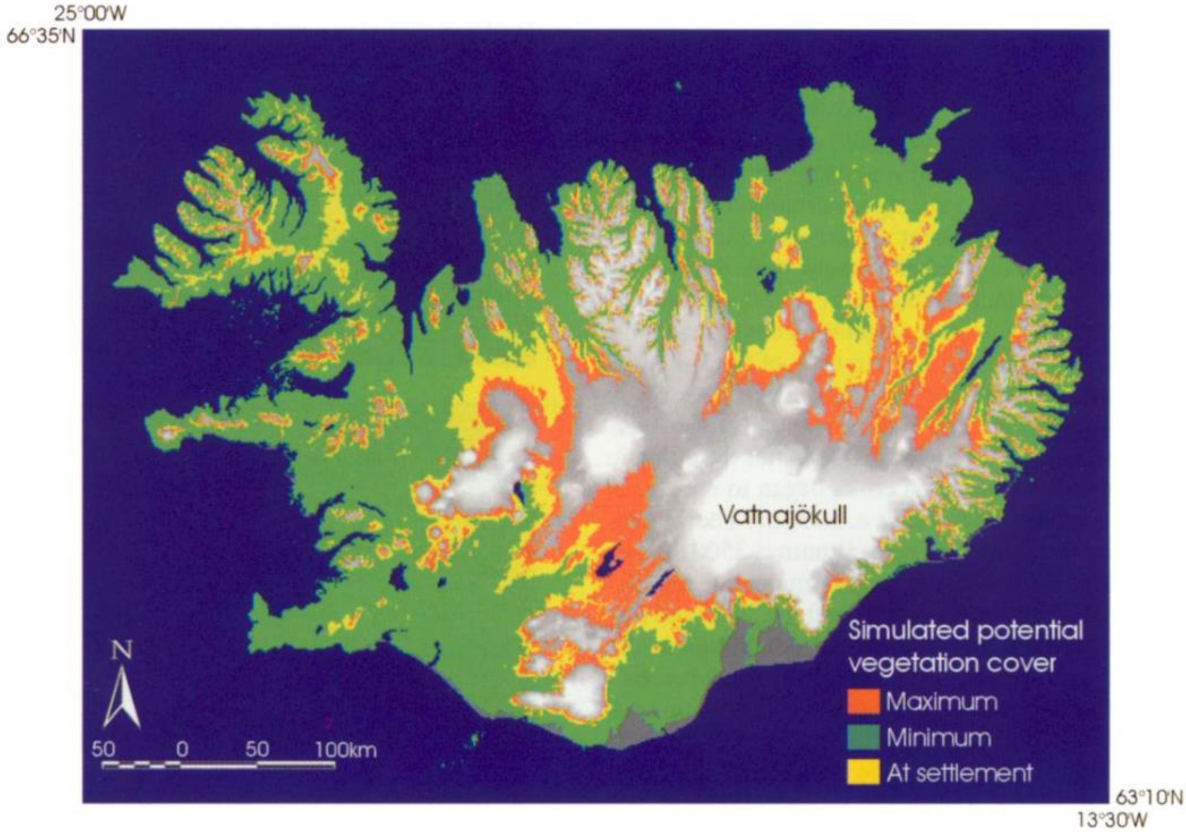

Figure 3: Simulated Holocene vegetation cover of Iceland. Minimum vegetation cover in green, maximum vegetation cover in orange and the proposed cover at the time of the settlement in yellow. From "Simulating Icelandic Vegetation Cover during the Holocene Implications for Long-Term Land Degradation" by R. Ólafsdóttir, P. Schlyter and H. V. Haraldsson, 2001, Geografiska Annaler. Series A, Physical Geography, 83(4), p. 208. (https://www.jstor.org/stable/521537).

1.2 Settlement of Iceland

Íslendingabók (The Book of the Icelanders) and *Landnámabók* (The Book of Settlements) consist of descriptions of the settlement of Iceland and the first centuries of occupation as well as the first settlers and their descendants (*The Book of Settlements*, 1972, p. 1; *The Book of the Icelanders: Íslendingabók*, 1930, pp. 37–38). They are both on the other hand, written in the

12th century meanwhile the settlement itself occurred in the late 9th century. Some even think these accounts were written as political statements linking settlement farms to powerful families in the 13th century (Smith, 1995, pp. 321–322). Therefore, these sources cannot be considered reliable contemporary accounts and the first centuries of Icelandic occupation are estimated prehistoric (Vésteinsson, 1998, p. 1). According to Ari Fróði's *Íslendingabók* the country was settled in 870 AD (*The Book of the Icelanders: Íslendingabók*, 1930, p. 60) and luckily, around that time a volcanic eruption in Veiðivötn produced a tephra layer which spread across a large part of the island and can be found widely as a chronological marker in soil profiles (M. M. E. Schmid et al., 2017, p. 61). The tephra layer is called the *landnám* (e. settlement) tephra layer and has been dated to 877+/-1 AD (M. M. E. Schmid et al., 2017, pp. 56, 65). Most of the earliest archaeological remains found in the country are found above this layer but in a few places evidence of human activity has been found underneath the layer. These suggest arrival of humans before the tephra was deposited but none of them can be considered substantial evidence for settlement (Erlendsson, 2007, p. 27; Geirsdóttir et al., 2020, p. 16; M. M. E. Schmid et al., 2017, p. 57; Vésteinsson, 1998, pp. 2–4; Vésteinsson & McGovern, 2012, p. 207).

There are many possible reasons for why the Norse settled Iceland. The traditional explanation is that the settlers were fleeing King Harald Fairhair's effort to unify Norway and opted for a new beginning in a free land (Smith, 1995, p. 320). Other suggested reasons are overpopulation in Scandinavia, climatic deterioration and advances in boat-building techniques (Collins, 2010, p. 345). It should be pointed out that during the period of Viking expansion there was less sea ice present in the North Atlantic than in later centuries due to a warmer climate which made the conditions favourable for exploration in the area (Ogilvie et al., 2000, p. 43). No real agreement has been reached so far, most likely because there is no single explanation for the sudden raiding and migration of Scandinavians in the Viking Age (Collins, 2010, pp. 345–346). According to written sources the earliest settlers settled the coasts and claimed their land reaching inland into valleys which they then divided and granted other family members or friends (Smith, 1995, p. 320).

Ari Fróði states in *Íslendingabók* that Iceland was covered in forest between the mountains and the shore when it was settled (*The Book of the Icelanders: Íslendingabók*, 1930, p. 60). Therefore it has been expected that the first settlers sought out clearings to locate their farms avoiding forest clearance (Vésteinsson, 1998, p. 7). The houses (see Figure 4) were longhouses built from stones, timber and turf (Bending, 2007, p. 40; Zutter, 1997, p. 33). Flooded wetlands with nutritious sedges for fodder located close to coasts in the estuaries of

Figure 4: A reconstruction of an excavated Commonwealth period settlement in Þjórsárdalur. The buildings are made from turf, wood and stones. From "Gott að vita", n.d. (https://www.thjodveldisbaer.is/is/gott-ad-vita).

large rivers were prime conditions for the very earliest settlements of Iceland (Vésteinsson, 1998, p. 8). The secondary phase of settlement was likely located in forested areas needing clearance for construction and grazing (Bending, 2007, p. 20). According to *Íslendingabók* the whole of Iceland had been claimed by 930 AD (Smith, 1995, p. 320) and archaeological evidence supports that the settlement was in fact a rapid process happening in only a matter of decades (Vésteinsson et al., 2002, p. 106). The period after the settlement period is usually referred to as the Commonwealth period and lasted until 1262 when Iceland became a part of the Norwegian kingdom (Mooney & Guðmundsdóttir, 2020, p. 7).

Iceland was settled by Vikings who colonized the North Atlantic during the Viking Age in 750-1050 AD (Vésteinsson et al., 2002, p. 98). According to genetic studies based on Y chromosomes on Icelanders, patrilineal ancestors of modern Icelandic men were mainly of Norse origin (Helgason, Sigurðardóttir, Nicholson, et al., 2000, pp. 714–715), but based on mitochondrial DNA, matrilineal ancestors of modern Icelandic women were mainly from the British Isles (Helgason, Sigurðardóttir, Gulcher, et al., 2000, p. 1008). A possible explanation for this difference between the genetic origin of the sexes is that settlers included a number of people from the British Isles where the Vikings had settled before. They likely brought women from the British Isles they had married or bought, with them to settle Iceland (Helgason, Sigurðardóttir, Gulcher, et al., 2000, p. 999; Helgason, Sigurðardóttir, Nicholson, et al., 2000, p. 697).

1.3 Environmental exploitation

The settlers brought animal husbandry with them to the island, hence introducing herbivorous mammals to the Icelandic ecosystem (Mooney et al., 2022, p. 189; Vésteinsson et al., 2002, p. 101; Zutter, 1997, p. 41). Most of the farm sites relied on animal husbandry but some also had the option of hunting (Vésteinsson, 1998, p. 10). Evidence of hunting is for example a walrus species that used to breed in Iceland when the country was settled but was hunted to extinction by humans in the 11th-12th centuries (Keighley et al., 2019, p. 2661) and the Great Auk which was native to Iceland but was hunted to worldwide extinction in Iceland in the 19th century (Moum et al., 2002, p. 1434).

The animals imported by the settlers were sheep (see Figure 5), horses, cattle, dogs, pigs and goats but the two latter got increasingly rarer after the settlement (McGovern et al., 2007, p. 40). Both historical research and zooarchaeology indicate that early settlers prioritised dairy products and had a low sheep-to-cow ratio until the importance of sheep increased over the centuries, especially after “Black Death” (Eddudóttir et al., 2020, p. 2; McGovern et al., 2007, p. 40; Smith, 1995, p. 329; Vésteinsson, 1998, p. 7). Epidemics, volcanic eruptions and cooling climate steered farming practices from cattle to sheep as dairy producers which caused changes in land-use (Zutter, 1997, p. 181). The herbivorous animals required large areas of pastures making wood clearance preferable in forested locations (Trbojević, 2016, pp. 98, 199) and the need for fodder urged the settlers to promote the growth of grasses, sedges and weeds (Roy et al., 2017, p. 671).

Figure 5: Sheep in Icelandic nature. Settlers introduced grazing animals like sheep to Iceland in the 9th century. From "Bringing in the sheep" by Icelandic Lamb, 2022 (https://www.icelandiclamb.is/blogs/bringing-in-the-sheep/).

This deforestation had consequences which the settlers, used to the environments of Scandinavia and the British Isles, were probably unaware of (Trbojević, 2016, p. 203; Vésteinsson et al., 2002, p. 101). Following forest clearance the new pastures were grazed by domestic animals causing loss in vegetation cover resulting in soil erosion (Trbojević, 2016, p. 199). The soil in Iceland is primarily classified as Andosol because it is rich in volcanoclastic materials and therefore lacks cohesion, which makes it more vulnerable to erosional processes (Arnalds, 2008, pp. 409, 415). Soil erosion in Iceland is mostly associated with animal grazing and has been extremely active in Iceland since the settlement resulting in desertification (Arnalds, 2008, p. 416). The simultaneous increased importance of sheep, tree removal, volcanism and cooling climate due to the Little Ice Age resulted in increased degradation of soils (Eddudóttir et al., 2016, p. 725, 2020, p. 2).

The forest was also a resource in itself as firewood, charcoal and even construction material (Mooney et al., 2022, p. 191; Vésteinsson, 1998, p. 7). Iron was extracted from bogs in Iceland up to the 15th-16th century which required much birch-charcoal even though turf and peat were simultaneously used as fuel. Numerous remains of charcoal pits have been found in areas of severe soil erosion which show the devastating effects of charcoal making (Hallsdóttir & Caseldine, 2005, p. 329). Charcoal was essential in the maintenance of metal tools because it burns at a high temperature (Mooney et al., 2022, p. 193). Local woodland usually did not provide wood of sufficient quality for construction so driftwood and imported wood was also used as structural timbers for houses (Bending, 2007, p. 41; Mooney et al., 2022, p. 197; Smith, 1995, p. 336). Driftwood, as can be seen on Figure 6, is coniferous wood that originated in Siberia and floated on rivers into the Arctic Ocean where it was transported due to ocean currents and sea ice and washed up on the shores of Iceland (Eggertsson, 1993, p. 29; Mooney et al., 2022, p. 191).

According to research on fuel utilisation in early Iceland, the settlers brought a much more complex fuel use strategy than previously thought (Vésteinsson & Simpson, 2004, p. 182). Peat consists of accumulated plant remains located below water level in peat bogs and lakes (Sigurðsson & Hafstað, 1980, p. 11). The thickness of peat bogs depends on the annual amount of accumulated plant remains and is therefore influenced by climate and landscape of the surrounding area. Common plant remains in peat are sedges, mosses and other aquatic flora but they can also contain pieces of wood from ancient forests (Sigurðsson & Hafstað, 1980, pp. 25–26). Peat was sourced locally from peat bogs, dried and burned as fuel. It was likely a preferred source of fuel, especially in treeless settings, and may have been used mainly for industrial purposes (Bending, 2007, pp. 46–49; Vésteinsson & Simpson, 2004, pp. 181–182; Zutter, 1997, p. 33).

Figure 6: Driftwood in Strandir, Iceland. Driftwood from Siberia washes ashore in Iceland and piles up on the shores. From "Driftwood" by Haraldur Þór Stefánsson, n.d. (https://www.halli.is/image/I0000Qe6i19Qm1Q4).

Turf was also sourced from the surrounding area of farms and was both used as a construction material and as a fuel source, mainly where there was no other fuel source available (Vésteinsson & Simpson, 2004, p. 186). Turf blocks were cut from the uppermost vegetated mat on mires and then piled to dry before being used. Turf cutting practices have been in use since the settlement and have left distinctive scars in mires, some still visible today (Zutter, 1997, p. 123). Another abundant source of fuel in Iceland was animal dung which when burned could be interpreted as evidence of fuel resource scarcity, but it could also be used as a fertilizer (Vésteinsson & Simpson, 2004, p. 182). In coastal farms driftwood and seaweed were also used as fuel (Mooney et al., 2022, p. 193; Vésteinsson & Simpson, 2004, p. 186).

The settlers did not only bring livestock to the country but also cereal cultivation (Zutter, 1997, p. 41). Iceland is on the verge of possible cereal cultivation due to its geographical location and climate (Guðmundsson et al., 2004, p. 101), however, there is evidence from the first centuries of habitation in the country, such as pollen, charred grains, medieval written accounts and place names indicative of cultivation (Guðmundsson et al., 2004, p. 80; Riddell et al., 2018, pp. 681–682). The only cereal macrofossils found in Iceland are *Hordeum* (barley) but there have also been found pollen from *Avena* (oats) which have sometimes been interpreted as weed (Bending, 2007, p. 137; Riddell et al., 2018, p. 682).

Cooling climate in the 14th and 15th centuries has traditionally been deemed the cause of the demise of cereal cultivation in Iceland (Guðmundsson et al., 2004, p. 102; Riddell et al., 2018, p. 681). Still, there is also a possibility that an increased emphasis on sheep instead of cattle resulted in less available dung as fertilizer, which caused less fertile soil and therefore worse conditions for cereal cultivation (Guðmundsson et al., 2004, p. 102). Another hypothesis is lack of manpower due to plagues and increased importation of grains in exchange for Icelandic stockfish beginning in the 14th century (P. C. Buckland et al., 1998, p. 97; Þ. Einarsson, 1962, p. 457; Guðmundsson et al., 2004, p. 102).

Earlier environmental studies have implied that the deforestation of Iceland was due to the agricultural practices of the settlers of the island and their descendants and also, that the deforestation happened in a single generational span (Þ. Einarsson, 1962, p. 453; Hallsdóttir, 1987, pp. 33, 37). More recent studies have on the other hand demonstrated that woodland cover was already declining before the settlement as well as the deforestation pace being more variable, and even in some places woodland lingering for centuries after the settlement (Erlendsson, 2007, p. 268; Lawson et al., 2007, p. 14; Ólafsdóttir et al., 2001, p. 213). The deforestation of Iceland made the settlers more reliant on foreign shipping and increased the isolation of the island along with fuelling economic inequalities in the society due to limited access of fuel and construction materials (Smith, 1995, p. 336).

1.4 Eastern Iceland

In this paper, eastern Iceland is the area of focus. The eastern part of Iceland has often been neglected through Icelandic history, and in some ways still is. It has always been far away from places of administration, and it has until recently, also been hard to reach due to many natural obstacles. It is sparsely populated and has therefore witnessed less development and construction work, which is often the reason for archaeological discovery and research. This has resulted in a bias in the distribution of archaeological research between different parts of the country. Besides, there has always been a distribution bias in the archaeological data in the country, reflecting research interests and efforts of researchers rather than factual distribution (Smith, 1995, p. 328). The same applies to environmental studies, because most pollen studies in Iceland have been done in the south-western and northern parts of the country and more research is needed in the northwest, east and in the highlands (S. A. Jónsson, 2009, p. 1; Trbojević, 2016, p. 16).

As already mentioned, the east coast of Iceland is characterised by narrow fjords with tall mountains (see Figure 7) containing one of the oldest rock formations of the country. The mountains of the Eastfjords are compound of Miocene basalt layers which tilt towards the west and have red silt- and sandstone layers in between (Denk et al., 2011, pp. 21–22; Tryggvason, 1957, p. 102). The mountains are rich of amygdales and a unique source of Iceland spar is located in Reyðarfjörður which has been mined (Tryggvason, 1957, p. 105). At the bottom of these fjords are lowlands with farms and towns. On the western side of the mountain range is a flourishing valley, Fljótsdalur with lake Lögurinn which drains towards north via the river Lagarfljót (Striberger et al., 2012, pp. 76–77). Along the lake is the largest natural forest in Iceland, Hallormsstaðaskógur (S. A. Jónsson, 2009, p. 1). Further to the west is Jökuldalur which is a highland valley and leads to Möðrudalsöræfi, a vast area of unvegetated wilderness (S. A. Jónsson, 2009, p. 8).

Figure 7: Seyðisfjörður. The Eastfjords are characterised by tall mountains and narrow fjords, such as Seyðisfjörður. (Photograph by Snædís Sunna Thorlacius).

The east part of Iceland has a more variable climate than the rest of the country (Guttormsson, 1974, p. 36). The part of Iceland with the most continental climate is the northeastern part where there is the most difference in temperature and the least precipitation because of the Vatnajökull glacier to the south (Kristinsson et al., 2019, p. 45). As previously stated the cold East Iceland Current flows along the east of Iceland but this often causes fog in the northeastern and eastern coasts making it much more common there than in other parts of the country (M. Á. Einarsson, 1984, p. 691; Guttormsson, 1974, pp. 37–38). During summer in the northern and eastern parts of Iceland, fair weather is associated with warm air from the south and a föhn effect from the mountains may even add to the temperature. On the other hand, fair weather in the southern and western part of the country is associated with cool air from the north and therefore does not reach the same temperatures (M. Á. Einarsson, 1984, p. 683). The highest ever measured temperature 30.5°C in Iceland was at Teigarhorn in the Eastfjords in 1939 and almost all of the highest temperature measurements have occurred in the east part of the country (Guttormsson, 1974, p. 37; T. Jónsson, 2007).

There are some plants that are only native to the eastern part of Iceland, such as *Saxifraga aizoides* and *Alchemilla faeroensis*, which is only native to eastern Iceland and the Faroe Islands (Guttormsson, 1974, pp. 42–44). Some think these species must have survived the last glaciation in refugium (Guttormsson, 1974, p. 42) but another possible explanation is that these plants have arrived on the east coast which faces Europe and have not yet managed to propagate to other parts of the country, probably because of obstacles such as glaciers and sand plains (Kristinsson et al., 2019, p. 47). One snail species *Arianta arbustorum* is also only native to the east part of Iceland and as already stated, reindeer as well (Guttormsson, 1974, pp. 46–47). A possible explanation for why the reindeer only survived in eastern Iceland is the continental climate north of Vatnajökull glacier where there is less precipitation during winter than in other places, resulting in less snow thickness (Guttormsson, 1974, p. 49).

The eastern part of Iceland is usually considered the most remote region of the country, being far from all administrative centres which have been located in the north, west and south through Iceland's history (S. A. Jónsson, 2009, p. 8). Not much is known about the history of this part of the country because the fewest written documents have been preserved from the east (S. A. Jónsson, 2009, p. 8). This is especially due to the *Jarðabók*, the Icelandic land register made in the beginning of the 18th century, for this area being burned in the Copenhagen fire in 1728 (Magnússon et al., 1980, p. V). In *Landnámabók* there are accounts from the settlement of eastern Iceland and it says that it was the first part of the country to become fully settled (*The Book of Settlements*, 1972, p. 109) which is not surprising because the eastern coast is the shortest distance from Norway. Many different men settled different areas of the fjords and valleys and divided their claimed land between their friends and families who followed them to Iceland (*The Book of Settlements*, 1972, pp. 109–127). Most of the fjords are hard to reach by land because the only way is over mountain roads, which can be impassable due to weather a big part of the year. However, many of the fjords have good natural anchorages and harbours which make them feasible for transportation by sea, especially for Viking settlers who arrived by ships.

As there is not a lot of written sources about the past of eastern Iceland through history, archaeology can be used to fill in the blanks. There have been a few important archaeological discoveries in eastern Iceland in the last decades. In Stöð in Stöðvarfjörður has been an ongoing excavation of the longest Viking Age hall in Iceland for the last seven years (B. F. Einarsson, 2020, p. 8, 2023, p. 3). It is in fact two halls; one younger, smaller hall inside an older, bigger hall. Bjarni F. Einarsson has claimed the site to be a pre-settlement seasonal workstation or a kind of shieling from Norway before the country was settled (B. F. Einarsson, 2017b, p. 33) but this has not yet been demonstrated. In 2004 human remains of a Viking Age woman were found in a mountain pass in the Eastfjords (Þórhallsdóttir, 2018, p. 3). A salvage excavation was conducted where the remains had been found and in total 526 beads were retrieved, which makes this the site with by far most beads ever found in Iceland (Þórhallsdóttir, 2018, pp. 12, 41).

Two phases of foundations of a timber church were excavated in Þórarinsstaðir, southern Seyðisfjörður in the years 1998-1999. The older foundations were a part of a church which was probably built before 1000 making them one of the oldest signs of the Christianisation of Iceland (Kristjánsdóttir, 2014, pp. 101–102). An Augustinian monastery, Skriðuklaustur (see Figure 8), was excavated in Fljótsdalur in the years 2002-2012 (Kristjánsdóttir, 2015, pp. 153–154). It was the only monastery situated in eastern Iceland of the eleven monasteries operated in Iceland during the Roman Catholic period (1000-1550 AD) and the only one that has been fully excavated (Kristjánsdóttir, 2015, pp. 154, 157;

Figure 8: The ruins of Skriðuklaustur monastery. The ruins are exhibited at the site in Fljótsdalur. (Photograph by Snædís Sunna Thorlacius).

Kristjánsdóttir et al., 2014, p. 561). Skriðuklaustur was operated from 1493-1554 and is believed to have served the purpose of a hospital due to pathological symptoms on human skeletons excavated in the monastery cemetery (Kristjánsdóttir, 2015, pp. 166–167).

1.5 Research aim

In the years 2020-2023 the biggest commercial excavation ever conducted in eastern Iceland has been undertaken by Antikva ehf. in Fjörður, Seyðisfjörður, and has revealed archaeological features from all periods in Icelandic history. Among the features are a Viking Age hall, pagan graves, animal houses, a medieval midden, a modern farm mound and a water mill (Traustadóttir et al., 2022; Traustadóttir, Hjartarson, et al., 2023; Traustadóttir, Þórhallsdóttir, et al., 2023). Some of the best preserved turf walls belonging to a medieval structure ever found in the country appeared in the archaeological excavation of summer 2022 (Traustadóttir, Þórhallsdóttir, et al., 2023) and samples were taken from the structure's floor and hearths for investigation. Micro- and macro-botanical remains from these contexts, among others, have been retrieved and analysed and will be presented here in relation to environmental conditions of post-settlement eastern Iceland. This is done to add to the scarce existing environmental data from this area and to gain a better idea of the environment and living conditions of the early habitants of eastern Iceland.

The eastern part of Iceland has a different climate, fauna and flora than other parts of the country which makes it interesting to wonder if the environmental conditions during the settlement and the changes following it, were comparable to other parts of the country. Therefore, it is intriguing to compare the results from existing research findings from the east part of the country to the rest of the country. The aim of this research is to get a comprehensive image of the pre- and post-settlement environment in eastern Iceland by revising previous botanical studies from the area along with macro- and micro-botanical analysis from Fjörður, archaeological site in eastern Iceland. The agricultural and exploitative practices of humans and their effect on the environment of the area will be discussed and compared to the rest of the country, with special emphasis on livestock, arable agriculture and domestic use of plants.

1.6 Organization

In chapter 2 the methodologies of archaeobotanical research that have been employed in eastern Iceland will be discussed. The pros and cons of micro- and macro-botanical research will be compared as well as the potential and drawbacks of the methods and interpretations of archaeobotanical data. The evidence of human exploitation detected in botanical remains will be introduced and methods employed on samples from Fjörður described. In chapter 3 previous botanical research in eastern Iceland, environmental and archaeological, will be outlined, as well as a discussion on the botanical remains retrieved from the medieval site of Fjörður. In chapter 4 the botanical results presented in chapter 3 will be discussed in relation to the vegetation and different types of human exploitation. They will subsequently be compared with the rest of the country and the differences and similarities will be analysed, with possible explanations presented. Finally, concluding remarks will be stated and potential future research suggested.

2. Material and methods

2.1 Archaeobotany

The material used in this research is archaeobotanical data from published articles and reports on environmental and archaeological research in eastern Iceland, along with new data from Fjörður, which is added to the existing dataset. The methods used in these studies include macro- and micro-botanical analysis from both archaeological and non-archaeological contexts and one ancient sedimentary DNA research on lake sediments. The main methods used in these studies will be introduced and discussed in this chapter to enhance understanding of the data and interpretations discussed in later chapters.

Plant remains can be used to reconstruct past ecosystems and landscapes. Furthermore, they can be evidence of the relationship between humans and plants, such as human exploitation and past food economies (Cappers & Neef, 2021, p. 9). Humans have used plants for many different purposes through human existence, such as food, fuel, clothing, construction and for medicinal and religious purposes (Cappers & Neef, 2021, p. 17). However, studies based on botanical remains are obscured by many different processes that can affect their interpretation. These processes are called post-depositional processes or taphonomic processes and include for example mixing, contamination and preservation. This applies to ecological reconstructions and causes a discrepancy between the established vegetation and botanical remains present in the soil (Cappers & Neef, 2021, pp. 123–125).

Plant remains vary in sizes from macro-botanical remains such as wood fragments, flowers, leaves, stems, roots and buds to micro-botanical remains such as pollen and spores. Furthermore the constituents of plants can be examined such as phytoliths, starches, lipids, isotopes and DNA (Cappers & Neef, 2021, pp. 13–14). Spores are formed by fungi, mosses, clubmosses, quillworts, ferns and horsetails and are single cell offspring that can germinate and grow into an adult under suitable conditions. Pollen grains are cells produced by seed plants that are released from a male reproductive structure and transported to a female reproductive structure, where they can fuse with an ovule and prompt fertilization. A fertilized ovule can develop into a multicellular seed which is then dispersed and can grow into a new adult (Cappers & Neef, 2021, pp. 21–22).

2.1.1 Micro-botanical remains

Pollen can be dispersed by wind, water, insects and other animals over considerable distances. Due to the long distances pollen can travel, they can reflect both the local and the regional vegetation. Pollen from plants that are wind pollinated are more likely to be found in pollen cores because they produce pollen in a larger amount than plants that are insect pollinated. This is because insect pollination is more effective than wind pollination and therefore needs less pollen production (Cappers & Neef, 2021, pp. 23–25; Moore et al., 1991, p. 2). When pollen lands in soil it gets stratified, reflecting the environment it belonged to and when studied, it can be used to reconstruct the same environment (Moore et al., 1991, p. 2).

"Palynology is concerned with both the structure and the formation of pollen grains and spores, and also with their dispersal and their preservation under certain environmental conditions" (Moore et al., 1991, p. 1). Pollen and spores have many similar characteristics, such as their size (usually 20-40 µm) and the fact that they need dispersal for their adequate function. They are also both surrounded by tough, resistant walls which help them preserve longer and often have diagnostic features (see Figure 9) useful in palynological analysis (Moore et al., 1991, p. 1). Pollen and spores are best preserved under anaerobic conditions and can, in fact be preserved for millions of years (Cappers & Neef, 2021, p. 26). Pollen can usually only be identified to family or generic level but occasionally it can be identified to species level (Moore et al., 1991, pp. 1–2).

To extract the micro-botanical remains in a sample, concentration procedures are necessary. These techniques focus on dissolution and removal of non-pollen matrix in the sediment and therefore depend on the different materials present in the sample. For example, can potassium hydroxide be used on peat samples, hydrochloric acid on samples rich in calcium carbonate, hydrofluoric acid on silica-rich samples and acetolysis to remove

Figure 9: Betula pollen seen through a high power binocular microscope. It can be easily identified by its three vestibular pores. Found in a sample from a floor layer in Fjörður. (Photograph by Snædís Sunna Thorlacius).

cellulose. These methods can be applied to concentrate pollen and spores without damaging them because of their extreme resistance to many corrosive chemicals (Moore et al., 1991, pp. 41–44).

When interpreting pollen diagrams, it is important to bear in mind that a proportion of species in pollen rain is not necessarily equal to the proportion of those species in the vegetation. Furthermore, "the pollen production varies among plant species and relates, among other things, to the number of pollen in a stamen, the number of stamens in a flower, the number of flowers on a plant, and the type of pollination" (Cappers & Neef, 2021, pp. 27–28). For example, barley and wheat are both self-pollinating which often results in cereal pollen being represented by small percentages (Cappers & Neef, 2021, p. 27).

2.1.2 Macro-botanical remains

Macro-botanical remains are the most common type of archaeobotanical remains studied, because they are "highly visible, likely to be recovered and assumed to directly reflect cultural uses of plants" (Zutter, 1999, p. 833). Macro-botanical research is usually mainly focused on the analysis of seeds and fruits, which have many diagnostic features (see Figure 10) and can therefore in most cases be identified to a species level. The taxonomical resolution and quantification of macro-botanical remains make it possible to reconstruct the surrounding vegetation using detailed information on ecological requirements (Cappers & Neef, 2021, pp. 32–35). The preservation of seeds depends on environmental conditions, but they are best preserved under extremely dry conditions and in waterlogged soils (Cappers & Neef, 2021, p. 125). There is scarcity of research on macro-botanical remains from archaeological contexts in Iceland (Martin, 2002, p. 32) because the conditions are often not suitable for good macro-botanical preservation due to intense freeze and thaw conditions (Zutter, 1999, p. 833).

Figure 10: Charred Carex seeds seen through a microscope. They can be identified by their trigonous shape. Found in a sample from a floor layer in Fjörður. (Photograph by Snædís Sunna Thorlacius).

Seeds can be dispersed over a wide range of distances. Some plants produce seeds that are dispersed over small distances but can survive for considerable periods in the soil due to, for example dormancy. These seeds usually lack morphological features for transport and can be identified in the archaeological material by a large number, distributed densely over a small area (Cappers & Neef, 2021, p. 75). Other plants produce seeds that are dispersed over long distances. These kinds of plants produce seeds in larger numbers because they have a smaller chance of landing in a spot appropriate for germination. They are able to travel widely due to morphological adaptations to external dispersal vectors, such as water, wind and animals (Cappers & Neef, 2021, pp. 75–76). For example, seeds that are dispersed by wind are light and often have wings or hairs that enable them to glide, meanwhile seeds adapted to animal dispersal are often consumed and end up in the excrement, which is excellent for germination (Cappers & Neef, 2021, pp. 76–78).

Wood remains found in archaeological contexts can be interpreted for example as remnants of former vegetation, trade, fuel, building materials and tools. Wood remains can be identified to genus level due to characteristic wood structures visible in thin sections (Cappers & Neef, 2021, p. 32). Trees produce a new growth ring every year making it possible to recognize annual rings and thus determine their age using dendrochronology. Wood can be preserved in waterlogged or desiccated conditions, but charred wood, including charcoal used as fuel and wood that has burned accidentally, can be preserved in different moisture conditions (Cappers & Neef, 2021, pp. 31–32). Non-native wood found in Iceland can both be of driftwood origin or imported, but so far there has not been found a sufficient method to distinguish between them (Mooney et al., 2022, pp. 197–199).

"The goal of all recovery methods is to successfully isolate plant remains from their surrounding sediment matrix without loss or damage" (White & Shelton, 2015, p. 95). Many different methods can be used to retrieve macro-botanical remains from sediments. Dry screening can be practical in dry conditions but botanical remains may be lost or damaged using this method, meanwhile wet screening/sieving is suitable for waterlogged contexts but it can be very physically demanding and can also damage botanical remains (White & Shelton, 2015, pp. 96–99). Floatation is based on the principle that light fraction, such as charred plant remains, float to the water's surface meanwhile heavy fraction, such as lithics, sink to the bottom. Different versions of both manual and machine-assisted floatation devices have been designed with different qualities for different situations, such as access to water and electricity, conditions of the plant remains and funding (White & Shelton, 2015, pp. 100–106).

The number of seeds or fruits from each species retrieved can be indicative of their relative contribution in past vegetation or diet, but it does not necessarily coincide with their original representation in the vegetation or diet (Cappers & Neef, 2021, p. 73). Therefore, it is very important to keep in mind that "the representativeness of a particular plant species in a seed bank depends on, among other factors, the number of seeds that are produced, the kind of seed dispersal, seed predation, and the resistance to decay" (Cappers & Neef, 2021, p. 32). Macro-botanical records enable more certain interpretations of past plant presence than micro-botanical records, because seeds and fruits offer higher taxonomic resolution and a more local signal than pollen (Geirsdóttir et al., 2020, p. 13; Hallsdóttir, 1987, p. 37). Similarly, macro-botanical remains from archaeological contexts give more information on the relationship between humans and plants (Bending, 2007, p. 10). On the other hand, macro-botanical sample sizes are generally low and can rarely capture the full range of vegetation (Geirsdóttir et al., 2020, p. 13).

2.2 Evidence of human exploitation

Humans are experts in exploiting their environment and thus, many different types of evidence of human exploitation of plants can be observed. Expected evidence of impact by agricultural communities on vegetation are destruction of natural vegetation and an introduction of crop and weed species associated with arable and pastoral activities (Moore et al., 1991, p. 9). This is evident in Iceland as charcoal layers from shortly after the settlement have often been interpreted as evidence of land clearance with fire at the same time as grassland taxa increased at the expense of woodland taxa (Bending, 2007, p. 37).

Primary anthropogenic pollen indicators are plants that can be indicative of human impact, such as crops like cereals. Secondary anthropogenic pollen indicators are plants that indirectly indicate human presence, such as weeds which can be products of agriculture or various species of plantains that tolerate trampling (Cappers & Neef, 2021, p. 27). Moreover, humans can act as pollinators using artificial pollination to ensure high yields and have been doing so for thousands of years (Cappers & Neef, 2021, pp. 73–74). People can also function as dispersal agents of seeds and fruits from off-site vegetation to settlements in many ways, such as collecting, harvesting and importing non-native species. In that way seeds and fruits of non-native plants can be evidence of long-distance trade connections (Cappers & Neef, 2021, p. 35).

The appearance of cereal pollen has long been considered evidence of human presence in Iceland (Erlendsson, 2007, p. 68). Cereal pollen is bigger than other grass pollen and most cereal pollen found in Iceland is of *Hordeum* group, which includes both *Hordeum vulgare* and *Leymus arenarius*. The former is not native in Iceland but was introduced and cultivated. The latter occurs naturally in many places on the island and all cereal pollen found pre-settlement has been estimated to be of this taxon (Þ. Einarsson, 1962, pp. 449–450; Erlendsson, 2007, p. 82). *Hordeum* and *Triticum* have to be identified to a subspecies or variety in order to model former crop selection (Cappers & Neef, 2021, p. 35) which can make *Hordeum* group pollen problematic as an indicator of cultivation (Erlendsson, 2007, p. 82). Therefore, it is more reliable if also weed taxa commonly associated with arable activities are present in botanical assemblages to underscore arable activity (Erlendsson, 2007, pp. 123, 210, 251, 258). On the other hand, when *Avena*-type pollen is present it strongly suggests cultivation because "no Poaceae pollen from wild grasses in Iceland belong to the *Avena*-type group" (Erlendsson, 2007, p. 120).

For a long time, it was assumed that there was a congruence between macro- and micro-botanical remains and that they corresponded to each other. It has though been demonstrated that this is not always the case. Cynthia Zutter (1999) retrieved both macro- and micro-botanical remains from two farm middens in Iceland and came to the conclusion that there was not a congruence between them, but that "each type provided data regarding different Icelandic plant-use practices" (p. 843). In fact, she found there were substantial numbers of macro-botanical remains from heath shrubs but on the other hand there were low pollen percentages from the same vegetation category. This can be interpreted as evidence of these plants being preferentially collected as sustenance for both humans and animals. Zutter claims this should be expected because "plants and plant parts are differentially collected and utilized by humans and these patterns of plant-use will effect [*sic*] whether or not micro or macro remnants are encorporated [*sic*] into the archaeological record" (Zutter, 1999, p. 843). Collection of multiple archaeobotanical datasets from archaeological sites is suggested to achieve a bigger range of past plant use (Zutter, 1999, p. 843).

2.3 Methodology

The author conducted micro- and macro-botanical analysis on samples from the archaeological site of Fjörður in Seyðisfjörður, Iceland. This was done to add to the limited existing archaeobotanical data available for eastern Iceland and to gain more knowledge about the relationship between the early settlers and the environment of the area. Archaeological layers of interest were retrieved for research in the summer of 2022 and a subsample was shipped from Iceland to Leiden University, The Netherlands. The samples used for botanical research were retrieved from floor, hearth and charcoal layers from medieval structures. The methodology of micro- and macro-botanical analysis done on the samples from Fjörður, is described below. The results will be discussed in upcoming chapters in relation to other research on the environment and human exploitation of eastern Iceland.

2.3.1 Micro-botanical remains

A subsample from a floor layer in a structure from the period 940-1100 AD was prepared for pollen analysis according to Moore et al. (1991) and Faegri et al. (1989). A *Lycopodium* tablet was added to the sample to estimate pollen concentration values according to Stockmarr (1971). The preparation procedure included tetrasodium pyrophosphate to break cohesive bonds between particles, potassium hydroxide to dissolve humic acids, acetolysis to remove cellulose and lignin, sodium polytungstate to make organic matter float to the top and ethanol and isopropyl alcohol to remove water. After the preparation the material was mixed with silicone oil and spread over a microscope slide. Then it was examined in a high power binocular microscope in x400 magnification. The pollen and spores were counted from three rows on the slide; one near the edge, one in the middle and one in between those two. The pollen and spore specimens were identified to a suitable taxonomic level with the aid of lab assistant Ilse Kamerling, published pollen catalogues (Beug, 2004; Moore et al., 1991), articles (García et al., 2004; Piasai & Sudsanguan, 2018; van Geel et al., 1980, 2003) and reference material available at the botany lab of Leiden University. Separation of Poaceae grains from larger grains of wild grasses and cereals follows Andersen (1979). All pollen taxa were included in the pollen sum and their frequency compared (see Table 2). The preservation of micro-botanical remains in the examined layer was good. The nomenclature follows Moore et al. (1991).

2.3.2 Macro-botanical remains

Subsamples from a floor layer and hearth from a structure from the period 940-1100 AD and a charcoal layer from a structure from the period 1160-1300 AD were soaked in water and dishwashing liquid in buckets for at least 24 hours to segregate the soil. The soil was then wet sieved through a stack of sieves of decreasing mesh size (see Figure 11) and thus divided according to size. The sieves were 1 mm, 0,5 mm, 0,25 mm and 0,15 mm meshed and the material from each sieve was put into separate beakers with water. The material in each beaker was poured into a petri dish which was then examined under a low powered binocular microscope (see Figure

Figure 11: Soil sieving. The soil was soaked and then poured through sieves of different mesh size. The photograph was taken in the Laboratory for Archaeobotanical studies in Leiden University. (Photograph by Snædís Sunna Thorlacius).

12). Specimens of interest were picked out and collected onto a petri dish with paper drenched in ethanol for preservation. The macro-botanical remains were identified to a suitable taxonomic level with the aid of Dr. Michael Field, a published botanical catalogue (Cappers et al., 2006) and reference material available at the botany lab of Leiden University. The preservation of macro-botanical remains in the examined layers was not ideal but there were both charred and un-charred remains. The number of specimens retrieved was too small for statistical analysis. The Flora followed is *Flóra Íslands: Blómplöntur og byrkningar* (Kristinsson et al., 2019).

Figure 12: Microscopic work. The sieved material was put in beakers and poured into petri dishes which were examined under a microscope. The photograph was taken in the Laboratory for Archaeobotanical studies in Leiden University. (Photograph by Snædís Sunna Thorlacius).

3. Previous research

According to the author's knowledge, archaeobotanical research has been done on ten sites in eastern Iceland, which can be seen labelled yellow on Figure 13 and listed in Table 1. The locations are Þistilfjörður, Nykurvatn, Geirsstaðir, Þórarinsstaðir, Hallormsstaðaskógur, Stöð, Hrafnkelsdalur, Pálstóftir, Papey and Hoffell. New archaeobotanical results from the site of Fjörður (labelled blue in Figure 13) are also published in this paper. Here the sites will be introduced and their results addressed with special emphasis on their pre- and post-settlement vegetation and the evidence of anthropogenic influence on the environment.

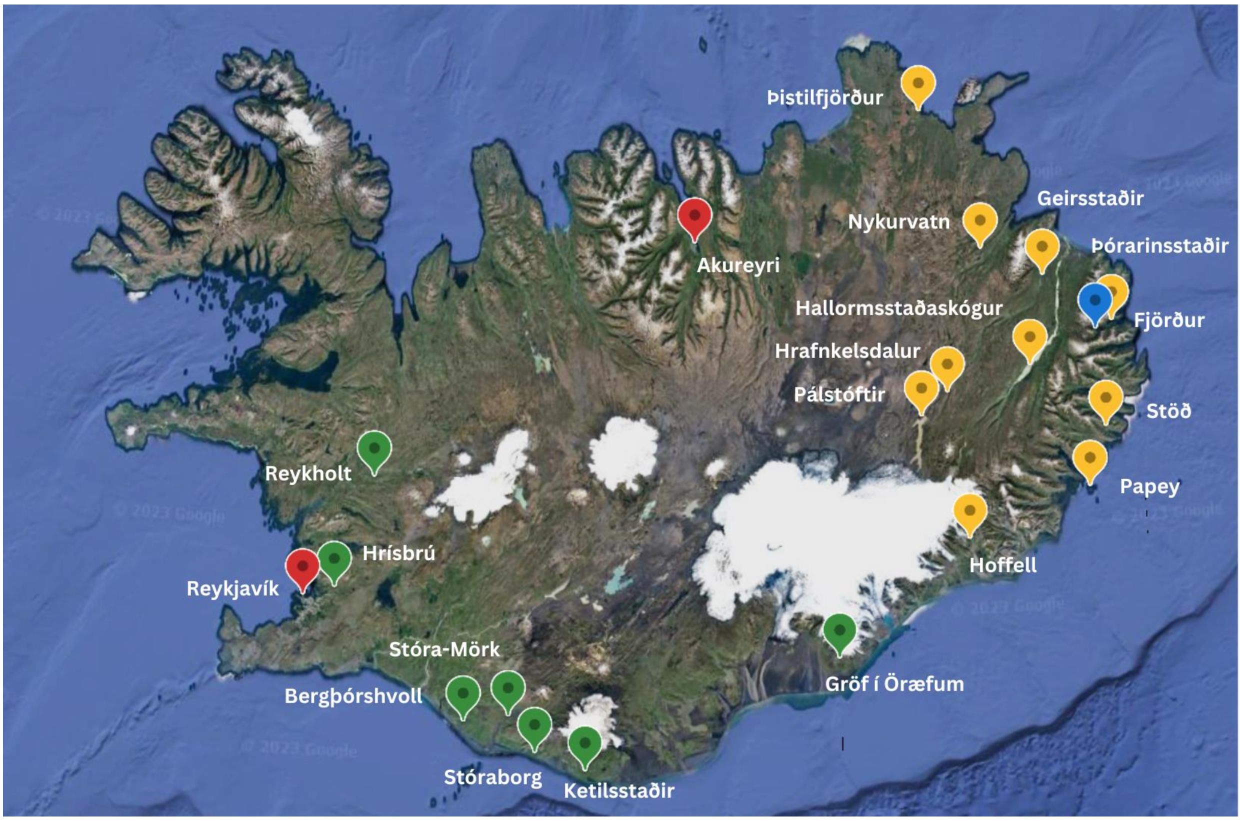

Figure 13: A map of Iceland with the location of the sites mentioned in this paper. Yellow = the sites where archaeobotanical research has been conducted in eastern Iceland. Blue = archaeobotanical data introduced in this paper. Green = other sites mentioned in relation to the sites in question. Red = big towns. Created with Google Earth (https://earth.google.com/web/).

Table 1: Previous archaeobotanical research in eastern Iceland. The authors, publication year, site and type of archaeobotanical data of all the sites in eastern Iceland where archaeobotanical research has been conducted.

Author(s)	Publication year	Site	Archaeobotanical data
Zutter	1997, 1999	Þistilfjörður	Pollen, macros
Karlsdóttir et al.	2014	Þistilfjörður	Pollen
Roy et al.	2017, 2018	Þistilfjörður	Pollen, macros
Alsos et al.	2021	Nykurvatn	Plant DNA
Griffin	1999	Geirsstaðir	Pollen, macros
Guðmundsdóttir	2013	Þórarinsstaðir	Wood
Einarsson	1961	Hallormsstaðaskógur	Pollen
Jónsson	2009	Hallormsstaðaskógur	Pollen
Einarsson	2015-2023	Stöð	Charcoal
Hallsdóttir	1982	Hrafnkelsdalur	Pollen
Guðmundsson/Verrill/Milek	2007	Pálstóftir	Pollen, macros
Buckland	1995	Papey	Pollen, charcoal
Okko	1955	Hoffell	Pollen

3.1 Þistilfjörður

Three botanical studies have been conducted in the vicinity of Svalbarð by Þistilfjörður bay on the northeast corner of Iceland. Both micro- and macro-botanical research was done on the farm midden of Svalbarð and in a wetland associated with the farm (Zutter, 1997, p. 7, 1999, p. 833). Svalbarð farm has been inhabited since the first centuries after the settlement and the midden consists of a millennium of habitation (Zutter, 1997, p. 73). A research focused on birch hybridization was also based on pollen analysis from the area (Karlsdóttir et al., 2014, p. 97). Another research on the vegetation history and human impact on the landscape and vegetation of the area was based on both micro- and macro-botanical analysis from peat cores collected near abandoned farms close to Svalbarð (Roy et al., 2017, p. 671, 2018, p. 1).

Around 9000 years ago dwarf birch found its way to Northeast Iceland and started colonizing the area (Karlsdóttir et al., 2014, p. 105). There was a peak in *Betula pubescens* pollen at 7,500-7,100 years ago but based on the *Betula* pollen accumulation rate birch woodlands in Þistilfjörður were “never dense during the Holocene, but rather a shrubland with dwarf birch and scattered birch trees” (Karlsdóttir et al., 2014, p. 105). According to Roy et al. (2018, p. 9) there were suitable environmental conditions for a development of a birch forest from 6,430 to 5,810 years ago in the Þistilfjörður area. The birch subsequently started to decline and the woodland gave way for mires and heathland. Another birch peak was around 4,800 to 4,250 years ago (Roy et al., 2018, p. 9). Similarly, the *Betula* pollen peak in a monolith from the same area was around 4,700 years ago and has been declining ever since (Karlsdóttir et al., 2014, p. 105). Both Roy et al. (2018, p. 11) and Karlsdóttir et al. (2014, p. 105) agree that since around 4,000 years ago *Betula* has been disappearing in the area and it was absent during the Medieval Warm Period (850-1250 AD). On the other hand, Zutter previously concluded that the environment around Svalbarð was dominated by woodland between 3,500-2,200 years ago and subsequently dominated by wetlands between 2,000-1,200 years ago. These changes were possibly associated with changes in climatic conditions but could also have been due to changes in hydrological and/or edaphic conditions (Zutter, 1997, p. 116).

The archaeobotanical record of Svalbarð indicates that the vegetation around the farm consisted mainly of wetlands, anthropogenic grasslands and heathland shrubs (Zutter, 1997, p. 140). There were however, differences in the amount of evidence of human influence between the sample sites around Svalbarð, which Zutter suggests may be because a part of the record was removed due to peat or turf cutting, probably for fuel or construction material (Zutter, 1997, p. 122). According to Zutter (1997, p. 142) the settlement of the Þistilfjörður area altered the vegetation with intensive and extensive land use such as clearing and burning of woodland for grazing. An indication of human influence in Svalbarð is represented in a decrease in birch woodlands and a distinctive increase in *Equisetum* and grasslands with apophytes. There was also a peak of charcoal particles indicating human presence and charcoal retrieved from the midden, mainly from *Picea* taxa (Zutter, 1997, pp. 122, 128). Furthermore, there was a small number of *Hordeum* group pollen recovered in the Svalbarð midden which could be due to importation of cereals or *Leymus arenarius*. It cannot be considered sufficient evidence for cereal cultivation, which is no wonder considering its northerly location (Zutter, 1997, p. 143).

On the contrary, the study by Karlsdóttir et al. (2014, p. 102) did not identify any obvious changes in vegetation that could be attributed to the settlement in the area and similarly Roy et al. (2018, p. 12) did not detect any drastic changes in the vegetation of the area during the last 1000 years, apart from a decline in most species during 1500-1800 AD which could be due to the Little Ice Age. According to Roy et al. (2018, p. 12) there were only scattered birch trees in the area when it was settled, which was in the middle of the 10th century (Roy et al., 2017, p. 684). The human settlement in the area only slightly affected the birch vegetation which was already in decline (Karlsdóttir et al., 2014, p. 105). But, increase in Poaceae and the appearance of *Polygonum cf. aviculare* as well as charcoal fragments and calcined bone, indicate human presence in Svalbarðstunga (Roy et al., 2018, pp. 11–12). A possible explanation for this inconsistency between researches in the same area is the difference in topography of the sample sites (Roy et al., 2018, p. 11).

According to the macro-botanical research done by Zutter on the midden in Svalbarð, the period from the settlement to 1050 AD was characterized by an abundance of grasses and apophytes which were subsequently replaced by heathland taxa until the 17th century (Zutter, 1997, p. 133). In the first centuries following the settlement, grass hay was probably the most common fodder, but possibly wetland taxa were collected as a supplementary fodder source (Zutter, 1997, p. 140). From 1150-1636 AD the macro-fossil record consisted of large amounts of heathland taxa (Zutter, 1997, p. 140) but the micro-botanical record on the same midden demonstrated that Poaceae and Cyperaceae dominated the whole record and heathland taxa was only present in low proportions (Zutter, 1997, pp. 134–135). This discrepancy in the macro- and micro-botanical records in the midden "suggests that heath taxa were being selectively collected, possibly as a source of leaf-hay fodder for livestock and berries for human consumption" (Zutter, 1997, p. 140). The results of a research done on plant and insect macrofossils and diatoms on peat monoliths in Þistilfjörður, indicate the area was a wet meadow or a peatland from the settlement until 1400 AD. They also demonstrate that some areas were used as pastures and were fertilized to encourage sedge growth for fodder intended for domestic animals (Roy et al., 2017, pp. 681–682).

3.2 Nykurvatn

At Nykurvatn a lake sediment core was analysed for ancient sedimentary DNA to determine Holocene vegetation development in the area. The lake is located more than 400 m above sea level in a highland plateau in northeastern Iceland (Alsos et al., 2021, p. 4). In total 172 plant taxa were identified in the sedimentary record which spanned the last 8,600 years (Alsos et al., 2021, p. 1). The sedimentary record from Nykurvatn shows no significant changes in vegetation during the whole period and suggests that there never developed a woodland cover at the site (Alsos et al., 2021, p. 13). At Nykurvatn there was detected obvious human impact, reflected in the disappearance of *Juniperus communis* at 1040 AD as well as an increase in grass taxa. This was probably caused by grazing animals but likely accompanied by cutting (Alsos et al., 2021, p. 14).

3.3 Geirsstaðir

On the site of Geirsstaðir in the Northeast of Iceland a church dated to around 900-1100 AD was excavated in 1997 (Kristjánsdóttir, 1998, p. 14). A reconstruction of the church based on the archaeological excavation can be seen on Figure 14. Samples were retrieved from floor layers of the structure for micro- and macro-botanical analysis by Kerstin Griffin (Griffin, 1999). According to her research on the floor layer, the roof collapsed on top of the floor layer shortly after the structure was no longer in use. It was possibly torn down by people because all timber in the structure had been removed, probably to reuse or use as fuel (Kristjánsdóttir, 1998, pp. 17–18). One piece of wood, which Kristjánsdóttir theorises may have belonged to the façade, was sampled and identified as *Betula*

Figure 14: A reconstruction of the Geirsstaðir church. The reconstruction was based on the archaeological evidence and is open to visitors. (Photograph by Snædís Sunna Thorlacius).

(Kristjánsdóttir, 1998, p. 19).

In Geirsstaðir were found charcoal pits under and in front of the church structure, possibly used for iron working because of remains of ash, charcoal, peat ash, slag and melted iron (Kristjánsdóttir, 1998, p. 12). Based on this it is possible that in the spot where the church was located was originally a smithy from the farm, which was later improved and turned into a church (Kristjánsdóttir, 1998, p. 26). The plant remains found in the floor layers of the church in Geirsstaðir were few and monotonous with only *Selaginella*, Cyperaceae and *Coenococcum* present (Griffin, 1999, p. 2; Kristjánsdóttir, 1998, p. 18). Therefore, it is hard to make any assumptions about the environment of the site. *Selaginella* was predominant in the floor layer which could be explained by the plant being placed on the floor to dry it up (Kristjánsdóttir, 1998, p. 26). One of the reasoning behind the structure being a church is the fact that no evidence of dung, wool, food, cooking nor fuel was found which makes the function of the structure likely not an animal house, dwelling, pantry nor storage (Kristjánsdóttir, 1998, p. 19).

3.4 Þórarinsstaðir

Previously mentioned Þórarinsstaðir is located in Seyðisfjörður, in the Eastfjords. Wood samples from the church structures, coffins and charcoal found in Þórarinsstaðir were first analysed by Simona Lazzeri and Nicola Macchioni (Kristjánsdóttir et al., 2001, p. 97) but revised by Lísabet Guðmundsdóttir (Guðmundsdóttir, 2013, p. 66). Wood from the church structures, coffins and charcoal found in Þórarinsstaðir seems to both have been made from native wood, driftwood and imported wood (Guðmundsdóttir, 2013, p. 69). The church structures were mainly made from trees which are common as driftwood, such as *Larix, Pinus sylvestris, Picea* and *Pinus cembra* but also local wood such as *Betula* and *Salix* (Guðmundsdóttir, 2013, pp. 70–76). Wood from coffins found in Þórarinsstaðir has been analysed as *Larix, Picea* and *Pinus sylvestris* and charcoal found in many graves in Þórarinsstaðir has been analysed as *Larix, Picea abies, Pinus sylvestris, Pinus cembra, Betula* and *Quercus* (Guðmundsdóttir, 2013, p. 73).

Quercus is non-native in Iceland but the charcoal of this species found in graves was found along with *Betula* charcoal and could therefore be from artifacts made of these two species which were burned and then put in the grave of their owners (Guðmundsdóttir, 2013, p. 77). Wood of *Pinus pinea* was also found in a church structure. It grows around the Mediterranean and was therefore most likely imported but this species was commonly used for shipbuilding (Guðmundsdóttir, 2013, pp. 70–71). Based on this, the *Pinus pinea* remains found in Þórarinsstaðir could be from a reused part of a ship (Kristjánsdóttir et al., 2001, p. 104).

There was another archaeological artifact originated from the Mediterranean found in Þórarinsstaðir, a porphyry stone most likely from Egypt and probably serving the purpose of an altar stone (Kristjánsdóttir, 2014, pp. 106–107).

3.5 Hallormsstaðaskógur

Hallormsstaðaskógur forest in Fljótsdalshérað (see Figure 15) is the largest natural forest in Iceland (S. A. Jónsson, 2009, p. 1). In his PhD research Þorleifur Einarsson analysed pollen samples from Hallormsstaðaskógur among other places (Þ. Einarsson, 1961, p. 13). Later on Sverrir Aðalsteinn Jónsson also conducted a pollen study on a core from a small pond in Hallormsstaðaskógur (S. A. Jónsson, 2009, p. 24) and his more recent results will be considered here. Jónsson's pollen analysis demonstrated that the last hundreds of years before the settlement, the area was covered by birch forest. Furthermore, its cover was increasing and culminated shortly before the settlement (S. A. Jónsson, 2009, pp. 45–48).

After the area around Hallormsstaðaskógur was settled the forest around the pond quickly started to retreat along with an increase in the sedimentation rate, until the forest had

Figure 15: Hallormsstaðaskógur forest by lake Lögurinn. The largest natural forest in Iceland. (Photograph by Snædís Sunna Thorlacius).

almost disappeared by year 1070 AD (S. A. Jónsson, 2009, p. 48). The forest cover started to recover drastically in the 15th century which has been explained by the population decrease caused by Black Death and/or the importation of iron resulting in less demand of charcoal (S. A. Jónsson, 2009, pp. 49–50). The reason for Hallormsstaðaskógur's survival is that it did not go extinct before the population decrease in the 15th century and could therefore use the opportunity for recovery, meanwhile most other forests had already been too exploited to recover (S. A. Jónsson, 2009, p. 50).

3.6 Stöð

There has been an ongoing excavation of previously mentioned Stöð in Stöðvarfjörður since 2015 (B. F. Einarsson, 2023, p. 3). Charcoal remains retrieved from the Viking Age halls have been analysed by Ólafur Eggertsson and some have been radiocarbon dated. Furthermore, over a hundred eDNA samples have been retrieved inside the halls and around them, which results have yet to be published (B. F. Einarsson, 2023, p. 21). The analysis of the charcoal has shown that most of the wood used for fuel was *Betula* and *Salix,* which are both local taxa. Nevertheless, a few samples have been identified as other taxa, such as *Juniperus* which was also local, *Quercus* which could have been imported and *Pinus* which could have been driftwood (B. F. Einarsson, 2021, p. 75, 2022, p. 33, 2023, p. 22). Einarsson claims that driftwood was likely not used as fuel because it contains too much salt. He also points out that most of the coniferous charcoal found on the site belongs to the older phase, which therefore could have been from wood brought by the settlers, instead of driftwood from the nearby shore (B. F. Einarsson, 2021, p. 21). No peat ash has been found in Stöð (B. F. Einarsson, personal communication, May 28, 2023).

3.7 Pálstóftir

Pálstóftir was an archaeological site located at 580 m above sea level in the highlands of eastern Iceland (see Figure 16). It has been interpreted as a shieling in use between 950 and 1070 AD (Lucas, 2007, p. 3). In the research of Pálstóftir, samples were retrieved from cultural layers for all kinds of analysis, such as macro- and micro-botanical, micromorphological, chemical and for the retrieval of bone, insect, wood and other organic remains (Guðmundsson, 2007, p. 1). Pollen analysis was conducted on samples from a soil section in the vicinity of the archaeological site and on cultural layers from structures on the site (Verrill, 2007, p. 1).

The earliest part of the Pálstóftir pollen record is from shortly after the initial settlement of Iceland and shows a high level of Cyperaceae but relatively low Poaceae levels. Arboreal or shrub taxa representation was also relatively low with *Salix* being the principal component

Figure 16: The ruins of Pálstóftir during excavation. The site has now been submerged by a reservoir for a hydropower plant. From "Fornleifauppgröftur á Pálstóftum við Kárahnjúka 2005" by L. Gavin, 2007, p. 23. (https://www.nabohome.org/uploads/fsi/KHN05_Palstoftir.pdf).

(Verrill, 2007, pp. 2–3). *Betula* began to expand slightly after this initial period, which could be interpreted as readjustment following the first clearance efforts of the settlers, but overall tree and shrub taxa still declined. There is evidence of renewed clearance activity with increasing grass, sedge and herb pollen at the expense of trees and shrubs during the period between 960-1025 AD. During this period there were low microscopic charcoal values which indicate that fire was not used as a clearance method but probably grazing, which fits the interpretation of Pálstóftir being a shieling (Verrill, 2007, pp. 2–4).

A sample from a floor layer in an archaeological structure from this same period was dominated by grass and sedge pollen and had a lower level of *Betula* and *Salix* pollen than the samples from the section, which could be a consequence of the vegetation in the immediate vicinity of the structure (Verrill, 2007, pp. 2–4). In the period 1025-1290 AD there was a decline in Cyperaceae and Poaceae but an increase in *Salix* and an increase in the variety of herb taxa. This could be interpreted as a reduction in grazing intensity which fits the timing of the abandonment of the site in the late eleventh century. Fern spores of *Selaginella selaginoides*, *Diphasiastrum* and *Polypodium* were present at low levels during this period but declined later. After 1290 AD willow continued expanding and grasses declined, as well as a reduction in floristic diversity occurred, probably a consequence of the re-establishment of *Salix* scrub (Verrill, 2007, pp. 2–4).

Most of the macro-botanical remains retrieved from cultural layers in Pálstóftir were charcoal analysed as *Salix* and *Betula.* Other taxa found in the samples were *Empetrum nigrum* leaves and *Juniperus communis* leaves as well as a part of a *Dryas octopetala.* The macro-botanical remains retrieved from Pálstóftir most likely origin from fuel gathered from the vicinity and therefore reflect the environment and vegetation of the site (Guðmundsson, 2007, p. 2). Based on micromorphological research on floor layers in Pálstóftir there is evidence of different fuel use, charred wood in the earlier period and peat ash in the later period (Milek, 2007, p. 9). One charred seed of *Stellaria media* was found in Pálstóftir which probably came from animal dung being burned as fuel (Guðmundsson, 2007, p. 2). In the pollen records of Pálstóftir there were occasional *Alnus* and *Pinus* present which are taxa not native to Iceland and have been interpreted as a result of long-distance airborne transport (Verrill, 2007, p. 3).

3.8 Hrafnkelsdalur

Many farm ruins have been found in high-altitude Hrafnkelsdalur valley. This sparked interest in investigating the impact of human settlement on the vegetation in the area, which was the purpose of Margrét Hallsdóttir's pollen analysis there (Hallsdóttir, 1982, p. 253). She sampled two cores in the area reaching as far back as 550 AD and identified around 50 taxa of pollen and eight of spores (Hallsdóttir, 1982, pp. 255–257). The dominating environment at the high-altitude site of Hrafnkelsdalur, both pre- and post-settlement, was wetlands with sedge vegetation and grassland. This is probably due to the site being located above the limit of birch forest growth during this period (Hallsdóttir, 1982, pp. 257, 261).

In the site of Hrafnkelsdalur, human impact was detected as disappearance of *Angelica* due to grazing and an increase in *Galium*, *Thalictrum alpinum, Equisetum* and Caryophyllaceae. In the 13th century brushwood increased which has been interpreted as consequence of leaf-hay gathering and winter grazing ceasing in the area (Hallsdóttir, 1982, pp. 260–261). In Hrafnkelsdalur there was an increase in Cerealea type pollen after the settlement which has been interpreted as evidence of *Avena* and *Hordeum* cultivation, even though some of it could also be due to the spread of *Leymus arenarius.* At the end of the 11th century there was a rise in *Selaginella selaginoides* which was interpreted as evidence of abandonment of cultivated fields in the area and most likely the abandonment of the inhabitation, but there probably was a shieling in the area later on (Hallsdóttir, 1982, p. 260).

3.9 Papey

On the island of Papey off the southeast coast of Iceland archaeological excavations were conducted in the 1960s-1980s. The modern surface of the island is covered in *Carex*-dominated bog over deep peat deposits. Samples were retrieved from a pit cut into a peat-filled basin in proximity of the archaeological remains for insect, pollen and charcoal research (P. C. Buckland et al., 1995, pp. 246–247). The occupation period of the settlement in Papey was at least two centuries, from after the settlement tephra had fallen, until its abandonment in the first half of the 12th century (P. C. Buckland et al., 1995, pp. 253–256).

The pollen from the earliest phase of the Papey profile showed an aquatic environment which was then replaced by a heath environment. After that Poaceae and Cyperaceae became the dominant taxa alternately (P. C. Buckland et al., 1995, pp. 256–259). In the pollen analysis done on samples from Papey, *Betula* pollen never exceeded 3.5% of the pollen sum which shows that there is no clear evidence for birch growth on the island, but the pollen present is evidence of birch presence regionally (P. C. Buckland et al., 1995, p. 259). *Betula* percentages and concentrations declined directly below the settlement tephra layer which could reflect changes on the mainland. There was also a peak in microscopic charcoal frequency directly below the settlement tephra layer which could be interpreted as human presence in the region before the settlement of Papey was established (P. C. Buckland et al., 1995, pp. 259–261).

Pollen analysis from Papey has shown an increase in Cyperaceae, *Potentilla* and *Rumex acetosa* type shortly after the settlement tephra layer, but the two latter have been linked to the appearance of hay meadows and grazing. Furthermore, *Succisa pratensis* pollen occurred for the first time above the settlement tephra indicating introduction with the hay and dunnage of the early settlers. On the other hand, *Betula* and Poaceae decreased after the settlement, the *Betula* likely reflecting the mainland development (P. C. Buckland et al., 1995, pp. 259–260). *Filicales* seems to have disappeared during the settlement and did not return until a while after the settlement had been abandoned. This could be due to domestic animals but this development is opposite to the development often observed on the mainland, where spores became more common after the settlement because of the landscape opening (P. C. Buckland et al., 1995, pp. 259–260). Insects found in samples from Papey related to livestock are for example *Melophagus ovinus* (sheep ked) which is only found on sheep and *Lathridius minutus* and *Xylodromus concinnus* which primary habitats are places where decaying hay is present such as in hay barns (P. C. Buckland et al., 1995, p. 254).

Pieces of crosses made from driftwood of Siberian origin were found in Papey, which gave evasive radiocarbon dates deemed unreliable. *Betula* and *Larix* charcoal from a floor layer in an archaeological structure in Papey was also dated but the results could not be considered very reliable because the charcoal could have been from peat, giving a much older date than when it was in use (P. C. Buckland et al., 1995, pp. 248–249).

3.10 Hoffell

The Finnish geologist Veikko Okko studied glacial drift in Iceland in the 1950s and in relation to that he conducted pollen analysis on a soil section from Hoffell, east of Vatnajökull. The generated pollen diagram does not have any dating but it shows that the flora contained *Betula* pollen in much greater abundance earlier than in present times and that *Salix,* Poaceae and Cyperaceae pollen increased at its expense (Okko, 1955, pp. 19–20). Otherwise, other deductions cannot be made from this data because of the lack of chronology and low resolution.

3.11 Fjörður

The ongoing excavation of the archaeological site of Fjörður is located in Seyðisfjörður, at the head of the fjord. During the excavation season of summer 2022, a few medieval buildings were discovered and excavated (Traustadóttir, Þórhallsdóttir, et al., 2023). One of those buildings, dated to 940-1100 AD, had two hearths in separate corners and surprisingly well preserved turf walls (see Figure 17) due to a landslide that leaned up to them and consequently supported and protected them ever since (Traustadóttir, Þórhallsdóttir, et al., 2023). Micro- and

Figure 17: The sampled hearth. This hearth was located in a corner of a well preserved turf building dated to 940-1100 AD. The turf layers in the walls can be seen as alternating colours. Published with permission from Antikva ehf.

macro-botanical remains were retrieved from a hearth and a floor layer from this building. Pollen sequences based on cores from the midden at Fjörður and from a nearby wetland are still in progress. Therefore, there is yet a lack of satisfactory data on the environmental conditions of the area.

The macro-remains retrieved from the cultural layers of Fjörður were mainly *Selaginella selaginoides,* Caryophyllaceae*,* Ericaceae and mosses. As can be seen in Table 2, the pollen analysed from the same floor layer contained all of the previous taxa but was dominated by Poaceae (see Figure 18), including *Hordeum* group pollen based on Andersen (1979, p. 82), and the second most common taxon was Cyperaceae. Among the other pollen taxa found were *Betula* (see Figure 9)*, Ranunculus* type*,* Lactuceae*, Thalictrum, Calluna, Galium, Salix, Potentilla,* and *Typha angustifolia* type. These taxa most likely reflect the vegetation surrounding the site. A likely explanation for why Poaceae dominated the pollen assemblage but was virtually nonexistent in the macrofossil assemblage is that Poaceae macrofossils generally do not preserve well (Michael Field, personal communication, April 28, 2023). Coniferous tracheids (see Figure 18) were recognised under the microscope which could be interpreted as evidence of either imported wood or more likely driftwood.

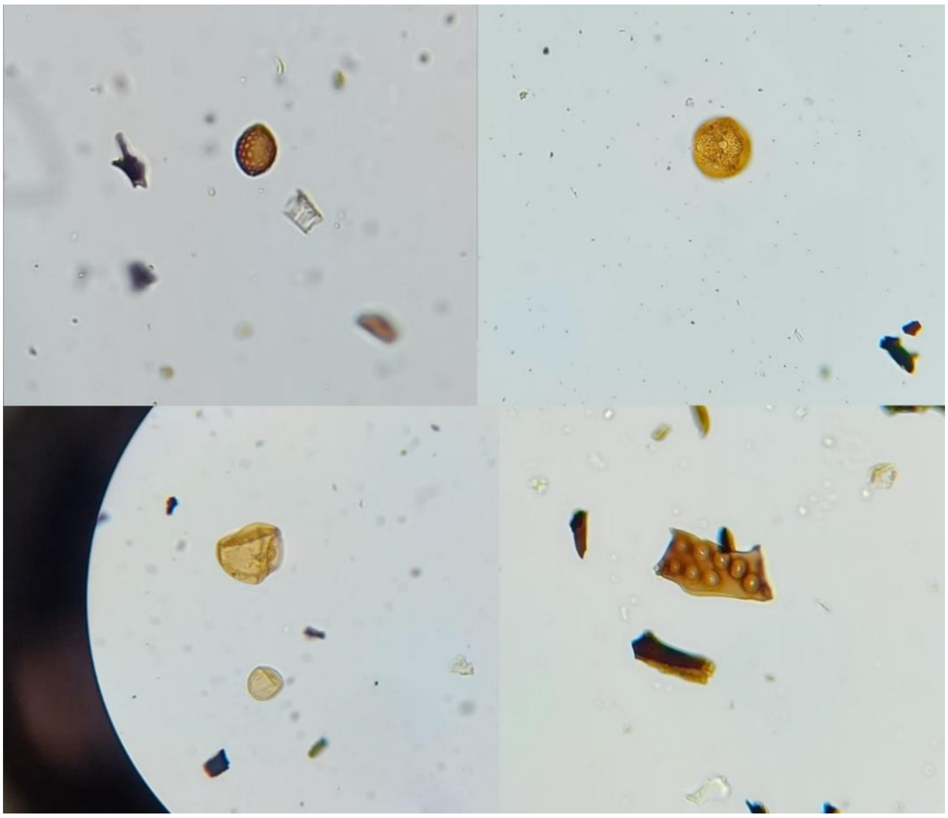

Figure 18: Example of micro-botanical remains retrieved from the floor layer from Fjörður. Top left is a Gelasinospora fungal spore, top right is a Caryophyllaceae pollen grain, bottom left are two Poaceae pollen grains (the upper big one identified to Hordeum group) and bottom right is a coniferous tracheid. (Photograph by Snædís Sunna Thorlacius).

Table 2: List of micro-botanical remains found in a floor layer from a medieval structure in Fjörður, eastern Iceland. The list consists of a total sum of pollen taxa and non-pollen palynomorph taxa divided by types. Methods and means of identification are described in chapter 2.3.1.

Pollen	Count	Non-Pollen Palynomorphs	Count
Trees		**Lesser plants**	
Betula	10	*Pteropsida* monolete	28
cf. *Juniperus*	4	*Selaginella*	15
cf. *Sciadopitys*	1	Reticulate fern spore	1
cf. *Taxodiaceae*	1	Fern spore	1
Shrubs		*Equisetum*	1
Calluna	2	cf. *Botrychium*	1
Vaccinium	2	**Fungi**	
Salix	2	*Gelasinospora* sp.	8
Ericales undiff.	1	*Chaetomium* HDV type 7A	6
Herbs		*Sordaria*	5
Poaceae	113	*Sporormiella* type 113	2
Cyperaceae	18	*Podospora* HDV type 368	1
Hordeum group	12	**Other**	
Ranunculus type	9	Unidentified spore	7
Caryophyllaceae	4		
Lactuceae	4		
Thalictrum	3		
Urtica/Parietaria/Morus	2		
Rumex acetosa type	2		
Potentilla	2		
Galium	1		
Asteraceae undiff.	1		
Apiaceae	1		
cf. Thymelaeaceae	1		
Aquatics			
Typha angustifolia type	3		
Potamogeton/Triglochin	3		
Other			
Unidentified-Scabrate verrucate/inaperturate	2		
cf. *Scrophulariaceae*	1		
Unidentified-Monocolpate reticulate	1		
Lycopodium spike	35		
Indeterminable	17		
Total	**258**	**Total**	**76**

The sampled floor layer and hearth from the structure in Fjörður dated to 940-1100 AD mainly consisted of peat ash. Another layer, which was sampled from another structure on the site dated to 1160-1300 AD (Traustadóttir, Þórhallsdóttir, et al., 2023) was solely made from various sizes of charcoal pieces (see Figure 19). This allows the interpretation of peat being used as fuel in the 10th-11th centuries and charcoal being used as fuel in the 12th-13th centuries. But this does not eliminate the possibility of both fuels being used during the whole period, possibly along with others, which is the most probable scenario.

Figure 19: Charcoal pieces being sieved. A sampled layer from a building in Fjörður dated to 1160-1300 AD contained mainly charcoal. The photograph was taken in the Laboratory for Archaeobotanical studies in Leiden University. (Photograph by Snædís Sunna Thorlacius).

In the floor layer from the structure in Fjörður, both Cyperaceae pollen and charred *Carex* seeds (see Figure 10) were found which could be evidence of sedge hay fodder being collected from wet meadows for domestic animals. On the other hand, the pollen could simply reflect the vegetation in the area and the seeds could be from peat which was burned as fuel. Spores of animal dung loving *Sordaria* fungus were also found in the same layer which further supports the presence of livestock. There were quite a few *Hordeum* group pollen (see Figure 18) found in the floor layer from Fjörður which could be from a cereal taxon. Furthermore, a charred *Hordeum* seed (see Figure 20) was found in the hearth sample which was probably meant for human consumption and may have been cultivated in Fjörður or imported.

Figure 20: Hordeum seed. A charred Hordeum seed found in a sample from a hearth in Fjörður seen through a microscope. (Photograph by Snædís Sunna Thorlacius).

4. Discussion

In this chapter the results of the environmental and archaeobotanical research done in eastern Iceland discussed in chapter 3 will be summarised and discussed in relation to other proxies and the rest of the country. Firstly, the environment and vegetation before the settlement will be compared and then the environmental effect of the settlement and changes related to it. Subsequently, archaeobotanical evidence of human exploitation of the environment such as domestic use, livestock and cultivation based on botanical evidence along with other archaeological and environmental indications, will be compared.

4.1 Pre-settlement

4.1.1 Environment and vegetation

The general picture of the vegetation of Iceland prior to the arrival of humans was characterized by birch woodland (see Figure 21) in the drier areas of the lowland, sheltering tall herb communities, dwarf shrub heath on less fertile soils and more exposed areas and sedge dominated mires (Hallsdóttir, 1987, p. 36). Due to lack of environmental research on the east part of Iceland it is interesting to examine if the same applies to this area as the rest of the country, especially when considering the unique characteristics of the sea currents, climate and flora (see chapter 1). The present data on the environment and vegetation of eastern Iceland pre- and post-settlement will be discussed here and compared to similar data from other parts of the country. These research sites have different locations, elevations, contexts, ranges and resolutions and can therefore be used for variable interpretations of the environment and

Figure 21: Þórsmörk, southern Iceland. The wooded landscape of Þórsmörk might resemble what large parts of Iceland looked like when Norse settlers arrived in the 9th century. (Photograph by Snædís Sunna Thorlacius).

vegetation of the area.

A few environmental investigations not based on botanical data have been conducted in the east part of Iceland and will firstly be discussed in relation to the archaeobotanical data. They can still provide important proxy data regarding environmental conditions and change related to vegetation. Analysis on a 10,500 year continuous sediment sequence from lake Lögurinn has demonstrated a Holocene Thermal Maximum for the region ca 7,900 to 7,000 years ago (Striberger et al., 2012, p. 85). This agrees with the estimation of the Holocene Thermal Maximum in Northern Iceland based on chironomid-inferred temperatures and pollen records, occurring ca. 8,000-6,000 years ago (Caseldine et al., 2006, p. 2329). On the other hand, temperature reconstructions based on subfossil midges from lakes in Northern and Northeastern Iceland indicate a general trend of warming through the early and middle Holocene, culminating less than 5,000 years ago (Axford et al., 2007, p. 3354).

Based on pollen and macrofossil analysis in North and Northwest Iceland, the maximum expansion of birch woodland in Iceland happened during the Holocene Thermal Maximum (Eddudóttir et al., 2016, p. 723; Wastl et al., 2001, p. 199). According to data from Þistilfjörður, the arrival of dwarf birch to Northeast Iceland was around 9,000 years ago (Karlsdóttir et al., 2014, p. 105), which is later than in some other parts of Iceland (Hallsdóttir & Caseldine, 2005, p. 319). This could be explained by the limited birch conditions of the Þistilfjörður area (Karlsdóttir et al., 2014, p. 105). According to the palynological results of Karlsdóttir et al. (2014, p. 105) in Þistilfjörður there was a short-lived *Betula pubescens* pollen peak at 7,500-7,100 years ago, which fits into the proposed Holocene Thermal Maximum by Striberger et al. (2012, p. 85), but the maximum *Betula* pollen peak did not occur until 4,700 years ago. This pollen peak has also been detected in the pollen records of Roy et al. occurring at 4,800 to 4,250 years ago (Roy et al., 2018, p. 9) and fits with the peak warmth in North Iceland occurring less than 5,000 years ago, according to Holocene temperature estimations based on subfossil midges (Axford et al., 2007, p. 3354). The pollen peaks detected in the records of Zutter were at 6,300-6,000 years ago and 3,500-2,200 years ago, which does not fit with the results of the other records of the area (Zutter, 1997, p. 116). Based on the results of Karlsdóttir et al., (2014) and Roy et al., (2018), it can be concluded that there were warmer conditions 7,900-7,000 years ago and again less than 5,000 years ago. Both periods resulted in peaks in birch expansion which has been declining since around 4,000 years ago (Karlsdóttir et al., 2014, p. 105; Roy et al., 2018, p. 11). It depends on which period is considered represent the Holocene Thermal Maximum if the maximum distribution of woodland in eastern Iceland happened simultaneously or not.

A multiproxy study was done on lake sediments spanning the last 3000 years from lake Gripdeild, west of Lögurinn. It shows a constant cooling along with increased landscape instability and soil erosion through the record, culminating in the period of the Little Ice Age between 1250-1900 AD (Bergþórsdóttir, 2014, p. 37). Comparatively, a Neoglacial cooling started around 3,000 years ago in Northeast Iceland based on chironomid data (Axford et al., 2007, p. 3354). Likewise, combined palynological records from southwestern to northeastern Iceland demonstrated a climatic deterioration starting around 3,000 years ago, which along with human exploitation, is likely responsible for the maximum land degradation after the settlement (Ólafsdóttir et al., 2001, pp. 208, 213). High resolution lake sediment records from seven lakes spread from South to Northwest Iceland, similarly revealed landscape instability and soil erosion starting in the Middle to Late Holocene. This was likely triggered by natural events like volcanic eruptions, which caused irreversible soil erosion several centuries before the settlement, contradicting the previously thought human effect being the triggering factor (Geirsdóttir et al., 2020, p. 16).

During the latter half of the Holocene the vegetation generally changed towards more open and patchy birch woodland with expanding mires and heathland, especially in the lowlands. Waves of woodland regeneration occurred in the late Holocene and a *Betula* pollen peak is often apparent shortly before the settlement or below the Landnám tephra (Hallsdóttir, 1987, p. 33; Hallsdóttir & Caseldine, 2005, pp. 328–329). According to terrestrial pollen from the south and west of Iceland the final pre-settlement expansion of *Betula* (cf. *pubescens*) occurred 600-800 AD which was likely due to a short episode of improved conditions during a relatively harsh climatic period. Even though improved flowering conditions are considered contributing to the pollen rise, an increase in woodland extent and density during this period is likely also responsible (Erlendsson & Edwards, 2009, p. 1089). This trend can be seen in the Hallormsstaðaskógur pollen record as a culmination of *Betula* pollen just before the settlement (S. A. Jónsson, 2009, p. 48).

The only sites in eastern Iceland offering reliable archaeobotanical data from before the settlement are Þistilfjörður, Nykurvatn, Hallormsstaðaskógur, Hrafnkelsdalur and Papey. Based on pollen records there was no woodland in Þistilfjörður (Karlsdóttir et al., 2014, p. 105; Roy et al., 2018, p. 11), Nykurvatn (Alsos et al., 2021, p. 13), Hrafnkelsdalur (Hallsdóttir, 1982, p. 262) nor Papey (P. C. Buckland et al., 1995, p. 259) when settlers arrived. At the time of the settlement the environment in Þistilfjörður was characterised by peatland, heathland (Roy et al., 2018, p. 12) and wetland (Zutter, 1997, p. 116), Hrafnkelsdalur by wetlands with sedge vegetation and grassland (Hallsdóttir, 1982, pp. 257, 261) and Papey was also sedge dominated during the settlement (P. C. Buckland et al., 1995, p. 257). It is important to keep in mind that Icelandic pollen research can be biased because there is heavy reliance on peat deposits where sedge pollen can be over-represented (Zutter, 1997, p. 173).

Another vital observation is that these sites do not reflect the best vegetation conditions. As can be seen on Figure 11, Þistilfjörður, Þórarinsstaðir, Fjörður, Stöð, Papey and Hoffell are all coastal sites. Furthermore, Þistilfjörður is located very northerly and "conditions in the oceanic Northeast Iceland were near the lower limits of the temperature requirements of downy birch for most of the Holocene" (Karlsdóttir et al., 2014, p. 107). Besides, Papey is a small island outside of the mainland, unsheltered and exposed to the weather forces. Hallormsstaðaskógur is the only true inland site, but Geirsstaðir is somewhere between an inland site and a coastal site, located in a river plain in a wide valley. On the other hand, Nykurvatn, Hrafnkelsdalur and Pálstóftir are all highland sites located more than 400 m above sea level (Alsos et al., 2021, p. 4; Hallsdóttir, 1982, p. 254; Lucas, 2007, p. 5). The upper limit of birch growth has been estimated at 450-500 m above sea level during optimum climatic conditions based on micro- and macro-botanical research on cores in North Iceland (Wastl et al., 2001, p. 197).

When considering this, it is hardly surprising that most of these sites were unforested when settlers arrived, but this also highlights the need for more environmental research on sites where woodland was more likely present in pre-settlement times. Nevertheless, the fact that there never developed a woodland cover at Nykurvatn (Alsos et al., 2021, p. 13) is opposed to highland sites in North and Northwest Iceland, which showed birch woodland during the Holocene Thermal Maximum (Eddudóttir et al., 2016, p. 723; Wastl et al., 2001, p. 199). This may be an indication of a difference in vegetation development at higher elevation between the west and east parts of northern Iceland, which may be rooted in the difference in the dominant ocean currents (Alsos et al., 2021, p. 13).

Most of these sites do not provide prime conditions for forest formation, but according to a long-term potential vegetation cover model based on pollen from sites in southwestern and northern Iceland, the average potential vegetation cover when the country was settled had reduced to about 50%, including less than 10% birch forest cover. This does not support the view of an extensive forest cover during the settlement of Iceland as had previously been presumed (Ólafsdóttir et al., 2001, p. 207) but rather fits the woodless landscape evident in eastern Iceland according to the data available. The only site with evidence of woodland present at settlement times is in Hallormsstaðaskógur, which is no surprise considering that it is the biggest natural forest in Iceland in modern times (S. A. Jónsson, 2009, pp. 1, 45).

To summarise, the pre-settlement environment of eastern Iceland was quite versatile, spanning the range from heavily wooded areas to sedge dominated wetland, but most of the sites seem to have been characterised by heathland and grassland. These differences can be attributed to the different geographical locations of the sites, such as their topography, elevation and distance from the shore. Differences in pre-settlement vegetation have also been detected in other parts of the country. Egill Erlendsson conducted pollen research on three different sites in southern and western Iceland, which indicated different pre-settlement vegetation. The inland Reykholtsdalur area was largely wooded by open *Betula pubescens* woodland allowing shrubs like *Salix, Betula nana* and *Juniperus communis* to flourish (Erlendsson, 2007, pp. 235–238). Stóra-Mörk was similarly characterised by open *Betula pubescens* woodland in which *Salix* flourished (Erlendsson, 2007, p. 242). However, in Ketilsstaðir in Mýrdalur, there was no woodland cover which is unlike most other sites studied in southern Iceland. The conditions were rather quite open and wet, which could perhaps be explained by the exposed coastal conditions of Mýrdalur (Erlendsson, 2007, p. 241).

4.2 Post-settlement

4.2.1 Environment and vegetation

In general the main characteristic of the change in vegetation in Iceland due to the settlement is the increase of grasses at the expense of birch (Hallsdóttir, 1987, p. 34). Some of the sites in eastern Iceland showed clear evidence of anthropogenic influence at the time of or after the settlement but others did not show strong or even any evidence of environmental and/or vegetational change. The different records from Þistilfjörður show different results; Zutter observed *Betula* decline and an increase in grasses, *Equisetum*, apophytes and a peak of charcoal particles (Zutter, 1997, p. 122) meanwhile Karlsdóttir et al. (2014, p. 102) and Roy et al. (2018, p. 12) did not observe any drastic environmental changes attributed to human settlement in the area. Evidence for human presence was though detected as a slight increase in grasses (Karlsdóttir et al., 2014, p. 102) and introduction of anthropogenic indicators (Roy et al., 2018, p. 11). This range of human influence on the environment has been detected in other parts of the country as well. According to Erlendsson's results the environmental changes caused by the settlement of Iceland were different between areas. In places where woodland was absent at the time of settlement the changes were not as dramatic but the vegetation was still affected (Erlendsson, 2007, p. 268).

The immediate influence of human settlement in Hallormsstaðaskógur was a steady decline in the birch forest until around 1070 AD when the forest around the sample site had almost disappeared (S. A. Jónsson, 2009, p. 48). This rapid deforestation following the arrival of humans has been demonstrated in many sites in Iceland (Hallsdóttir & Caseldine, 2005, p. 329). Generally, rapid deforestation occurred close to settlements but further away woodland lingered longer, as seen in Erlendsson's (2007, p. 268) research. However, it is interesting that the sample site in Hallormsstaðaskógur is quite a distance from the nearest farm and seems to have disappeared more rapidly than expected (S. A. Jónsson, 2009, pp. 48–49). The sudden disappearance of *Juniperus communis* detected at 1040 AD in Nykurvatn (Alsos et al., 2021, p. 14) has also been observed in a lake in the Northwest Icelandic highland margin around 1,000 years ago (Eddudóttir et al., 2016, p. 724).

In Pálstóftir there are no pre-settlement pollen data, so the influence of settlement is hard to detect. Considering the site is located at an elevation of 580 m above sea level it is unlikely that it was forested during the settlement period. Sedges were dominant in 880-960 AD which has been interpreted as reflecting post-clearance activities of the newly arrived settlers (Verrill, 2007, pp. 2–3). Due to the fact that there was scarce woody taxa present in Hrafnkelsdalur when it was settled, no dramatic changes followed human arrival, but the clearest evidence was the disappearance of *Angelica* which is very popular among grazing animals and has also been used as human sustenance and medicine through the ages (Hallsdóttir, 1982, p. 262; Kristinsson et al., 2019, p. 674). Papey presented similar problems due to its unforested nature prior to the settlement, but the anthropogenic indicator *Succisa pratensis* and an increase in *Rumex acetosa* type has been attributed to human activity in the area as well as the disappearance of *Filicales* (P. C. Buckland et al., 1995, pp. 259–260). The presence of both *Succisa pratensis* and *Rumex acetosa* type has been interpreted as reflecting a change from stability to landscape disturbance following the settlement (Bending, 2007, p. 88).

The resurgence of scrub coverage in Pálstóftir after 1025 AD has been interpreted as the result of the abandonment of the site (Verrill, 2007, pp. 2–3). The farms investigated in Hrafnkelsdalur were abandoned by the 12^{th}-13^{th} centuries (Hallsdóttir, 1982, p. 263). Subsequently, there was an increase in scrubs such as *Salix, Juniperus* and *Betula* which is evidence of vegetative resurgence after human abandonment (Hallsdóttir, 1982, pp. 260–261). The abandoned farms investigated by Roy et al. (2017, p. 682) in Þistilfjörður can be considered marginal highland settlements due to their elevation, but most such settlements were abandoned by the 13^{th}-14^{th} centuries (Vésteinsson & McGovern, 2012, p. 209). Interestingly, the farms in Þistilfjörður were not abandoned until the late 16^{th} century, which has been explained by the fact that the area was treeless when it was settled and therefore had more grazing resilience than previously forested areas which were abandoned earlier (Roy et al., 2017, pp. 682–683). This has also been attested by Erlendsson who claims that where woodland was absent the environment had developed a more robust vegetation able to withstand more grazing (Erlendsson, 2007, p. 268).

The sediment sequence from lake Lögurinn detected an increase in carbon around 950 years ago, which has been linked to increased soil erosion due to land use following the settlement of Iceland (Striberger et al., 2012, p. 87). There was also an increase in the sedimentation rate detected immediately after the settlement in Hallormsstaðaskógur (S. A. Jónsson, 2009, p. 48). The same applies to an increase in soil erosion detected at 1000 AD in a lake sediment record from northwestern Iceland (Eddudóttir et al., 2016, pp. 724–725) and an increase in sediment accumulation rates during the initial period of settlement, especially in upland areas, according to geomorphological and tephrochronological research in southern Iceland (Dugmore et al., 2000, p. 29).

An indication of a short warmer period around 900-1100 AD was detected in the lake sediments of Gripdeild (Bergþórsdóttir, 2014, p. 45) which fits with the general interval of the Medieval Warm Period from the 9th to the 13th centuries (Hughes & Diaz, 1994, p. 111; Ogilvie et al., 2000, p. 43). This indication is however more subtle than from sites in western and central Iceland, which may be explained by the altitude of the Gripdeild site, but also its distance from the warm Irminger Current and the cooling influence of the nearby East Iceland Current (Bergþórsdóttir, 2014, p. 42). Pollen records from Þistilfjörður show increasing abundance of wild herbaceous and peatland species from 900-1330 AD indicating warm and wet conditions (Roy et al., 2018, p. 11) and diatom data also shows a general trend toward warm and wet climate conditions in Þistilfjörður 800-1200 AD (Roy et al., 2017, p. 683). On the other hand, there was no strong indication of more thermophilic flora during the Medieval Warm Period, in the DNA data from Nykurvatn, than other periods (Alsos et al., 2021, p. 14).

he culmination of soil erosion and landscape instability in 1250-1900 AD, according to the Gripdeild sediment data (Bergþórsdóttir, 2014, p. 37), likely reflects the Little Ice Age which some believe to have begun in the 13th century and lasted until the 19th /20th century (Ogilvie & Jónsson, 2001, pp. 11–12). The general decline in almost all species during the period 1500-1800 AD in a pollen record from the Þistilfjörður area could also have been due to the Little Ice Age (Roy et al., 2018, p. 12). The cooling effect of the later part of the Little Ice Age can also be recognised in the lake sediments from Lögurinn as an expansion of Eyjabakkajökull glacier which reached its maximum Holocene extent during this period (Striberger et al., 2012, p. 87).

In the pollen record from Hallormsstaðaskógur there is clear evidence of forest recovery starting in 1430 AD but from around 1750 AD there was a slow but constant retreat of birch until the forest had almost completely disappeared by 1900 AD (S. A. Jónsson, 2009, pp. 49–50). Comparatively, around 1500 AD and after 1700 AD there were catastrophic soil erosion phases in northeastern Iceland, which can also be linked to the effect of the Little Ice Age accelerated by anthropogenic exploitation (Ólafsdóttir et al., 2001, pp. 211–213; Ólafsdóttir & Guðmundsson, 2002, pp. 165–166). In summary, grazing livestock and woodcutting reduced the resilience of the Icelandic ecosystem to a cooling climate and tephra deposition. It weakened any potential for recovery during the Medieval Warm Period and the ecosystem struggled to withstand further grazing, tephra deposition and the cooling conditions of the Little Ice Age (Eddudóttir et al., 2016, p. 725).

4.2.2 Domestic use

Humans are specialised in using their environment for their benefit. Many ways of domestic use of plants by early Icelanders are known as their environment offered various functional plant resources such as trees, driftwood, peat, turf and edible and medicinal plants (Bending, 2007, pp. 131–143). It is interesting to see the evidence of these human activities in the archaeological record of eastern Iceland, their consequences and differences or similarities to other parts of the country.

Wood remains from Geirsstaðir were identified as *Betula*, probably locally sourced (Kristjánsdóttir, 1998, p. 19). However, the church structures and coffins from Þórarinsstaðir were mainly made from coniferous wood such as *Pinus sylvestris, Pinus cembra, Picea* and *Larix*. These taxa are common as driftwood which indicates an abundance of driftwood on the shores of Seyðisfjörður during the first centuries of habitation (Guðmundsdóttir, 2013, pp. 75–76). The coniferous tracheids encountered in the micro-botanical remains from Fjörður also suggest the presence of driftwood in Seyðisfjörður. The crosses found in Papey made from driftwood are another example of driftwood use in eastern Iceland (P. C. Buckland et al., 1995, p. 248). According to analysis of wood remains from church structures and coffins, driftwood taxa have been identified in three churches in northern Iceland, demonstrating how common and vital the resource of driftwood must have been in the first centuries of habitation on this treeless island (Guðmundsdóttir, 2013, pp. 90–91).

Charcoal was among the botanical remains retrieved at Pálstóftir (Guðmundsson, 2007, p. 2), Geirsstaðir (Kristjánsdóttir, 1998, p. 12), Þórarinsstaðir (Kristjánsdóttir et al., 2001, p. 101), Svalbarð (Zutter, 1997, p. 128), Papey (P. C. Buckland et al., 1995, p. 249), Stöð (B. F. Einarsson, 2022, p. 33) and Fjörður. The charcoal from Geirsstaðir and Fjörður was not identified but the charcoal from Pálstóftir consisted of *Salix* and *Betula* (Guðmundsson, 2007, p. 2), from Papey consisted of *Betula* and *Larix* (P. C. Buckland et al., 1995, p. 249), the charcoal from Svalbarð was identified as *Picea* (Zutter, 1997, p. 128), from Stöð mainly *Betula* and *Salix* but also *Quercus* and *Pinus* (B. F. Einarsson, 2022, p. 33) and charcoal remains from graves and a hearth in Þórarinsstaðir were identified as *Betula, Quercus, Pinus sylvestris, Pinus cembra, Larix, Picea* and *Salix* (Guðmundsdóttir, 2013, pp. 72, 77). This shows both local woodlands being used for fuel such as *Betula* and *Salix*, common driftwood taxa such as *Picea, Pinus* and *Larix* and imported wood such as *Quercus*. According to a study on wood exploitation in the Norse North Atlantic, the most common type of wood used in Iceland for charcoal making was birch, but there has also been found evidence of driftwood being used for charcoal (Mooney et al., 2022, p. 193). The remains of *Quercus* and *Pinus pinea* found in Þórarinsstaðir are evidence of long distance transport of wood, but most likely in the form of artifacts (Guðmundsdóttir, 2013, pp. 76–77). This does not only apply to the church at Þórarinsstaðir because wood remains from six graves in the graveyard of Hrísbrú in Southwest Iceland were also identified as *Quercus* (Guðmundsdóttir, 2013, p. 89).

Peat ash was found in Geirsstaðir (Kristjánsdóttir, 1998, p. 12), Pálstóftir (Milek, 2007, p. 9), Papey (Eldjárn & Sveinbjarnardóttir, 1989, p. 134) and Fjörður. In the floor layers of Pálstóftir there was evidence of wood being used as fuel in the earlier phase and peat being used as fuel in the later phase (Milek, 2007, p. 9). On the other hand, in Fjörður there was evidence of peat being used in the 10^{th}-11^{th} centuries and wood in the 12^{th}-13^{th} centuries, even though the most likely case is that both fuels were being used through the whole period. This has though been observed in the midden of Hofstaðir in northeastern Iceland, where the use of wood as fuel increased with time, contrary to previous beliefs. This has indicated the application of resource management, such as wood and peat, in the middle ages related to social hierarchy (Simpson et al., 2003, p. 1415; Vésteinsson & Simpson, 2004, p. 181). It is surprising that no peat ash has still been found in Stöð (B. F. Einarsson, personal communication, May 28, 2023) when compared to other sites in the region.

The only evidence of animal dung being used for fuel is from Pálstóftir, where there was a charred *Stellaria media* seed retrieved, interpreted as belonging to burned animal dung (Guðmundsson, 2007, p. 2). The fuel utilisation strategy of the settlers has proven to be more complicated than previously thought, showing use of multiple different fuel sources from their arrival, with trends in utilisation mix for different purposes (Simpson et al., 2003, p. 1415; Vésteinsson & Simpson, 2004, p. 182). Therefore, it can be assumed that the inhabitants of eastern Iceland used many different fuel sources simultaneously and that wood and peat were not mutually exclusive. Peat kept being used through the ages as evidence of peat cutting (see Figure 22) post 1717 AD observed in Svalbarð demonstrates (Zutter, 1997, p. 122).

Figure 22: Remnants of peat cutting in Papey. A photograph taken in Papey by Guðni Þórðarson in 1952. The wet area is most likely an old peat cutting area which filled with water. From "Sarpur: Menningarsögulegt gagnasafn", GÞ-4587 by G. Þórðarson, 1952 (https://sarpur.is/Adfang.aspx?AdfangID=1774594).

Another domestic use of a plant was observed in Geirsstaðir where *Selaginella* remains were so dominant in the floor layer that it has been suggested that the plant was placed on the wet floor to dry it (Kristjánsdóttir, 1998, p. 26). Likewise, there was a lot of *Selaginella* remains found in the floor layer in Fjörður so it could be suggested that the same applied there. Spreading plant matter on the floors has been observed in both Stóraborg in the south and Svalbarð, and in Reykholt the most abundant type of remains recovered were *Selaginella* (Bending, 2007, p. 39). The placement of twigs, woodchips and peat on floors has also been suggested for soaking up liquids and providing insulation (Bending, 2007, p. 33). Turf was the main construction material for houses in Iceland from the settlement until the 20th century (van Hoof & van Dijken, 2008, pp. 1023–1024). Turf was widely available and locally sourced (Vésteinsson & Simpson, 2004, p. 186) and can therefore be assumed to have been used in every farmstead in Iceland, including the eastern part.

4.2.3 Livestock

As seen above, the most common environmental changes of human arrival in Iceland are the effects of the grazing livestock they brought along with them. The farmers who settled the country practised animal-based agriculture and most of the animals relied on food in the nature all year round, which required some kind of pastoralism (Hallsdóttir, 1987, p. 36). In most places this is manifested as forest clearance for pasture (Hallsdóttir, 1982, p. 262) which was observed in Hallormsstaðaskógur (S. A. Jónsson, 2009, pp. 48–49). In less forested sites the grazing was reflected in different ways.

Evidence of grazing has been observed in Þistilfjörður as a vegetation change in favour of pasture species such as *Stellaria media* and as an increase in Poaceae (Roy et al., 2017, pp. 681–682; Zutter, 1997, p. 122). The pollen assemblage from Papey demonstrated a rapid rise in Cyperaceae and a rise in *Potentilla* which has been linked to the effects of grazing. There was also a rise in *Rumex acetosa* type shortly after the settlement (P. C. Buckland et al., 1995, p. 260), which is known to grow in hayfields (Kristinsson et al., 2019, p. 480) and therefore implies hayfield establishment. In Hrafnkelsdalur grazing was manifested as a disappearance of *Angelica* which is very popular by sheep (Hallsdóttir, 1982, p. 262) but this has also been observed in Northwest and South Iceland and was similarly linked to grazing activities (Eddudóttir et al., 2020, p. 11; Erlendsson, 2007, p. 249). At Nykurvatn the disappearance of *Juniperus communis* shortly after the settlement has been linked to the effects of grazing but also cutting by humans (Alsos et al., 2021, p. 14). According to ancient sedimentary DNA from lake sediments in Northwest Iceland, a *Juniperus communis* disappearance attributed to the same causes took place more than a century earlier (Alsos et al., 2021, p. 14). This has also been observed in pollen records from lakes in northern Iceland around the same period and also interpreted as evidence of grazing (Eddudóttir et al., 2016, p. 724, 2020, p. 10).

Heathland management, commonly practiced in the Viking Age in the North Atlantic, involved maintenance and utilization of Ericaceae dominated heaths and can often be observed in botanical records as an expansion of heathlands (Zutter, 1997, pp. 65–66). In Hrafnkelsdalur there was an increase in *Thalictrum alpinum* and *Galium* after the settlement (Hallsdóttir, 1982, pp. 260–263) but a rise in these taxa has previously been interpreted as evidence of expanding heathlands following forest clearance (Hallsdóttir, 1987, p. 34). The discrepancy in heathland taxa in the macro- and micro-botanical records from the midden in Svalbarð, has been interpreted as a selective collection of heath taxa as fodder for livestock (Zutter, 1997, p. 140, 1999, p. 843). This reason could also be applicable for the Cyperaceae pollen and *Carex* seeds found in the floor layer in Fjörður. *Calluna vulgaris* completely disappeared from the Svalbarð midden deposit after 1636 AD which has been attributed to improper heath maintenance practices (Zutter, 1997, pp. 145–146).

The need for fodder steered the efforts of farmers towards managing their environment in order to promote growth of suitable taxa, such as grasses, sedges and weeds (Roy et al., 2017, p. 671). This has been observed in Svalbarð where the increase in herbaceous macro- and micro-fossils suggests human attempts at encouraging sedge growth for fodder (Roy et al., 2017, p. 682). The charred *Stellaria media* seed found in Pálstóftir, probably from animal dung is therefore evidence of livestock presence at the site (Guðmundsson, 2007, p. 2). *Stellaria media,* which was also observed in Svalbarð, and is known to grow on fertilized soil, has been interpreted as implying anthropogenic fertilization (Kristinsson et al., 2019, p. 494; Roy et al., 2017, p. 682).

Other indirect evidence for the presence of livestock is for example insects and fungi reliant on them or their products. The three insects found in Papey reliant on sheep or hay, *Melophagus ovinus*, *Lathridius minutus* and *Xylodromus concinnus* were introduced by humans when they settled the country (P. C. Buckland et al., 1995, p. 254). The two latter species are among the most common synanthropic species of beetles found in archaeological assemblages in South Iceland (P. Buckland et al., 1991, p. 138). *Lathridius minutus* was also found in a peat monolith from Þistilfjörður indicating human introduction in the first centuries after the settlement (Roy et al., 2017, p. 682). In the floor layer of Fjörður, spores of *Sordaria*-type fungus were found which have also been found in a sediment profile close to the archaeological site of Hrísbrú in southwestern Iceland (M. M. Schmid et al., 2018, p. 4). This fungus, along with two other types found in Hrísbrú and Fjörður (*Sporormiella* type and *Podospora* type) are dung loving fungi and are considered reliant on herbivore dung for germination (M. M. Schmid et al., 2018, pp. 12–13). These fungi appeared below the settlement tephra layer in Hrísbrú (M. M. Schmid et al., 2018, p. 12) but have also been observed in lake sediment records in northern Iceland increasing in the 12th-13th centuries, indicating grazing in the area (Eddudóttir et al., 2016, p. 724, 2020, p. 13).

4.2.4 Arable agriculture

Only three of the sites in eastern Iceland showed any evidence of arable agriculture. From the Svalbarð midden were retrieved *Hordeum* group pollen which have been attributed to imported cereals. This is because cereal macrofossils were absent in the midden and the pollen could have originated in *Leymus arenarius* which is local in the area (Zutter, 1997, p. 143). On the other hand, an increase in Cerealea type pollen was detected shortly after the settlement in

Hrafnkelsdalur and has been attributed to cereal cultivation. *Leymus arenarius* is also local in the Hrafnkelsdalur area and could therefore be responsible for at least some of the Cerealea type pollen, but a rise in *Selaginella* pollen has also been interpreted as an indication of abandonment of the cultivated fields (Hallsdóttir, 1982, p. 260).

In Erlendsson's pollen research, evidence of cultivation was present in all three sites in southern and western Iceland. Nevertheless, the pollen signal for cereal cultivation was weak and the possibility of *Leymus arenarius* being responsible for it quite strong, especially in the south coast where sand plains provide ideal conditions for its growth. However, *Avena* pollen found in Stóra-Mörk and Ketilsstaðir is more definitive of crops, but only suggests cultivation as a supplement to pastoralism (Erlendsson, 2007, p. 269). In three other sample sites in the southwest of the country, cereal pollen was present from around the settlement until the 12th to the 16th century (Hallsdóttir, 1987, p. 34). These examples show a common trend in cultivation attempts during the first centuries of habitation (Erlendsson, 2007, p. 253) which were likely also practiced in the east. *Hordeum* group pollen was found in the floor layer from Fjörður (see Figure 18) but *Leymus arenarius* is not native to Seyðisfjörður (Kristinsson et al., 2019, p. 298). This cannot exclude the possibility of *Leymus arenarius* having grown in Seyðisfjörður in the past or the transportation of its pollen from its native areas nearby. Nevertheless, it makes the *Hordeum* group pollen present in Fjörður more likely to represent cereal cultivation in the area. Furthermore, a charred *Hordeum* seed was found in a hearth in the same structure (see Figure 20), which is, as far as the author knows, the first cereal macrofossil retrieved from an archaeological context in eastern Iceland.

Hordeum seeds have been found in many sites in Iceland, mainly in the southern and western part (Mooney & Guðmundsdóttir, 2020, p. 7). Barley and other weed seeds from the 10th-12th centuries were retrieved from a hearth in Reykholt, western Iceland, but it could not be confidently determined if they were grown locally or imported (Guðmundsson et al., 2012, pp. 115–116). The biggest cereal assemblage found in Iceland is from Lækjargata, downtown Reykjavík, where over 1,700 remains of barley (see Figure 23), oats and flax were found. They were retrieved mainly from floors and hearths of a longhouse and outhouses dated to the first decades after the settlement of Iceland. The abundance of grain along with the weed flora found at the site implies local cultivation but it cannot be considered conclusive proof (Mooney & Guðmundsdóttir, 2020, pp. 8–15). One of the strongest indications for local cereal cultivation is from Gröf in Öræfi, southeastern Iceland, where remains of a drying kiln were found containing around 500 charred *Hordeum* seeds. The assemblage consisted of fairly small seeds, likely due to poor growing conditions and contained leaves, stems, roots and hairs of *Hordeum*

(Friðriksson, 1959, pp. 88–91). The barley seed assemblage, found in a supposedly burned down cereal storehouse in Bergþórshvoll, southwestern Iceland, similarly contained different parts of the plants and was grown in poor conditions, indicating that it was grown locally (Friðriksson, 1960, pp. 64–70).

Figure 23: Charred Hordeum from Lækjargata. Hordeum vulgare seeds retrieved from the longhouse in Lækjargata. From "Barley cultivation in Viking Age Iceland in light of evidence from Lækjargata 10–12, Reykjavík" by D. E. Mooney and L. Guðmundsdóttir, in V. Santeri and P. Lagerås (Eds.), Archaeobotanical studies of past plant cultivation in northern Europe (Vol 5, p. 12), 2020, Barkhuis.

4.3 Conclusion

There is both evidence for the Holocene Thermal Maximum in eastern Iceland happening simultaneously to the rest of the country, around 7,900-7,000 years ago, and much later or less than 5,000 years ago. There seems to have been increasing soil erosion since at least 3000 years ago in eastern Iceland which is comparable to the other parts of the country and demonstrates a degrading landscape long before the arrival of humans. There is evidence for the Medieval Warm Period in eastern Iceland but weaker than in the rest of the country. The most likely reason for this is the fact that the cold East Iceland Current weakened the warming effect of the period meanwhile the rest of the country was warmed by the southerly Irminger Current. There seems to be stronger evidence for the effects of the Little Ice Age in eastern Iceland, apparent in both soil erosion, cooling climate and a decline in plant species.

Betula reached Northeast Iceland around 9000 years ago and there was a *Betula* expansion in the east during both warm periods, in the eighth millennium BP and in the fifth millennium BP. The maximum expansion of *Betula* woodland seems to have happened during the later period or less than 5000 years ago. Yet, this is only based on one record from Þistilfjörður and can therefore not be considered very reliable. The absence of woodland in the highland sites in eastern Iceland is opposed to highland sites in the north and northwest of the country, suggesting a difference in vegetation depending on the prevailing ocean currents. The commonly observed *Betula* expansion shortly before the settlement can be seen in the Hallormsstaðaskógur pollen records which suggests a short period of improved conditions.

The pre-settlement environment in eastern Iceland seems to have been quite variable as has been noted elsewhere in Iceland and can be expected due to geographical differences between sites. Most of the sites in eastern Iceland where environmental records are present do not demonstrate forested environments at the time of the settlement, only the records of Hallormsstaðaskógur show clear evidence of woodland. Majority of the sites were surrounded by heathlands and grasslands when the country was settled but this result might be misleading due to the unsuitable environments for woodland growth at most of the other sites, which are located by the coast or in high altitudes, and lack of environmental research in more suitable areas. The fact that the majority of the sites from eastern Iceland do not seem to have been wooded when settlers arrived agrees with a long-term potential vegetation cover model which observed reduction of forest cover to less than 10% by the time of the settlement, contrary to earlier beliefs of the country being forested from mountains to shores.

The settlement had varying influences on the environment and vegetation of the sites in eastern Iceland. In Hallormsstaðaskógur there was a rapid decline of birch in the first couple of centuries after the settlement, which has been observed widely in Iceland. In Þistilfjörður there were contradicting results, but the more recent conclusions agreed that there was no obvious human influence observed attributing to the human settlement. In treeless environments the main evidence for human presence is the replacement of taxa that are preferred by grazers by more grazing tolerant taxa and an introduction of anthropogenic indicators. These processes have been observed elsewhere in the country as well. There is evidence of increased soil erosion following the settlement in Hallormsstaðarskógur and Lögurinn which has been acknowledged repeatedly elsewhere in the country. Some marginal highland farms in eastern Iceland seem to have been abandoned later than similar farms elsewhere in Iceland, perhaps because the landscape was less wooded making the vegetation more robust and tolerant to grazing. The environmental aftermath of farm abandonment can be seen in a resurgence of scrub in Pálstóftir and Hrafnkelsdalur.

The settlers of eastern Iceland used local trees for wood, driftwood and there is some evidence of imported wood, but mainly in the form of artifacts. Coniferous driftwood seems to have been the main wood type used for building in this area, as in the North of the country. Mainly local wood was used as fuel but there are examples of charcoal from foreign species, both common driftwood species and likely imported ones. This pattern has been observed elsewhere and evidence of imported wood, such as *Quercus*, has also been found in other parts of the country. Peat ash was found in many of the sites in eastern Iceland demonstrating the importance of peat as fuel in a treeless landscape. Furthermore, there was evidence in Pálstóftir of animal dung being used as fuel. This has been noticed elsewhere in the country, showing a versatile fuel utilisation strategy with different fuel use for different purposes. Turf was the main construction material in Iceland for a millennium and can therefore be assumed to have been utilised in all of the sites in eastern Iceland, just as the rest of the country. It has been suggested that plant matter, such as *Selaginella*, was used on domestic floors to dry them up. This has been observed in a few of the sites in eastern Iceland showing high concentrations of *Selaginella*.

The farmers who settled Iceland brought their pastoral lifestyle to a vulnerable environment unaccustomed to grazing. Evidence of this can be seen widely in the country and has been observed in most of the sites in question. In forested landscapes, such as Hallormsstaðaskógur, this is demonstrated as forest clearance for pasture. In less forested sites this is mainly reflected in a decline in less grazing tolerant taxa, such as *Angelica* and *Juniperus*, replaced by more grazing tolerant taxa, such as Poaceae and *Potentilla*. There is some evidence of anthropogenic fertilization to promote growth of suitable taxa for fodder as well as an increase in taxa that are known to grow in pastures and hayfields, such as *Stellaria media* and *Rumex acetosa*. Heathland expansion has been reflected in a rise in *Thalictrum alpinum* and *Galium*, as well as exploitation of heathlands for fodder. These agricultural practices and their environmental effects have been widely recognised in the whole country. Other indirect evidence for livestock observed in some of the sites are insects reliant on animals and animal dung loving fungi, which have also been observed elsewhere in the country.

Only three of the sites in eastern Iceland showed any evidence of arable agriculture. Cerealea type pollen was found in both Svalbarð and Hrafnkelsdalur, which could originate in *Leymus arenarius* which grows locally there. Nevertheless, *Hordeum* group pollen was also found in Fjörður, where *Leymus arenarius* is not native. A charred barley seed was found in a hearth in Fjörður making it the first cereal macrofossil found in an archaeological context in eastern Iceland. The seed and the pollen suggest barley cultivation in Seyðisfjörður in the first centuries after the settlement even though it cannot exclude the possibility of import. Barley seeds have been found in many archaeological sites, mainly in southern and western Iceland and cultivation has been argued in some of them. The lack of evidence of arable in eastern Iceland could reflect less cereal cultivation in this part of the country, possibly due to poor environmental conditions. It could also reflect less research effort, visible in the shortage of both environmental and archaeological research in this part of the country, and shortage of archaeobotanical research in general, which needs to be redressed. Furthermore, most of the researched sites in eastern Iceland are located in areas with poor conditions for cereal cultivation, such as highland sites and islands, which needs to be improved in the near future.

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