Chapter 2

The Palaeoenvironment of Mývatnssveit during the Viking Age and Early Medieval Period

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Introduction

Until recently very little was known about the history of environmental change in Mývatnssveit, although many other parts of Iceland have been investigated in some detail since the pioneering work of Sigurður Þórarinsson in the 1940s (e.g. Þórarinsson 1944) and Þorleifur Einarsson in the 1950s (e.g. Einarsson 1957, 1963). Notable multi-disciplinary research at the landscape scale, associated with archaeological excavation, has taken place and is still continuing in Reykholtsdalur in western Iceland (Buckland *et al.* 1992; Smith 1995; Dixon 1997) and in Eyjafjallahreppur in southern Iceland (e.g. Buckland *et al.* 1991; Dugmore and Buckland 1991; Mairs *et al.* 2006). A similar body of palaeoenvironmental evidence is now beginning to accumulate both from the site of Hofstaðir itself and from the surrounding landscape, capable of illuminating the nature of the Viking Age and early medieval site and placing it within a context of a complex and dynamic landscape.

The modern environment

The site of Hofstaðir (fig.2.1) is situated on a terrace above a bend of the river Laxá, at *c.* 250 m above sea level. This altitude is towards the upper end of the range for Icelandic settlements, although a number of extant and deserted farms in Mývatnssveit can be found above 300 m (Mývatn itself is at 277 m above sea level). Part of the reason that farming can be profitable here at these altitudes is that the climate of north-eastern Iceland is relatively dry and continental. The 1961–90 means for Reykjahlið are: annual average temperature, 1.4ºC; average annual maximum and minimum temperatures, 25.6ºC and -30.9ºC, respectively; average annual precipitation, 435 mm (data from www.vedur.is). Annual insolation at the site is between 750 and 800 kW h m^{-2}. Snow cover does not persist as long as elsewhere in the country. Today, the cultivated hayfields of Hofstaðir lie within an area of rough grazing land with extensive thufur (frost-heave hummock) formation. The vegetation is mostly dwarf-shrub grassland dominated by *Betula nana* (dwarf birch), *Vaccinium uliginosum* (bog myrtle), and *Empetrum nigrum* (crowberry). A more luxuri-

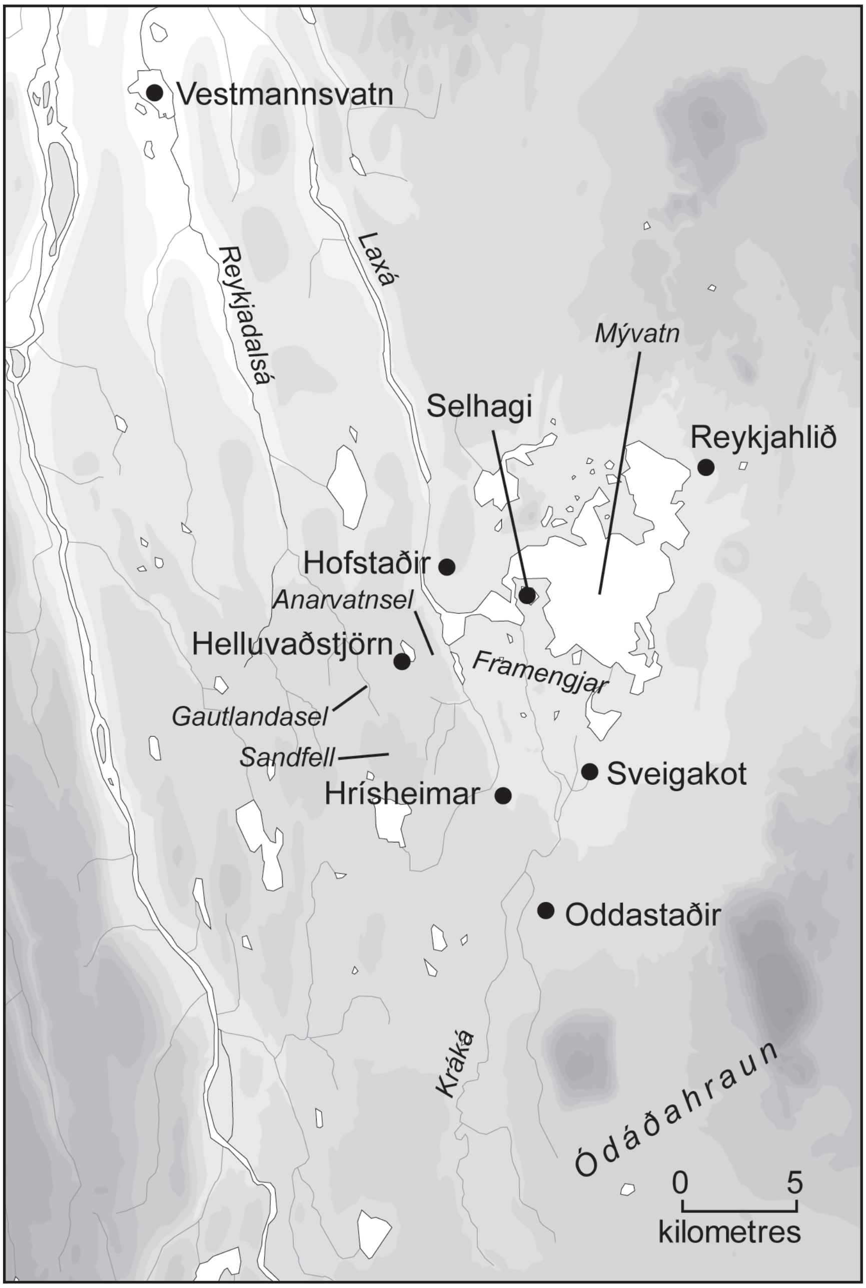

Figure 2.1 Location map, showing Hofstaðir and nearby sites. Undir Sandmúla is located c. 15 km to the south of the southern boundary of the map, while Höðagerði is 10 km north of the northern boundary.

ant willow (*Salix lanata* [woolly willow] and *S. phylicifolia* [tea-leaved willow]) and tall herb (notably *Geum rivale* [water avens] and *Angelica archangelica* [garden angelica]) flora exists on the relatively inaccessible, steep slopes of the Laxá valley, downhill from the farm, and on islands in the river. The lands of the Hofstaðir estate are not currently subject to significant soil erosion (see below). Extensive desert areas begin within 6 km to the north-northeast and 11 km to the southwest of the farm, and farms at higher altitudes or closer to the major desert areas are often affected by soil erosion to a much greater extent.

The landscape around Hofstaðir is gently hilly and consists of a mosaic of landscape features. One economically important component is the Framengjar, an area of wet meadows and ponds adjacent to the southern edge of Mývatn, which constitutes a rich grazing resource.

Figure 2.2 Evidence for frost heave in the soils at Hofstaðir: frost polygons viewed in section. Photograph: Karen Milek.

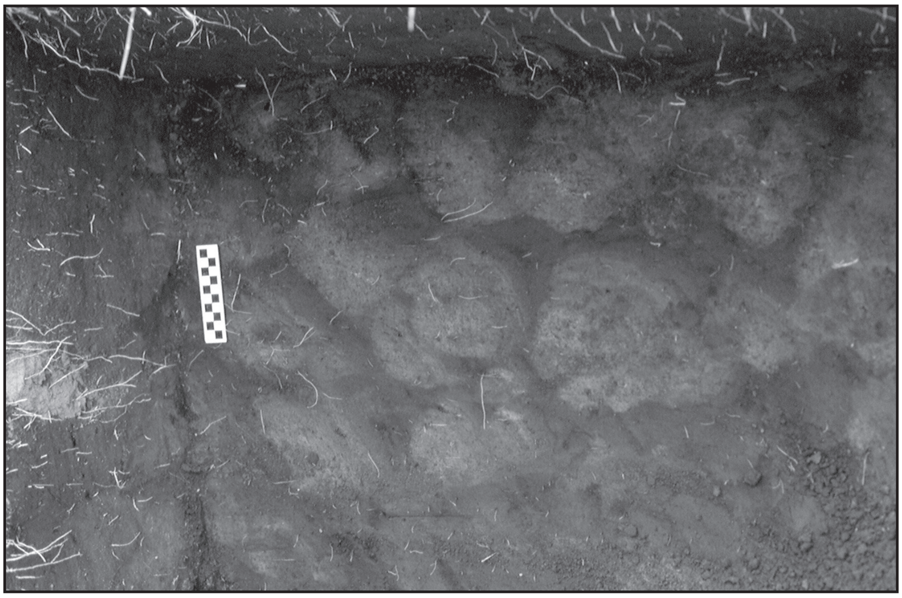

Figure 2.3 Evidence for frost heave in the soils at Hofstaðir: frost polygons viewed from above. Photograph: Karen Milek.

Small mires are common in the region and may have been important for hay, winter grazing, and bog iron production in the past (the latter demonstrated by excavations at Hrísheimar, 10 km south-southeast of Hofstaðir; McGovern *et al.* 2006, 2007). Birch (*Betula pubescens*) woodland, a potential source of browse, fodder, fuel, charcoal and timber in the past, occurs throughout the region wherever it is protected from grazing, for example on the extensive rough lava fields to the east of Mývatn. In Mývatnssveit, tree birch survives up to 400 m above sea level. The nearest extant patches of birch woodland to Hofstaðir are *c.* 3–5 km to the north and northeast, along the Laxá valley and around Vindbelgjarfjall.

The defining feature of the region is Mývatn itself, the third largest lake in Iceland and (very unusually) eutrophic, famed for its abundant and diverse migratory avifauna, as well as the

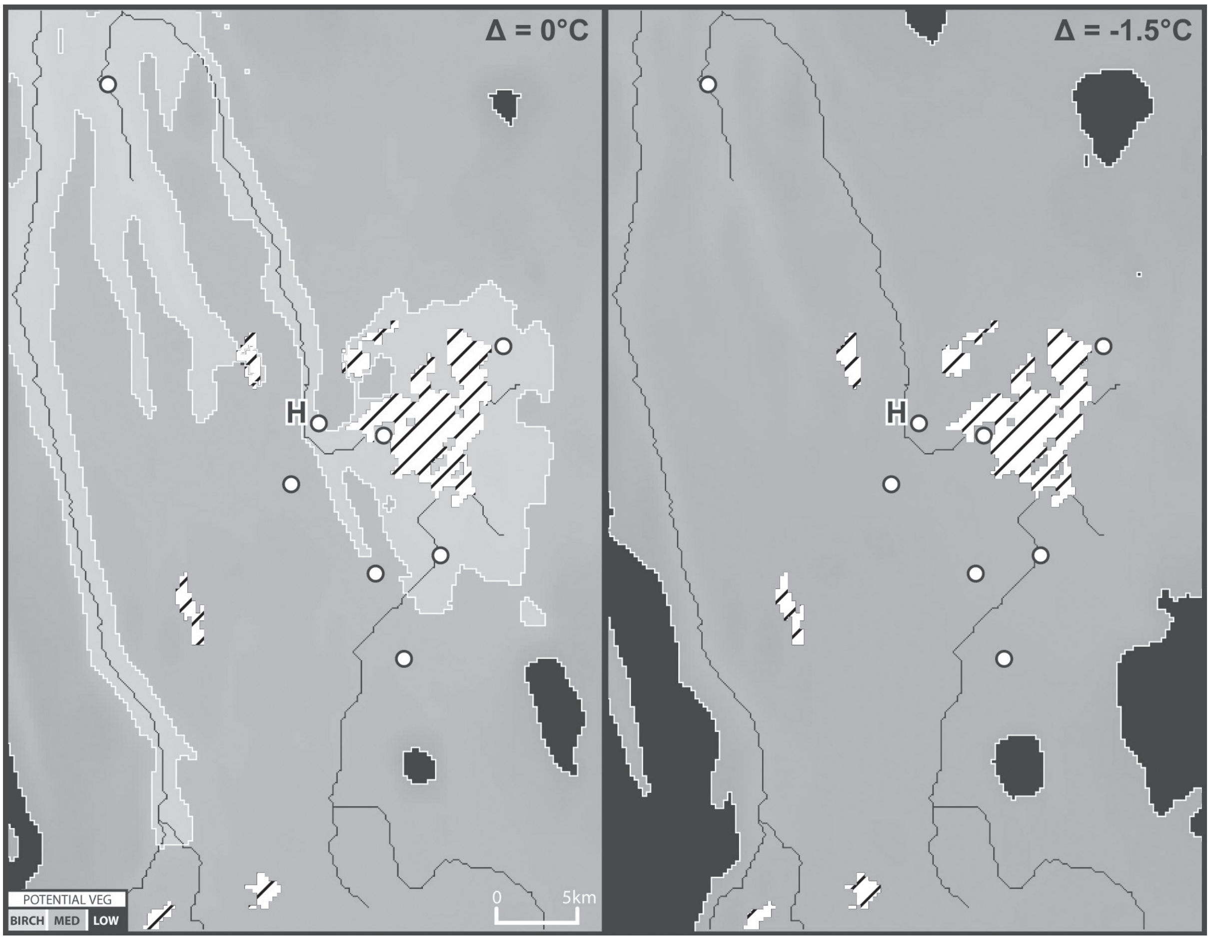

Figure 2.4 Potential vegetation cover in the Mývatn region from Casely (2006). Cover is based on a degree-day model, and uses the temperature limits for birch, medium and low vegetation defined by Ólafsdóttir *et al.* (2001). The left panel shows the modelled potential vegetation under the modern temperature regime. A 1.5°C drop in temperature (right panel) sees the potential birch limit retreat from the lake shore and major north-south trending valleys towards northern coastal areas. The northward migration of the limit for medium vegetation cover (for example grasses) under a 1.5°C drop in temperature indicates likely destabilisation of inland grazing areas. Cell resolution is 250m.

midges (Chironomidae) which lend it its name ('midge lake') (Einarsson *et al.* 2004). The lake is a valuable economic resource, in recent years yielding an apparently sustainable harvest of duck eggs (Á. Einarsson, pers. comm. 2005) and tens of thousands of fish each year (Gudbergsson 2004). The flood of organic detritus passing from the lake into the Laxá ('salmon river') accounts for the current importance of that river as a fishery for trout, as well as salmon in its lower reaches. The richness of the freshwater aquatic ecosystem helps to compensate for the relative isolation of the region from marine and coastal resources such as the fish, driftwood and beached whales referred to in texts such as *Grágás*; the coast lies 45 km to the north-northwest of Hofstaðir. Less productive lakes and rivers are also abundant in the landscape.

Climatic change

(AFC, AJD, ITL)

Despite the attentions of numerous researchers in recent years, much remains to be learned regarding the climatic history of Iceland since the settlement period. The Little Ice Age (Grove 1988) is now well established as an event with

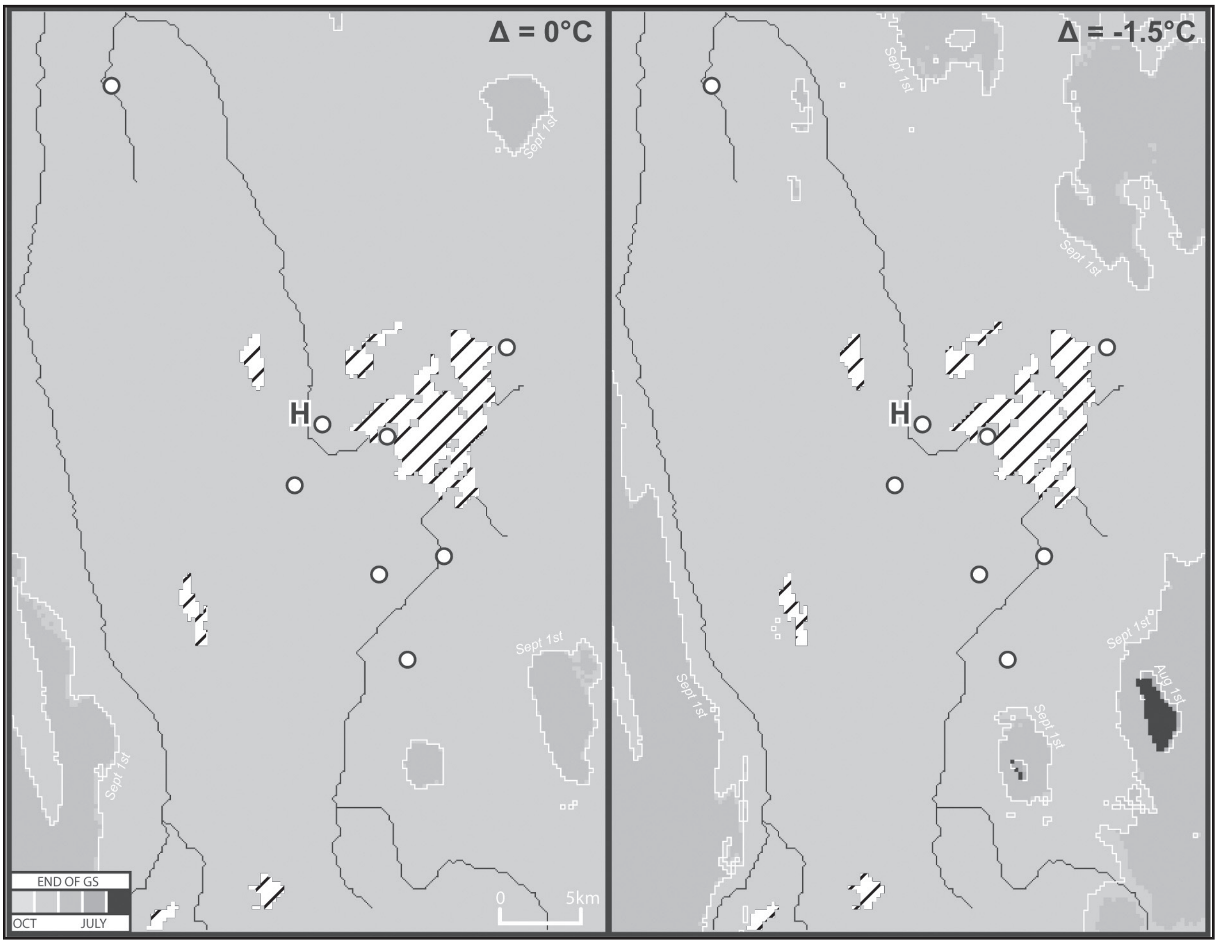

Figure 2.5 Growing season end date change around Mývatn, given a temperature change of 0°C (left) and -1.5°C (right), using Casely's (2006; Casely and Dugmore 2007) model. It highlights the substantial shortening of the growing season in inland areas with a small temperature drop, as shown by the migration of the September 1st growing season end date towards the southern shore of Mývatn.

an almost global reach (Meeker and Mayewski 2002). It has been characterized in Iceland using historical records (Ogilvie 1992), geomorphological evidence for glacier advance and retreat (e.g. Casely and Dugmore 2004; McKinzey *et al.* 2004; Kirkbride and Dugmore 2006) and solifluction (Kirkbride and Dugmore 2005), and the study of aeolian sediments (Jackson *et al.* 2005), and is considered to have been generally colder and windier than the 20th century. The details, however, remain obscure. For example, there is a continuing debate over the timing of its onset. There is some evidence for glacier re-advances as early as the 13th century (Bradwell *et al.* 2006), while evidence from the Greenland ice cores points to a major transition occurring regionally around AD 1400 (Meeker and Mayewski 2002). There is also some controversy over the dating of its most recent nadir, which probably occurred some time in the late 18th or 19th centuries (Casely and Dugmore 2004; McKinzey *et al.* 2004; Bradwell *et al.* 2006; Axford *et al.* 2009).

The Little Ice Age was preceded by the Medieval Warm Period, characterized by relatively warm and stable conditions regionally (Meeker and Mayewski 2002) – perhaps even warmer than the 20th century. Little direct evidence for this event has been found in Iceland itself, an exception being the study of Jackson *et al.* (2005) which pointed to lower wind speeds. However, as these authors point out, their data fit into a

Figure 2.6 Potential vegetation sensitivity around Mývatn, given a temperature change of ±1.5°C, using the model of Casely (2006). Sensitivity is calculated from potential birch vegetation cover; lightest colour areas have greatest stability to temperature changes, black areas are outside the potential birch limit. This highlights the marginality of the inland areas, and the ability of relatively small changes to translate over very large areas around Mývatn.

wider pattern which suggests that warm and stable conditions were prevalent throughout the North Atlantic region between approximately AD 900 and 1200. Thus, for the period when the aisled hall of Hofstaðir was occupied, it is likely that the local climate was similar to, or even slightly milder than at present.

Some caveats to the above conclusion should be mentioned. The first is that no robust palaeoclimatic records spanning the Viking Age and early Medieval Period have been published for the Mývatn region. Subfossil chironomids, widely used as palaeothermometers, have been studied from Mývatn itself (Einarsson *et al.* 2004) and two smaller lakes nearby, Helluvaðstjörn (Lawson *et al.* 2006, 2007) and Vestmannsvatn (Gathorne-Hardy *et al.* 2007), but no clear temperature signal was found in the data, possibly due in part to the overprint of other ecological effects (e.g. lake shallowing, nutrient enrichment) on any climatic signal (Gathorne-Hardy *et al.* 2007; cf. Axford *et al.* 2009). At the site of Hofstaðir, patterned ground in the form of small (10–20 cm wide) polygons was found outside the Viking Age structures in Area E (figs.2.2 and 2.3). These frost-heave features post-date the 10th-century tephra and pre-date the 1477 tephra, indicating an intensification of repeated freeze-thaw processes at some point between the 11th and 15th centuries, but the stratigraphy does not allow more precise dating. The lack of data specific to the region is problematic given the increasing recognition that climatic changes are not necessarily spatially congruent, particularly on shorter timescales (annual to centennial scales; e.g. Dawson *et al.* 2003, 2004; Jackson *et al.* 2005; Bradwell *et al.* 2006).

Numerical modelling offers a method for assessing the possible impacts of climatic change. Recent work (Casely 2006; Casely and Dugmore 2007) has shown that climate and vegetation can be modelled in Iceland, and how the possible effects on individual landholdings can be assessed.

The model developed by Casely (2006) is based on modern climate data and topography, with high (250 m) spatial resolution for the whole of Iceland. Modelled climate (temperature and precipitation) is assessed against the modern distribution of glaciers and constrained by past glacier fluctuations. This climate model provides the basis for inferring probable ecological and landscape impacts under differing scenarios of climatic change. The first output of interest here is a simulation of the probable effects of decadal climate trends on vegetation cover. Figure 2.4 shows modelled present-day

Site	HST	HST	HST	HST	HST		HST	HST	HST	HST	HST		
Context	6m	6n	7a	7b	8		5a	6d	6f	6o	6p		
Phase	I	I	I	I	I	**Phase 1 total**	II	II	II	II	II	**Phase 2 total**	**Area G total**
From random sub-sampling													
Bark		2F(0.07)	2F(0.29)	3F(0.48)	6F(0.35)	**13F(1.19)**		6F(0.48)	7F(0.59)	4F(0.79)	1F(0.16)	**18F(2.02)**	**31F(3.21)**
Betula sp. timber	6F(1.04)	10F(0.2)		9F(0.74)	6F(1.11)	**31F(3.09)**	2F(0.1)	10F(0.77)	20F(1.14)	7F(0.6)		**39F(2.61)**	**70F(5.7)**
Betula sp. roundwood (not pith to bark)	38F(22.88)	35F(9.21)	31F(20.06)	30F(4.77)	107F(58.08)	**240F(115.00)**	52F(12.91)	105F(14)	63F(13.14)	43F(6.40)	1F(0.17)	**264F(46.62)**	**504F(161.62)**
Betula sp. roundwood (pith to bark)	1F(0-.03)	2F(0.87)	3F(0.66)	3F(2.34)	17F(9.59)	**26F(13.49)**	2F(0.22)	8F(2.92)	3F(0.79)	3F(0.34)		**16F(4.27)**	**42F(17.76)**
Betula sp. rootwood	5F(0.88)	1F(0.07)			3F(1.91)	**9F(2.86)**		4F(1.25)	5F(0.95)	2F(0.14)		**11F(2.34)**	**20F(5.2)**
Salix sp. roundwood (not pith to bark)								1F(0.06)	1F(0.03)	1F(0.03)		**3F(0.04)**	**3F(0.14)**
Salix sp. roundwood (pith to bark)							1F(0.08)			1F(0.03)		**2F(0.11)**	**2F(0.11)**
Sorbus sp. timber					1F(0.02)	**1F(0.02)**		1F(0.24)		1F(0.03)		**2F(0.27)**	**3F(0.29)**
Sorbus sp. roundwood (not pith to bark)							1F(0.03)	2F(0.55)	1F(0.04)			**4F(0.62)**	**4F(0.62)**
Larix sp. timber				1F(0.08)		**1F(0.08)**			1F(0.02)			**1F(0.02)**	**2F(0.1)**
Coniferous bark				1F(0.02)	2F(0.19)	**3F(0.21)**							**3F(0.21)**
Deciduous timber					1F(0.03)	**1F(0.03)**							**1F(0.03)**
Deciduous roundwood (not pith to bark)		1F(0.07)	1F(0.27)			**2F(0.34)**		2F(0.52)		1F(0.03)		**3F(0.55)**	**5F(0.89)**
Deciduous rootwood			3F(1.45)	1F(0.13)	1F(0.1)	**5F(1.68)**				1F(0.03)		**1F(0.03)**	**6F(1.71)**
Indet rootwood								1F(0.09)				**1F(0.09)**	**1F(0.09)**
Indet			2F(0.54)	2F(0.06)	1F(0.1)	**5F(0.7)**	2F(0.04)	1F(0.05)	4F(0.37)	3F(0.06)	4F(0.38)	**15F(0.9)**	**20F(1.6)**
Total from random sub-sampling	**50F(24.83)**	**50F(10.49)**	**42F(23.27)**	**50F(8.62)**	**145F(71.48)**	**337F(138.69)**	**60F(13.38)**	**142F(20.93)**	**105F(17.07)**	**67F(8.5)**	**6F(0.71)**	**380F(60.59)**	**717F(199.28)**
From additional roundwood sorting													
Betula sp. roundwood (pith to bark)	15F(12.91)	10F(4.48)		21F(5.16)	5F(3.55)	**51F(26.1)**	1F(0.09)	3F(0.28)		2F(0.04)		**6F(0.41)**	**57F(26.51)**
Betula sp rootwood								1F(0.19)				**1F(0.19)**	**1F(0.19)**
Salix sp. roundwood (pith to bark)		1F(0.11)			1F(0.08)	**2F(0.19)**		1F(0.14)		2F(0.7)		**3F(0.84)**	**5F(1.03)**
Total from additional roundwood sorting	**15F(12.91)**	**11(4.59)**	**0**	**21F(5.16)**	**6F(3.63)**	**53F(26.29)**	**1F(0.09)**	**5F(0.61)**	**0**	**4F(0.79)**	**0**	**10F(1.44)**	**63F(27.73)**

Table 2.1 Charcoal identifications from Area G (summarised from Duarte 2007). Charcoal was retrieved throughh 100% dry-sieving (4 mm sieve) of the contexts identified in the section. Sub-samples for identification were randomly chosen using methods outlined by van der Veen and Fieller (1982) and Church *et al.* (2007). Charcoal identifications are indicated by number of fragments (F) followed by mass in grams in brackets.

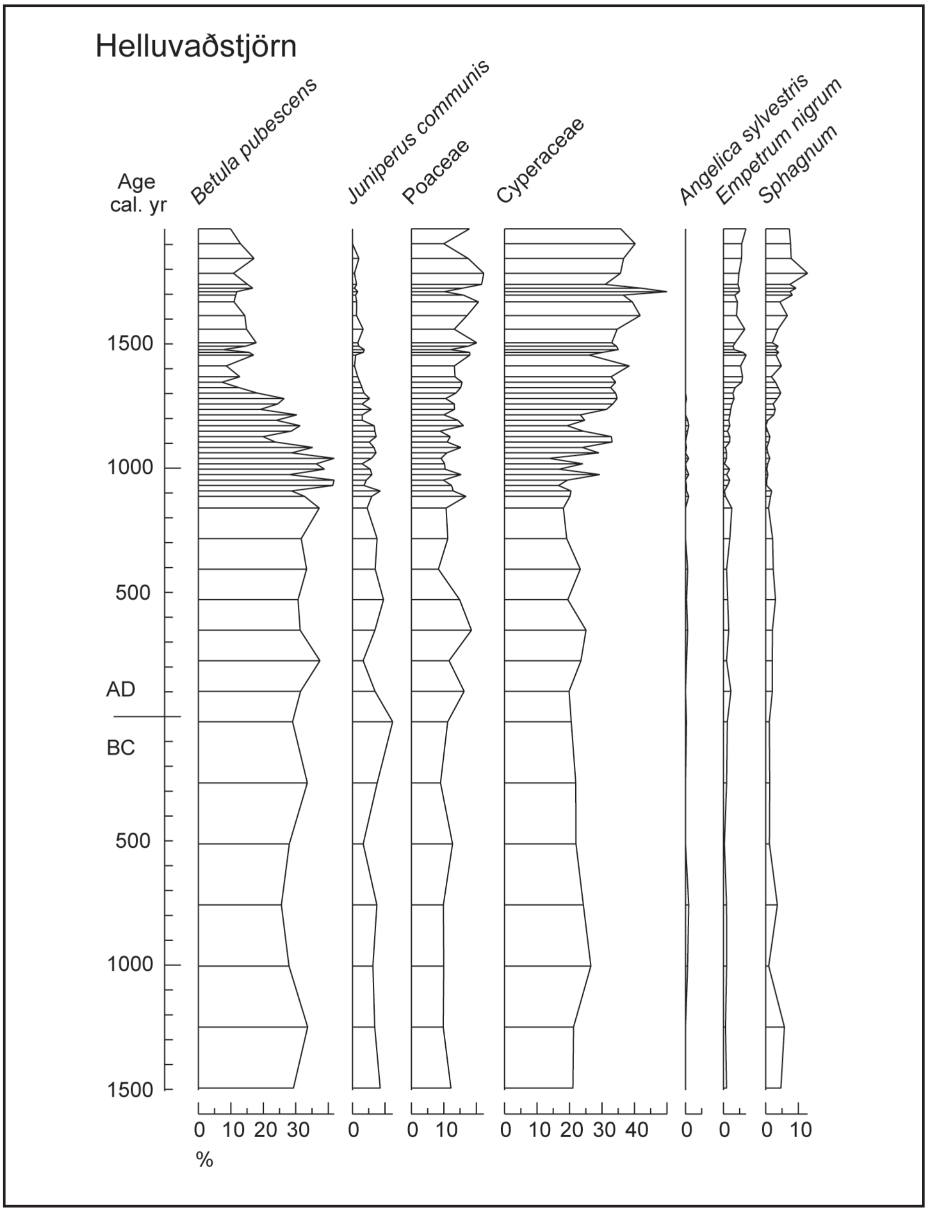

Figure 2.7 Summary pollen percentage data from Helluvaðstjörn (selected taxa). Methods and the age model follow Lawson *et al.* (2007).

cover, with birch cover light grey, a medium vegetation cover (darker grey, approximately grass cover), and low vegetation cover, including Arctic mosses and lichens. The modelled distribution of birch compares well to the limits of the present distribution of woodland (Casely and Dugmore 2007). The probable effect of a 1.5°C drop in temperature is also shown in Figure 2.4 (see Casely and Dugmore 2007 for details of the climatic scenarios employed). Hofstaðir lies on the modelled present-day birch margin, but remains well within the zone of medium vegetation cover even under such a temperature drop. This is in marked contrast to the areas to the south and east of Sveigakot and Oddastaðir, where the area capable of supporting grazing would decline substantially.

This idea of topography modulating the effect of climate change is reinforced by two further figures. The date of the end of the growing season (fig.2.5) shows a similar pattern to that in Figure 2.4. With a 1.5°C drop in temperature, the growing season shortens slightly at Hofstaðir, ending in mid-September. At higher elevations to the south the season shortens still further, ending in early September or even August. Fig-

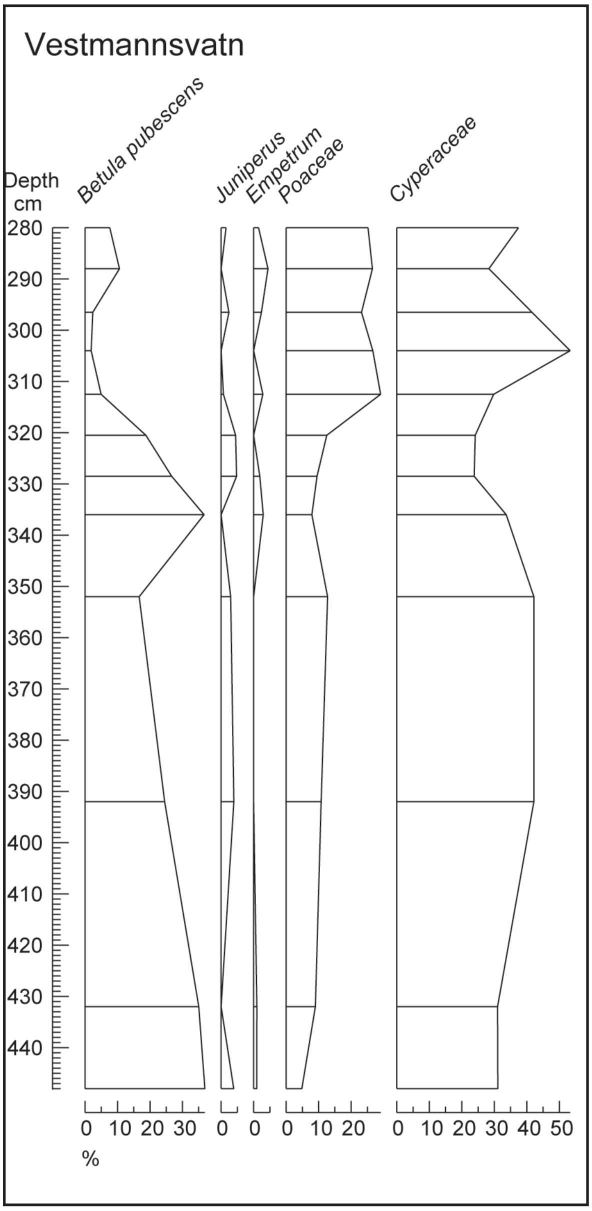

Figure 2.8 Summary pollen percentage data from Vestmannsvatn (selected taxa). Methods follow Lawson *et al.* (2007), except that very low pollen concentrations mean that counts are to a total land pollen sum of greater than 100 grains. These low counts are hence subject to substantial statistical variability.

ure 2.6 shows the sensitivity of the spatial extent of modelled birch woodland cover to changes of ±1.5°C. The palest areas (off the north of the frame) have continuous cover throughout the range of ±1.5°C, and the darkest areas have no potential cover even at +1.5°C. The sensitivity and marginality of inland areas, in contrast to the relative stability of Hofstaðir and other sites within the long north-south trending valleys, is essentially due to their spatial (altitudinal) proximity to major ecological boundaries.

Vegetation

(MJC, LD, KJE, ITL, AJN)

Data on vegetation change are available from a number of sources. Four samples from archaeological contexts at Hofstaðir have been analysed for pollen (Lucas 2001a; Chapter 3, this volume). Charcoal has also been analysed from Area G (table 2.1). Off-site pollen data are available from a nearby lake, Helluvaðstjörn (Lawson *et al.* 2007; figs.2.1 and 2.7), with skeleton diagrams available from Vestmannsvatn (fig.2.8) and Hrísheimar (fig.2.9). Further useful data on vegetation change in the wider landscape come from mapping and excavation of charcoal pits containing identifiable *B. pubescens* charcoal (Church *et al.* 2006), which are presumed to imply the presence of nearby woodland at the time they were in use, and from observations of macrofossils in soil and sediment sections. Evidence for cultivation at Hofstaðir itself is discussed in Chapter 7, this volume.

The traditional understanding (e.g. Hallsdóttir 1987; Hallsdóttir and Caseldine 2005), based on saga evidence (*Landnámabók* in particular) and apparently confirmed by pollen-analytical work, is that on the eve of settlement most of lowland Iceland below 300–400 m was covered in scrubby woodland dominated by a single taxon, *Betula pubescens* Ehrh. ssp. *tortuosa* (Lebed.) Nyman. The only other native tree is the much less abundant *Sorbus aucuparia* (rowan), which is all but invisible to pollen analysis as it is insect-pollinated. The pollen data from Helluvaðstjörn and Vestmannsvatn suggest that *B. pubescens* cover in their catchments was substantial before the settlement; the values of around 30% in both sequences may be consistent with continuous woodland cover (cf. Hallsdóttir 1987). Slight variations

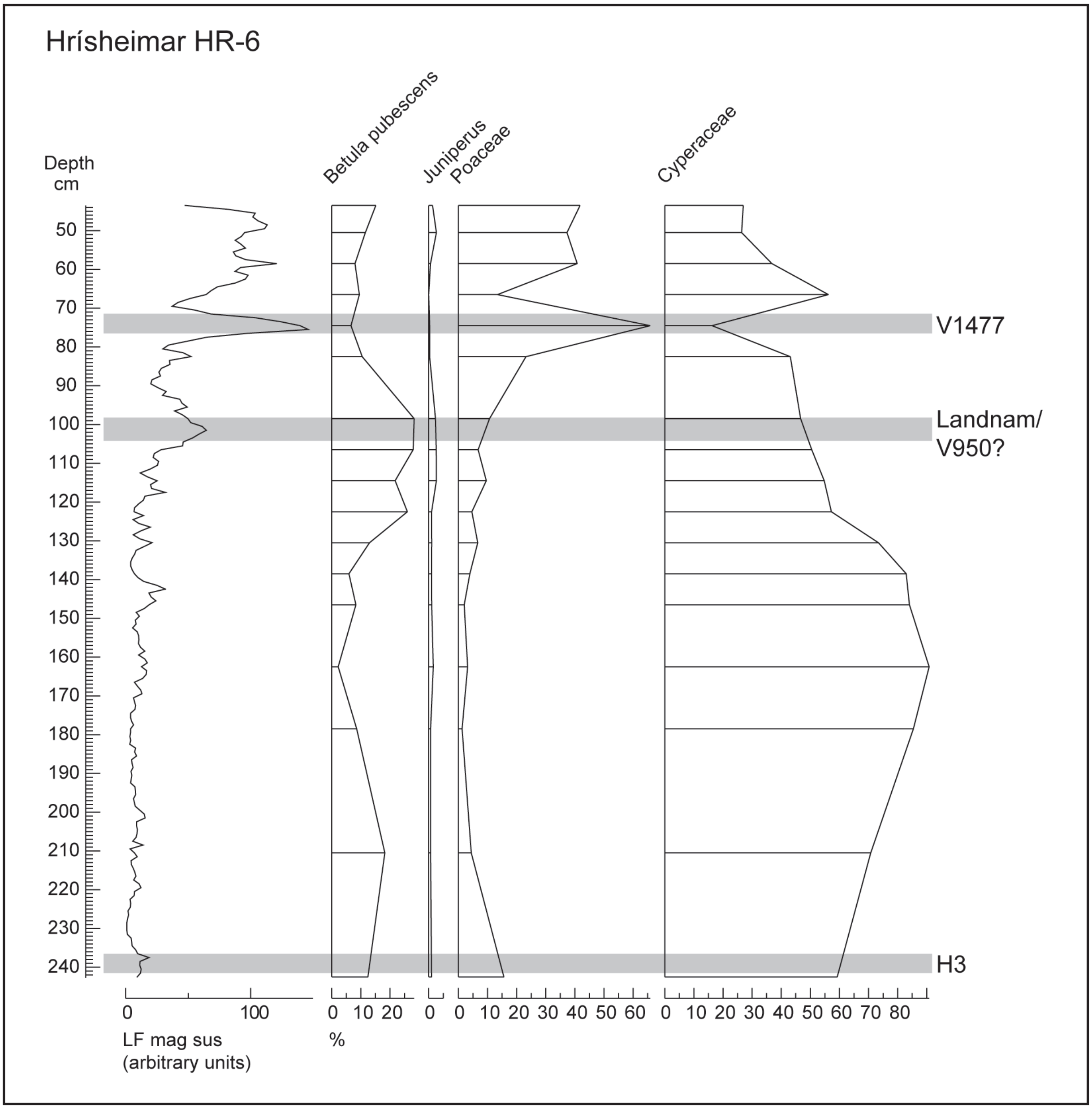

Figure 2.9 Summary pollen percentage data from Hrísheimar, core HR6, located approximately 150 m southeast of the farm site. Methods follow Lawson *et al.* (2007) and counts exceed 300 grains. Prominent tephra layers are marked.

in percentages over time may represent natural fluctuations in the density and/or pollen production of birch woodland in response to climatic changes (cf. Einarsson 1963; Hallsdóttir 1987). The data from Hrísheimar are substantially different: very low percentages and low influx values (on the order of 100 grains cm^{-2} yr^{-1}; cf. Hicks 2006) of *B. pubescens* in the pre-settlement part of the diagram suggest that the mire was an 'island' of sedge fen within what the lake diagrams would indicate to be a generally wooded landscape (stands of *B. pubescens* persist today on the slopes around Hrísheimar). Many other mires exist in the modern landscape and are likely to have been similarly unwooded, although finds of birch macrofossils in mid-Holocene peats at Hrísheimar and elsewhere in Iceland indicate that the less wet mires could have been covered in birch scrub, perhaps with periodic episodes of scrub advance and retreat in response to climatic changes (e.g. Bartley 1973). The first settlers would thus have encountered a landscape composed of a mosaic of scrubby woodland, probably more small lakes than are now present (due to subsequent drainage and infilling), and more or less unwooded *Carex/Eriophorum* (sedge and cottongrass) mires (cf. Vésteinsson 1998). Mires in particular would have been a more important resource than they perhaps seem today, useful for grazing livestock and as a source of peat for fuel (see Simpson *et al.* 2003 for a discussion of past fuel use in Mývatnssveit) and bog iron ore for metalworking. The woodland presumably would have thinned out at higher altitudes (above *c*. 300 m; cf. Hallsdóttir 1982; Wastl *et al.* 2001) and towards the dry interior, grading into fell-field vegetation and bare ground.

The traditional account would assert that the woodland was largely destroyed within one or two generations of the settlement, quickly attaining something like its present extent of approximately one tenth of its potential range. In the past decade or so, this scenario has been shown to require some qualification (Hallsdóttir and Caseldine 2005). In southern Iceland, for example, there was only sparse birch woodland evident prior to *landnám* at Ketilsstaðir, Mýrdalur, and this was probably due to its exposed coastal location (Edwards *et al.* 2005), while surveys of Eyjafjallahreppur have found remains of charcoal pits dating to the late 13th century in areas now cleared of woodland (Church *et al.* 2007; Dugmore *et al.* 2005; Sveinbjarnardóttir *et al.* 2006). Vésteinsson (1998: 25) cites documentary evidence for clearance of woodland related to the establishment of new farms as late as the 16th century in Skorradalur, Borgarfjörður. Palynological evidence for the persistence of woodland, on the other hand, is scarce. Outside Mývatnssveit just one published pollen site, Viðey near Reykjavík (Hallsdóttir 1993), shows evidence for birch woodland until after AD 1200, although, as a small island, Viðey may have been unusually protected from grazing.

Various strands of evidence point towards similar complexity in the pattern of woodland change around Hofstaðir in the centuries following settlement. It is not known whether the quite considerable patches of birch woodland around Mývatn, especially to the east, have been continuously wooded since prehistoric times. Soil micromorphological analysis has indicated that wood was being burnt at Hofstaðir at least until the late 10th century (Simpson *et al.* 2003; Vésteinsson and Simpson 2004), and at the nearby site of Sveigakot, south of Mývatn, until the 11th or 12th century (Milek 2001, 2002). Preliminary analysis of the charcoal retrieved from the Phase I and II contexts from Sveigakot Trench G (table 2.1) has indicated that *Betula* sp. roundwood was the dominant wood burnt in both phases, presumably harvested from the local region (Duarte 2007). Some birch timber and rootwood was also identified that must have involved the felling of trees or the use of dead wood, but the predominance of roundwood with bark still attached suggests some form of branch harvesting and potential management of the woodland resource. *Salix* sp. (willow) and *Sorbus* sp. were identified in both phases but only in small proportions, again reinforcing the importance of the birch wood. Intriguing rare identifications of conifer timber and bark were also made, with *Larix* sp. (larch) being identified where preservation of the charcoal allowed. *Larix* is exotic to Iceland and probably originated as driftwood, a common resource procurement strategy in the Norse North Atlantic (cf. Malmros 1990; Dickson 1992; Church *et al*. 2005), before being transported to Hofstaðir either as timber or charcoal. Alternatively, it could have arrived as part of artefacts imported from other countries where larch was present at the time. The discovery of this *Larix* charcoal strengthens the impression of strong trade networks existing in the region, as evidenced by zooarchaeology and artefacts (McGovern *et al.* 2006, 2007; Chapters 4 and 5, this volume).

In addition, several hundred charcoalmaking pits have been found on presently unwooded ridge tops in the region, containing birch charcoal radiocarbon dated to as late as the 12th century (Church *et al.* 2006). This constitutes strong evidence for the local persistence of woodland in these locations, as it seems unlikely that heavy wood would be transported unnecessarily (charcoal is much lighter than the wood from which it is made). Charcoal production in Iceland would have been important for producing iron from bog ore, as documented at Hrísheimar, and for repairing imported tools. Pollen evidence for the history of woodland after the settlement period is more equivocal. Data from Helluvaðstjörn suggest that deforestation was a gradual process from *landnám* until around AD 1300, since when little change in the degree of woodland cover has taken place. However, a rise in birch pollen concentrations in the sediments approximately coincident with *landnám* suggests that an alternative interpretation – that the birch pollen was reworked into the basin from the catchment soils following rapid deforestation – cannot be ruled out. At Hrísheimar, birch and juniper pollen percentages and concentrations actually increased before *landnám* (perhaps a response to climatic amelioration during the Medieval Warm Period?), but decreased afterwards; quite how quickly the decline occurred is not clear from the present data, but low values were reached some time before the deposition of the 1477 ash. In short, on the basis of all of the available data, it appears that some woodland was lost very quickly following the initial settlement, while elsewhere (on many ridgetops up to 300 m?) it was preserved for several centuries before it finally disappeared, and in a few areas the woodland may never have been cleared.

How and why did this deforestation take place? Three possible scenarios are: (i) deliberate clearance by axe or by fire to create land suitable for grazing or cultivation; (ii) over-exploitation of the woodlands, beyond their capacity for regeneration, for fuel or building; (iii) and the destruction of trees and/or saplings by introduced herbivores (cf. Buckland and Edwards 1984). A number of archaeological excavations of early farms, particularly towards the interior of Iceland, have found that they were built on a layer of charcoal, suggesting that fire was an important tool in land clearance (Smith 1995), although extensive charcoal layers have only very rarely been found in excavations in Mývatnssveit (Vésteinsson 2004b). Burning on a landscape scale in Mývatnssveit seems unlikely given that only small quantities of charcoal have been found in the palaeoecological records from Helluvaðstjörn, Hrísheimar and Vestmannsvatn. Over-exploitation of woodland is certainly a possibility, despite the evidence for restrictions on rights to gather wood evident in *Grágás* and suggested by the differential rights to woodland inferred by Simpson *et al.* (2003). Preliminary analysis of charcoal assemblages from a series of charcoal production pits at Höskuldsstaðir (approximately 20 km north of Hofstaðir) has suggested management of the birch woodland through episodic harvesting of branchwood, in an attempt to maintain the woodland (Church et al. 2006), a practice indicated from similar analysis on 10th–14th century charcoal production pits from Eyjafjallahreppur, southern Iceland (Church *et al.* 2007). The disappearance of pigs from the archaeofauna at an early date (McGovern *et al.*, Chapter 4, this volume) may also represent an attempt to preserve woodland. Pigs exert considerable damage to woodland through rooting, and preservation of rapidly diminishing woodland may have been one motivation for the transition to a sheep- and cattle-based economy (other explanations are of course possible; cf. Vésteinsson *et al.* 2002).

Aside from *Betula pubescens*, a number of other taxa underwent declines after *landnám*, according to the Helluvaðstjörn and Vestmannsvatn records; these include *Juniperus communis* (juniper), members of the Apiaceae

Historic tephras	
Veiðivötn	AD 1717
Veiðivötn	AD 1477
Hekla	AD 1300
Katla	AD 1262
Hekla	AD 1158
Hekla	AD 1104
Veiðivötn	ca. AD 950
Veiðivötn (Landnám)	AD 871±2
Pre-settlement tephras	
'b' and 'c'	ca. 1,300 / 1,400 years BP
Hverfjall	ca. 2,500 years BP
Hekla (H3)	ca. 2,800 years BP
Hekla (H4)	ca. 4,000 years BP

Table 2.2 Tephrochronology framework for soil environments in Mývatnssveit (based on Sigurgeirsson, 1995; 2001; pers comm.).

(of which *Angelica sylvestris*, or wild angelica, is the most palynologically abundant species), and *Filipendula ulmaria* (meadowsweet). It would be reasonable to assume that a number of less palynologically visible species associated with Icelandic woodland, such as *Vaccinium myrtillus* (bilberry) and *Geranium sylvaticum* (wood crane's-bill), also declined.

Other taxa more tolerant of herbivory or less strongly associated with woodland, such as *Plantago*, Poaceae, *Rumex acetosa* and *Thalictrum alpinum*, became more abundant after *landnám*. An expansion of acidophilic and/or hydrophilic taxa, including *Empetrum nigrum*, *Sphagnum*, *Selaginella selaginoides*, Cyperaceae, and *Potentilla* around Helluvaðstjörn in the centuries following *landnám* may reflect changes to the soils following deforestation: e.g. less interception of rainfall, higher moisture levels, more leaching, and hence waterlogging and acidification.

Tephra falls can have a considerable direct short-term impact on vegetation (Edwards *et al.* 1994, 2004; Edwards and Craigie 1998), and there is limited evidence for this in Mývatnssveit. In the Helluvaðstjörn record, the 1477 and 1717 tephras coincide with short-lived expansions of a number of taxa, including *Thalictrum* and Rubiaceae, perhaps responding to a decline in grazing pressure (Lawson *et al.* 2007). At Hrísheimar, grasses expand coincident with the deposition of the thick 1477 ash, which could be explained as an ecological response to drying of the mire surface, both through the drop in the organic content of the substrate and through the extermination of the moss flora. Similar, but more subtle effects may have accompanied the multiple ash falls of the 9th and 10th centuries.

Soils

(IAS, WPA, KBM, SM, GG)

Data on regional soil history are presented in detail here, followed by a short summary. Further consideration of the history of land management at Hofstaðir is given in Chapter 7.

Most Icelandic soils develop on polycycled aeolian and tephra materials interstratified with discrete tephra layers (Arnalds *et al.* 1995), and are classified as andosols according to the World Reference Base for Soil Resources (FAO 2006). They have andic properties, including high phosphate and high water retention, the latter of which makes them susceptible to frost heave and thufur formation, even in areas with a deep water table (Arnalds 2004). Their silty and fine sandy textures and low bulk density make them highly susceptible to erosion, and it is estimated that around 73% of Iceland's 103 000 km^2 has been affected by erosion (Arnalds *et al.* 2001). Hill slope processes such as solifluction, gelifluction, and frost creep are common, but aeolian deflation is the dominant erosion process. Since vegetation helps to prevent erosion by protecting and binding together the upper soil horizons, deforestation and other pressures on vegetation (e.g. grazing and trampling) are thought to be important initiators of erosion (Arnalds *et al.* 2001; Ólafsdóttir and Guðmundsson 2002). It is readily apparent that large-scale soil erosion has been active in the vicinity of Hofstaðir, most particularly to the south of Mývatn where four partly-deflated farm sites have been or are being excavated (Oddastaðir, Undir Sandmúla, Sveigakot and Hrísheimar), and other abandoned structures lie in what is now a gravel desert.

As soils reflect the environment in which they have been formed, variations in andosol accumulation characteristics can be considered as a record of natural and cultural environmental conditions. Here we use this record to interpret the soil environments of Hofstaðir and its estate and assess how distinctive (or otherwise) they were compared with other nearby localities during the Viking and Medieval periods. Our temporal framework is based on tephrochronology, with discrete tephra horizons evident in the soil profiles we have considered (table 2.2). Of key importance is the Veiðivötn "*landnám*" AD 871±2 and Veiðivötn *c*. AD 940 tephra horizons, which allow distinction between pre-settlement and post-settlement phases of accumulation. Our spatial framework is based on 108 soil profiles at six locations; horizon colours and textures, and soil accumulation rates were recorded for each profile. Additionally, three profiles located in upland domestic livestock grazing areas (one at Hofstaðir) and three in what became homefield areas where hay was produced for winter fodder (again, one at Hofstaðir) were characterized by micromorphology and chemical analysis of bulk samples. Our local soil accumulation rates can be compared with the regional soil accumulation rates determined for different altitudinal zones by Ólafsdóttir and Guðmundsson (2002).

Upland soil profiles

The three upland study areas are the grazing areas associated with farms known to have been occupied during the Viking period: the Sandfell and Gautlandasel shielings (altitudinal range: 360–450 m) belonging to Gautlönd, the grazing area of the Arnarvatnssel shieling (altitudinal range: 280–371 m) belonging to Arnarvatn, and the Hofstaðir estate (altitude range: 220–

Primary temporal phases	Secondary temporal phases	Regional (<300m)	Regional (300-350m)	Regional (350-400m)	Regional (>400m)	*Hofstaðir (220-320m) (n = 36)*	*Sandfell (360-450m) (n = 39)*	*Arnarvatnsel (280-371m) (n = 30)*
AD 1477 - Present		0.35	0.84	0.96	1.10	*0.14*	*0.61*	*0.18*
	AD 1717 - Present	-	-			-	*0.47*	*0.54*
	AD 1477 – AD 1717	-	-			-	*0.23*	*0.33*
***Landnám* – AD 1477**		0.15	0.10	0.13	0.45	*0.17*	*0.12*	*0.13*
	AD 1300 – AD 1477	-	-			-	*0.11*	*0.35*
	***Landnám* – AD 1300**	-	-			-	*0.15*	*0.15*
	***Landnám* – AD 1104**	-	-			-	*0.02*	*0.12*
2,800 yrs BP - *Landnám*		0.05	0.08	0.09	0.1	*0.04*	*0.09*	*0.10*
	2,500 yrs BP – *Landnám*	-	-	-	-	*0.13*	*0.13*	*0.15*

Table 2.3 Mean soil accumulation rates (mm/yr^{-1}), for three study areas in Mývatnssveit: Hofstaðir, Sandfell and Arnarvatnssel. Regional rates are based on Ólafsdóttir and Guðmundsson (2002).

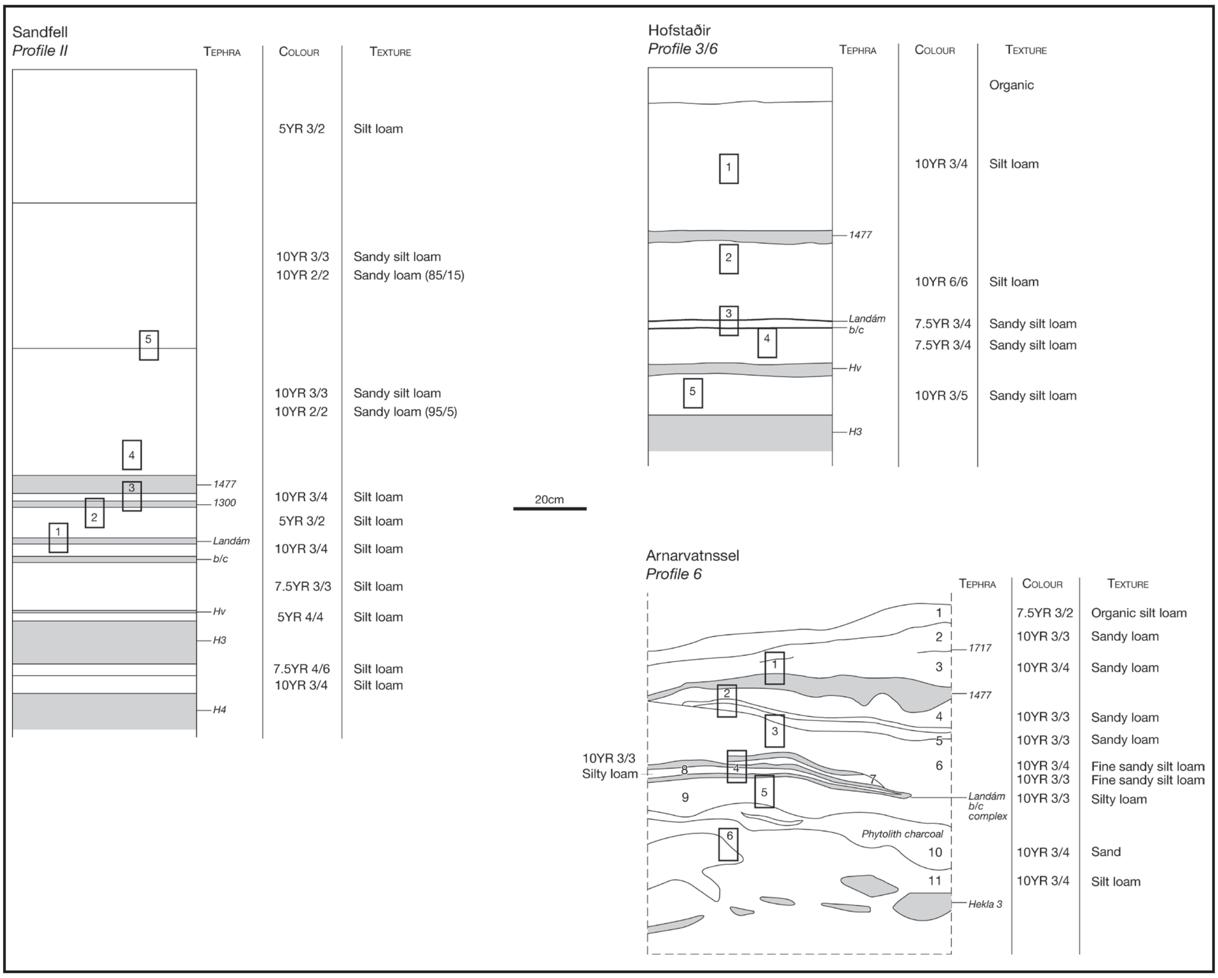

Figure 2.10 Soil profile descriptions and thin section sample locations for upland locations: Sandfell, Hofstaðir and Arnarvatnssel.

320 m). The Helluvaðstjörn pollen sequence described above is located between the Arnarvatnssel and Sandfell grazing areas.

Based on aerial photographs of the greater Hofstaðir estate (bounded by the Laxá, Mývatn, and Sandvatn) only 2% of the area is currently bare ground, most of which is concentrated at breaks of slope. In addition, complete tephrostratigraphies were found in each of 36 soil pits excavated at least as deep as the prehistoric Hekla-3 tephra layer, indicating no major episodes of vegetation clearance or erosion since that time (Simpson *et al.* 2004). Soil accumulation rates in the greater Hofstaðir estate increased from an average of 0.04 mm yr^{-1} before *landnám* (slightly below the <300 m regional average of 0.05 mm yr^{-1}) to 0.17 mm yr^{-1} between *landnám* and AD 1477, just over the regional average of 0.15 mm yr^{-1} (table 2.3; Simpson *et al.* 2004; Ólafsdóttir and Guðmundsson 2002). Some of this additional accumulation may be attributable to localised land management impacts. Since modelling of grazing scenarios has shown that there was more than enough biomass to support the numbers of livestock indicated in historical sources, even under deteriorating climatic conditions (Thomson and Simpson 2007; Chapter 7, this volume), it is likely that other land management practices, such as intensive winter grazing or the failure to remove livestock before the end of the growing season, might have initiated localised erosion (Simpson *et al.* 2001, 2004). The rate of soil accumulation decreased to an average of 0.14 mm yr^{-1} between 1477 and the present, well below the regional value of 0.35 mm yr^{-1}. This contrast between Hofstaðir and the surrounding landscape can be interpreted as an indication of improved land man-

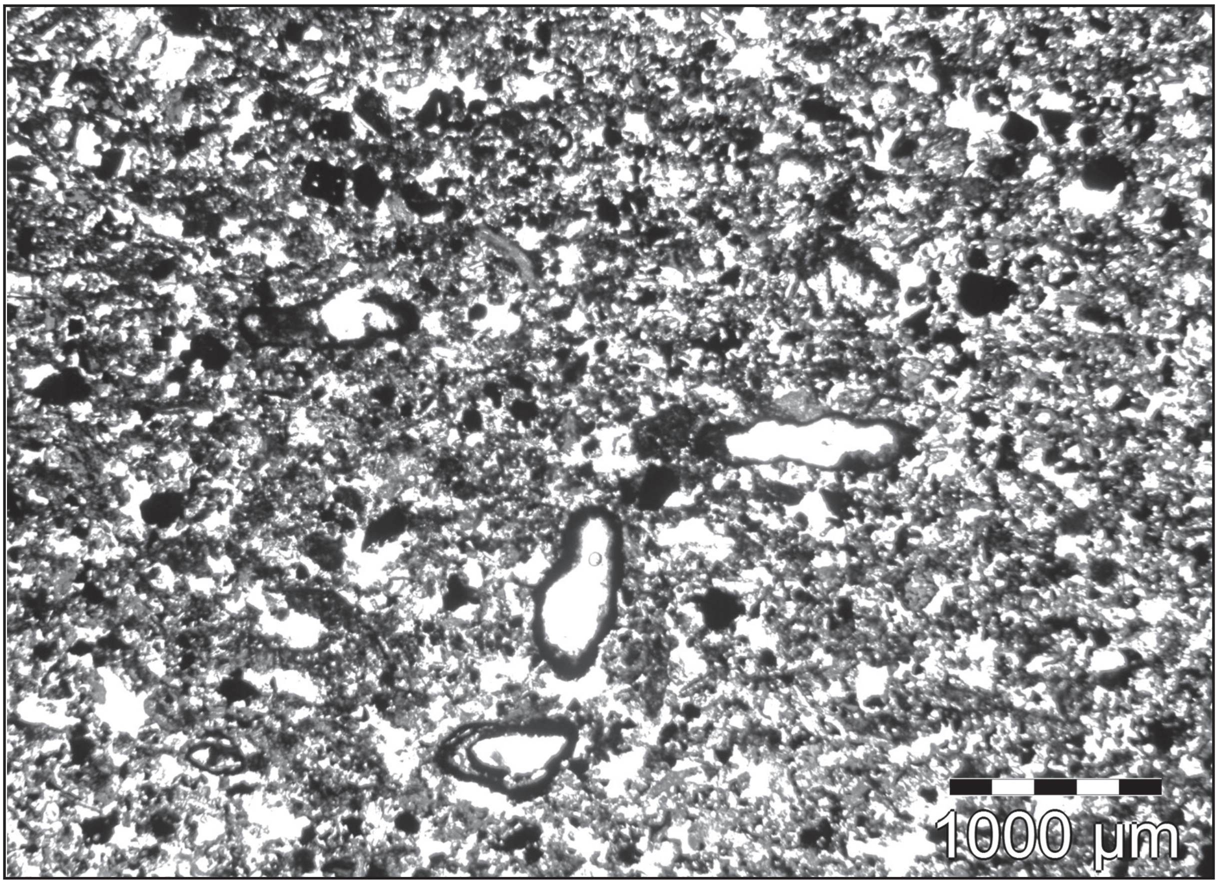

Figure 2.11 Brown and dark brown organo-mineral matrix with organic material. Sandfell Profile 11, Sample 1, Micro-horizon c, immediately below *landnám* tephra. Indicative of relatively stable, vegetation-covered landscape.

agement practices on the Hofstaðir estate which minimized the effects of grazing pressures on the local vegetation. However, further analyses are required to assess the relative contribution of locally- and more distantly-sourced aeolian materials on the Hofstaðir estate.

Soil micromorphological analysis of upland profiles at Hofstaðir (fig.2.10; see Chapter 7 this volume for further analyses; Simpson *et al.* 2004) shows that preserved pre-*landnám* soils consist of discrete fine angular and sub-angular mineral grains and a range of fine and coarse organic materials with associated very few to few phytoliths. These observations suggest that although there was some movement of soil material, high organic matter accumulation predominated in a relatively stable, well-vegetated landscape. Between the *landnám* and 1477 tephras the coarse material is better sorted and arranged into clustered and linear patterns. The proportion of fine organic material declines, although the proportion of coarse organic material changes little; there is also an increase in the frequency class of fine organomineral material (intimately mixed organic and mineral material, <63 µm). Microstructures remain predominantly granular with laminar structures, with associated silty textural pedofeatures also evident. These observations suggest a marked change in accumulation characteristics between pre- and post-*landnám* periods, with accelerated fine-grained aeolian deposition and reduced input of organic material from surface vegetation indicating greater landscape instability, a water-sorted contribution to soil accumulation in parts of the estate, and cryoturbation processes operating on relatively unstable soils, indicating a colder climate. Above the 1477 tephra, the frequency of coarse and fine organic materials increases and fine mineral material decreases.

This partly reflects proximity to the present-day land surface, but it is also evident that organic frequency classes closely resemble those of the pre-*landnám* soils; coarse mineral material frequency and distribution, on the other hand, are similar to the earlier historic phase. The soil micromorphology thus suggests a partial recovery of landscape stability, even though evidence of aeolian and water-related soil erosion is still apparent.

At Sandfell, aerial photographs indicate that *c.* 10% of the area is bare ground. To assess earlier patterns of soil movement, 39 randomly selected soil profiles were exposed across the area (table 2.3). From field-based observations, mean soil accumulation rates were 0.13 mm yr^{-1} between Hekla-3 (*c.* 2800 BP) and Hv (a prehistoric tephra from the nearby volcano Hverfjall, *c.* 2500 BP), and 0.09 mm yr^{-1} between Hv and *landnám*. This second value is very similar to the regional value, indicating uniformly limited soil movement across the region prior to settlement and suggesting a nearly stable landscape. However, the earlier, higher value suggests either an inherent susceptibility to erosion or a lag in the slowing of accumulation rates at Sandfell. Between *landnám* and 1477, accumulation rates increased to 0.12 mm yr^{-1}, remaining below the regional rate. A limited number of profiles with the 1104 and 1300 tephras allow sub-division of this period into three phases; mean values were 0.02 mm yr^{-1} between *landnám* and 1104, 0.15 mm yr^{-1} from *landnám* to 1300, and 0.11 mm yr^{-1} from 1300 to 1477. This suggests negligible initial impact with settlement, with the greatest pressure on this locality between 1104 and 1300, and a reduction in local impacts between 1300 and 1477. Soil accumulation rates increased markedly after 1477 to a mean of 0.61 mm yr^{-1}, although again this is lower than the regional mean. In profiles containing the 1717 tephra, mean accumulation rates are 0.23 mm yr^{-1} from 1477 to 1717 and 0.47 mm yr^{-1} from 1717 to the present day, indicating that the greatest increase in soil accumulation has occurred since 1717.

Thin section micromorphology provides more information on changing soil accumulation at Sandfell (Profile 11: fig.2.10; table 2.4). Soils immediately beneath the *landnám* tephra are characterized by very few to few well sorted coarse mineral materials within a brown and dark brown organomineral matrix, with frequent amorphous brown fine organic material and channel and chamber microstructures (fig.2.11). These observations suggest that while there was some aeolian deposition of mineral material, the dominant process was pedogenesis with the accumulation of organic material. This implies a relatively stable landscape at the time of settlement. Similar micromorphological features, and thus relative landscape stability, are evident between *landnám* and 1104 tephras, with sub-angular blocky structures formed beneath an organomineral-dominated microhorizon. Between the 1104 and 1477 tephras the proportion of wind-sorted coarse mineral material to organomineral and organic material increases, suggesting increasing landscape instability, although organic accumulation was still a significant component during this period. Micromorphological characteristics change with the rapid increase in soil accumulation rate after 1477. There is a marked increase in the occurrence of coarse mineral material and a corresponding decline in fine organomineral and organic materials, reflecting greater landscape instability (fig.2.12). As the profile developed with time the coarse mineral fraction increased in size, suggesting a further increase in erosion. Well-sorted sequences of coarse and less coarse mineral material also become apparent, reflecting erosion and accumulation episodes of varying magnitude.

Thirty randomly selected soil profiles were exposed to measure soil accumulation rates at Arnarvatnssel where 8% of the area is currently bare ground. Mean pre-*landnám* soil accumula-

Sandfell Profile II

Thin Section sample	Micro-horizon	COARSE MINERAL MATERIAL >63µm: TEPHRA: Vö 1477	Hekla 1300	Landnám 871	Brown	Pale brown	Grey	Black	Igneous rock	Phytoliths	Diatoms	Bone	Rubified mineral	FINE MINERAL MATERIAL	COARSE ORGANIC MATERIAL: Charcoal	Parenchymatic	Fungal Sclerotia	FINE ORGANIC MATERIAL: Cell residue	Amorphous (black)	Amorphous (brown)	PEDOFEATURES: Silt coatings	Amorphous crypto - crystalline (reddish brown)	Depletion	Excremental (mammillate)	Excremental (spheroidal)	MICROSTRUCTURE	COARSE MATERIAL ARRANGEMENT	GROUNDMASS b FABRIC	RELATED DISTRIBUTION
5	a				•	•••		•••	•	•	•			• Brown Organo mineral		•	•		•	•	*t*					Single grain Intergrain microaggregate	Random well sorted	Stipple	Enaulic
	b				•	••		••		•	•			•• Brown Organo mineral		•	•		•	•						Intergrain microaggregate	Random well sorted	Stipple	Enaulic
4					•	••		••	•	•	•			•• Brown Organo mineral		•	•		•	•						Intergrain microaggregate	Random well sorted	Stipple	Enaulic
3	a	••••																								Single grain Lenticular			
	b				•	••		••	•	•	•			••• Brown Organo mineral		•	•		•	••						Intergrain microaggregate	Random well sorted	Stipple	Porphyric
	c		••••																							Single grain			
	d				•	••		••	•	•	•			••• Brown Organo mineral		•	•		•	••						Intergrain microaggregate	Random well sorted	Stipple	Porphyric
2	a		••••																							Single grain			
	b				•	••		••	•	•				••• Brown Organo mineral		•	•		•	••						Intergrain microaggregate	Random well sorted	Stipple	Porphyric
	c													•••• Grey mineral Hekla 1104															
	d				•	•		•	•	•				••• Brown Organo mineral		•	•		•	•••						Intergrain microaggregate	Random	Stipple	Porphyric
1	a				•	••		••	•	•				••• Brown Organo mineral			•		•	••	•					Channel and chamber Subangular blocky	Well sorted	Stipple	Porphyric
	b			••••																•						Single grain	Random well sorted		
	c				•	•		•	•	•				••• Brown and Dark brown Organo mineral			•		•	•••						Channel and chamber	Random well sorted	Stipple	Porphyric

Frequency class refers to the appropriate area of section (Bullock *et al., 1985*) *t* Trace • Very few •• few ••• Frequent/common •••• Dominant/very dominant.
Frequency class for textural pedofeatures (Bullock *et al., 1985*) *t* Trace * Rare ** occasional *** Many

Table 2.4 Sandfell and Gautlandsel. Summary thin section descriptions, profile 11.

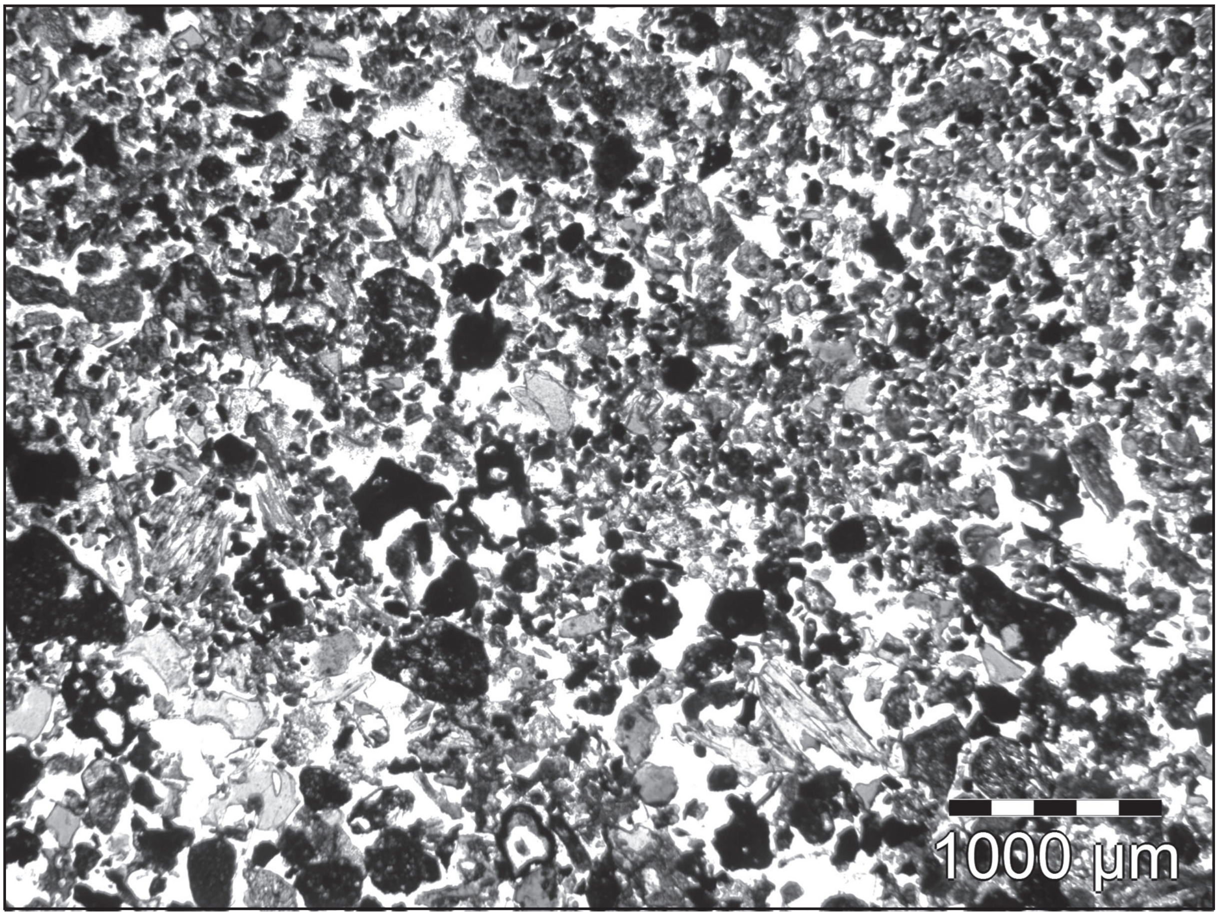

Figure 2.12 Coarse mineral material with very few organic materials. Sandfell Profile 11, Sample 5, Micro-horizon b, above 1477 tephra. Indicative of unstable landscape with limited local vegetation cover.

tion rates are 0.15 mm yr^{-1} between H3 and Hv, and 0.10 mm yr^{-1} between Hv and *landnám*, slightly higher than at Sandfell and perhaps indicating a greater inherent susceptibility to erosion (table 2.3). Between the *landnám* and 1477 tephras, accumulation rates increase to 0.13 mm yr^{-1}, close to the regional rates. Subdivision within this time period gives mean values of 0.12 mm yr^{-1} between *landnám* and 1104, 0.15 mm yr^{-1} between *landnám* and 1300, and 0.35 mm yr^{-1} between 1300 and 1477. This suggests a slight initial impact with settlement, with impact increasing through to 1300 and accelerating to 1477. In further contrast to Sandfell, mean accumulation rates decline after 1477, although in the few profiles containing the 1717 tephra accumulation rates parallel the increases at Sandfell.

In thin section, soil accumulation during earlier pre-*landnám* phases at Arnarvatnssel is dominated by medium sands with less frequent fine organomineral material and granular microstructures (fig.2.10; table 2.5). Much of the material in some micro-horizons is made up of siliceous phytoliths and diatoms, indicating that the accumulation in much of this part of the profile is the result of now decomposed organic material rather than aeolian deposition, and that the observed enhanced soil accumulation rates are in fact the result of vegetation cover and landscape stability. Immediately below the *landnám* tephra the frequency of fine organomineral material increases together with amorphous brown material and occurrences of excremental pedofeatures. These features, together with granular and channel and chamber microstructures, are also strongly indicative of a relatively stable, vegetation-covered land-

Arnarvatnssel Profile 6

Thin Section sample	Micro-horizon	Coarse mineral material >63μm – Tephra: Vö 1717	Tephra: Vö 1477	Tephra: Hekla 1300	Tephra: Landnám 871	Brown	Pale brown	Grey	Black	Igneous rock	Phytoliths	Diatoms	Bone	Rubified mineral	Fine mineral material	Coarse organic material: Charcoal	Parenchymatic	Fungal Sclerotia	Fine organic material: Cell residue	Amorphous (black)	Amorphous (brown)	Pedofeatures: Silt coatings	Amorphous crypto - crystalline (reddish brown)	Depletion	Excremental (mammillate)	Excremental (spheroidal)	Microstructure	Coarse material arrangement	Groundmass b fabric	Related distribution
1	a						••		••		•	•			••• Brown Organo mineral		•	•		•	••						Granular Lenticular	Random	Stipple	Porphyric
	b	•••													•• Brown Organo mineral						•						Single grain Lenticular	Random	Stipple	Porphyric
	c						••		••		•	•			••• Brown Organo mineral		•	•		•	••						Granular Lenticular	Random	Stipple	Porphyric
	d		••••																								Single grain			
	e						••		••		•	•			••• Brown Organo mineral		•	•		•	•						Lenticular	Random	Stipple	Porphyric
2	a		••••																								Single grain			
	b						••		••		•	•			•• Brown Organo mineral		•	•		•	•						Granular	Random	Stipple	Porphyric
	c						•••	••	••		••																			
3	a						••		••		•	•			•• Brown Organo mineral		•	•		•	•						Granular	Random	Stipple	Porphyric
	b						•••	•	••		••																Single grain			
4	a						••		••		•				••• Brown Organo mineral					•	•						Granular	Random	Stipple	Porphyric
	b				••••										••• Brown Organo mineral												Single grain			
	c						••		•		•				••• Brown Organo mineral			•		•	••		•				Granular Channel and chamber	Random	Stipple	Porphyric
5	a				••••																									
	b						•••		••		•				• Brown Organo mineral												Granular	Random	Stipple	Enaulic
	c						•		•		•••		••		• Brown Organo mineral			•				•					Granular	Random	Stipple	Enaulic
6	a						•••		••		•				•• Brown Organo mineral					•	•	•					Granular	Random	Stipple	Porphyric
	b						••••		•		•																			

Frequency class refers to the appropriate area of section (Bullock *et al., 1985*) *t* Trace • Very few •• few ••• Frequent/common •••• Dominant/very dominant.
Frequency class for textural pedofeatures (Bullock *et al., 1985*) *t* Trace * Rare ** occasional *** Many

Table 2.5 Arnarvatnssel. Summary thin section descriptions, profile 6.

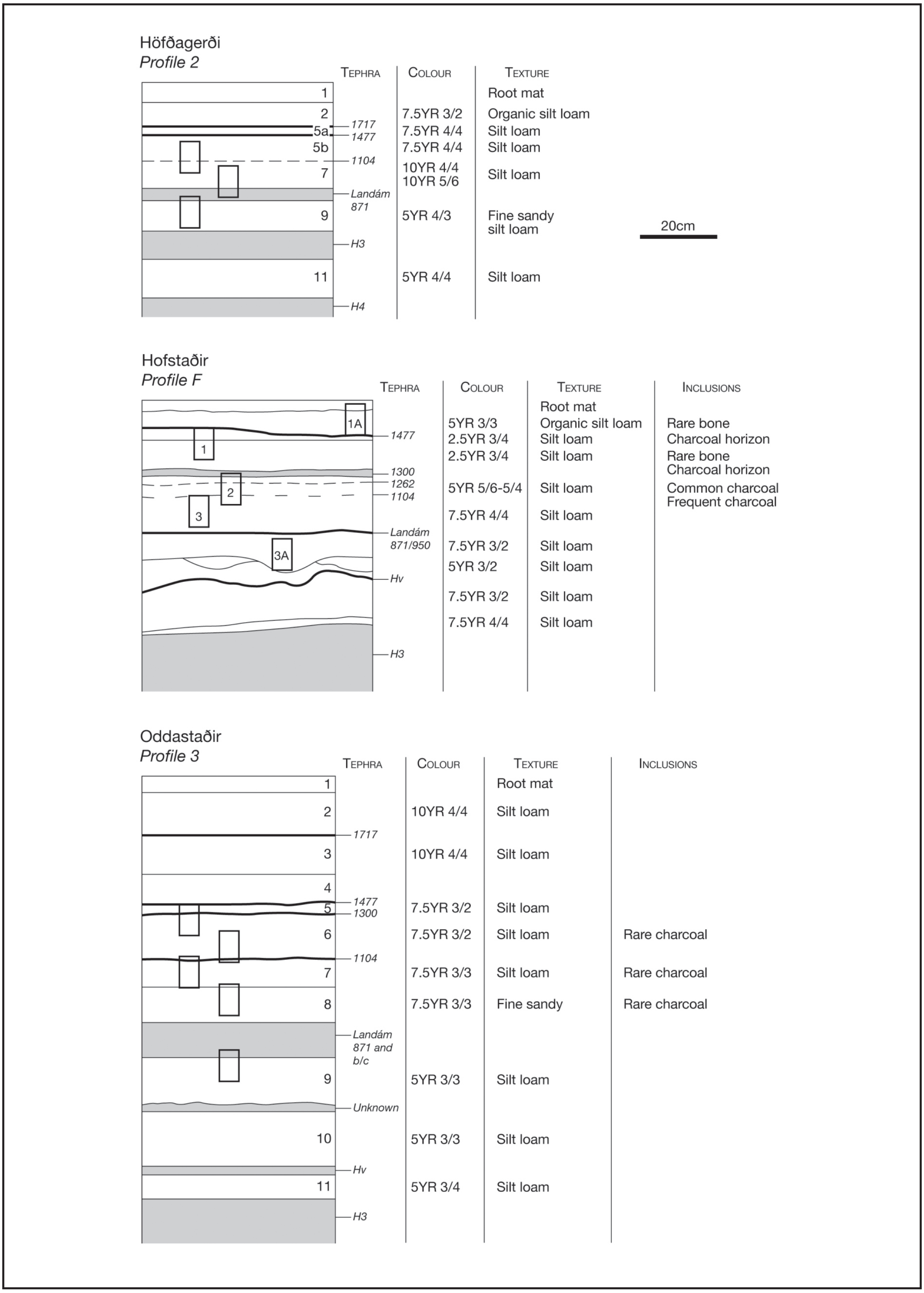

Figure 2.13 Soil profile descriptions and thin section sample locations for homefield locations: Höfðagerði, Hofstaðir and Oddastaðir.

Site	Horizon/ Sample	OM (%w/w)	Total N (% w/w)	Total P (mg/100g)	Total C (%w/w)	%Clay (total)	%Silt (total)	%Sand (total)	Texture
Höfðagerði	Horizon 2	11.8	0.36	85	6.12	2.9	52.3	44.8	Sandy silt loam
	Horizon 5A	24	0.53	143	0.53	4.3	66.7	29.0	Sandy silt loam
	Horizon 5B	28.7	0.65	183	10.7	5.3	86.1	8.5	Silt loam
	Horizon 7	27.9	0.68	200	10.4	2.8	55.6	41.6	Sandy silt loam
	Horizon 8	26.3	0.45	119	9.31	3.3	53.3	43.4	Sandy silt loam
	Horizon 9	9.4	0.32	111	5.84	2.7	41.2	56.1	Sandy loam
	Tephra H3	2.9	0.15	39	2.04	6.1	68.5	25.4	Sandy silt loam
	Horizon 11	4.1	0.19	141	3.4	3.5	45.5	51.0	Sandy loam
Oddastaðir	Horizon 2	5.7	0.18	66	2.85	4.6	48.8	46.6	Sandy silt loam
	Horizon 3	6.9	0.24	73	3.7	5.9	52.3	41.9	Sandy silt loam
	Horizon 5	7	0.25	81	3.58	2.9	47.8	49.3	Sandy silt loam
	Horizon 6	8.6	0.39	126	5.39	5.1	68.4	26.4	Sandy silt loam
	Horizon 7/8	9.5	0.35	132	5.11	3.8	64.3	32.0	Sandy silt loam
	Landnám tephra	2.8	0.12	66	1.51	4.4	55.6	40.1	Sandy silt loam
	Horizon 9	5.6	0.22	75	3.36	4.1	59.1	36.9	Sandy silt loam
Hofstaðir	Sample 1	10.4	0.41	447	5.91	FT	FT	FT	Sandy silt Loam
	Sample 2	28.3	0.63	459	9.24	FT	FT	FT	Sandy silt Loam
	Sample 3	11.5	0.44	204	6.48	FT	FT	FT	Sandy silt Loam
	Sample3A	25.6	0.65	195	9.17	FT	FT	FT	Sandy silt Loam

FT – assessed by field-texture

Table 2.6 Chemical and physical measurements of home-field soils in Mývatnssveit/Laxá valley.

scape at *landnám*. Between the *landnám* and 1477 tephras fine organic material becomes less abundant and discrete microhorizons occur dominated alternately by, on the one hand, weathered coarser and lenticular material, and on the other, finer material with a granular structure. This suggests a destabilised landscape with fluctuating sedimentary environments in a cooler climate. Further support for landscape instability comes from detailed examination of the 1477 tephra horizon where, in thin section, three 1477 tephra microhorizons are evident between lenticular silt accumulations; this suggests that the 1477 tephra was locally mobile after initial deposition. Fine organomineral and organic materials increase between the 1477 and 1717 tephras, implying that the landscape became more stable at this location.

Homefield soil profiles

Soils from within the boundaries of the semi-improved homefield areas at Höfðagerði, Oddastaðir and Hofstaðir were examined. At Höfðagerði and Oddastaðir six profiles were exposed on a transect across the homefield, while at Hofstaðir two profiles were exposed, avoiding the many buried turf structures in the homefield. One representative profile from each of the sites was considered in detail.

The site of Hofstaðir is on a well-drained brown andosol measuring over 1.1 m thick in the region of area G, grading to a more imperfectly drained andosol across the homefield. *In situ* soil was recorded below the archaeological deposits in numerous micromorphology samples across the site, and the upper A horizon of the local 10th century soil was also found in micromorphology samples from turf roof and wall construction materials. These Viking Age topsoils were orange brown to red-brown silty clay loams, with the ultrafine granular microstructure (rounded peds <0.5 mm in size) typical of the surface horizons of andosols (Arnalds *et al.* 1995). Within the homefield, the soil profile is characterized by dark brown colours beneath and dark reddish brown above the *landnám* tephra (fig.2.13). In soils above the *landnám* tephra, rare fine bone fragments are found with charcoal occurrences. Total phosphorus and total nitrogen values are enhanced above the *landnám* tephra with total phosphorus values the highest of the three homefield study profiles (table 2.6).

In thin section (see Chapter 7, this volume for more detailed analyses) soils prior to *landnám,* and continuing just above the *landnám* tephra, lack any evidence of cultural activity. They do have features indicative of imperfectly drained conditions that continue immediately above the *landnám* tephra to a microstratigraphic sequence of contrasting silt and fine sand accumulations indicative of landscape disturbance. Above this sequence, soil accumulation characteristics revert to an absence of cultural amendment. These observations suggest an initial impact followed by a hiatus after which cultural amendment of the soil began and which occurred dominantly just before 1104 and through to the 1477. Amendments included domestic waste, fuel residues and animal manures.

At Höfðagerði soil accumulations prior to settlement are reddish brown in colour, contrasting with the browns and dark yellowish browns of material accumulated after settlement (fig.2.13). Total phosphorus, total nitrogen and organic matter contents, indicative of organic amendment, show marked increases post settlement. The highest levels of total phosphorus and total nitrogen are evident immediately above the *landnám* tephra and below the 1104 tephra, and decline above the 1104 tephra (table 2.6). In thin section, features below the *landnám* tephra are dominated by a brown granular organomineral fine material (table 2.7). The *landnám* tephra itself has been disrupted, with mixing of material from the underlying horizon. Soil accumulation associated with settlement is characterized by a dense dark brown organomineral fine material with increased occurrences of fine organic material and excremental pedofeatures, and very few charcoal pieces. The occurrence of these features declines above the 1104 tephra, paralleling the measured total phosphorus and total nitrogen values.

Of the three homefield profiles considered, soils are thickest at Oddastaðir with reddish brown pre-*landnám* accumulations contrasting with very dark greyish browns of the post-*landnám* sequences, within which are embedded rare occurrences of charcoal (fig.2.13). These cultural inclusions are reflected in the total phosphorus, total nitrogen and organic matter values which, although having the lowest levels of the three homefield profiles, increase above the *landnám* tephra, are maintained between 1104 and 1300, and decline markedly above this tephra (table 2.6). In thin section (Profile 3: table 2.8), a fine organomineral granular material is dominant with frequent brown amorphous fine organic materials below and just above the *landnám* tephra. A sharp boundary is evident between this lower microhorizon and a complex repeating microhorizon sequence of silts and fine sands, fine grey mineral material and brown organomineral fine material; fine organic materials are few and microstructures are intergrain microaggregate and lenticular. This sequence of accumulation continues to the 1104 tephra. Between the 1104 and 1300 tephras, a consistent range of coarse mineral material is evident together with mixed brown and grey fine mineral material with intergrain microaggregate and lenticular microstructures maintained. Very few charcoal pieces are evident in this part of the stratigraphy and in

Höfðagerði

Thin Section sample	Micro-horizon	COARSE MINERAL MATERIAL >63µm: TEPHRA															FINE MINERAL MATERIAL	COARSE ORGANIC MATERIAL				FINE ORGANIC MATERIAL			PEDOFEATURES					MICROSTRUCTURE	COARSE MATERIAL ARRANGEMENT	GROUNDMASS b FABRIC	RELATED DISTRIBUTION
		Vö 1477	Hekla 1300	Katla 1262	Hekla 1104	Landnám 871	Hekla (H3)	Brown tephra	Pale brown	Grey	Black	Igneous rock	Phytoliths	Diatoms	Bone	Rubified mineral		Charcoal	Charcoal (with inclusions)	Parenchymatic	Fungal Sclerotia	Cell residue	Amorphous (black)	Amorphous (brown)	Silt infills	Amorphous crypto - crystalline (reddish brown)	Depletion	Excremental (mammillate)	Excremental (spheroidal)				
15 - 23	a							•	•	•							Dark Brown organo mineral	t		••	•		•	•				•		Crack	Random	Stipple Speckled	Porphyric
					••												• Grey; mineral																
	c							•	•	•			•	•		t	Dark Brown; organo mineral	•		••	•		••	••				••		Crack	Random	Stipple Speckled	Porphyric
21 - 29	a							•	•	•			•	•		t	•••• Dark Brown;Brown; organo mineral	•		•	•		••	••		•		••	•	Crack Channel	Random	Stipple Speckled	Porphyric
						••											••• Brown; organo mineral			•			•	•						Granular	Random	Stipple Speckled	Porphyric
29 - 37	a							•	•	•			•	•		t	•••• Brown; organo mineral			•	•		•	•		•		•		Granular	Random	Stipple Speckled	Porphyric
							••••										Pale Brown; mineral							•		•		•		Channel and chamber	_	Isotropic	_

Frequency class refers to the appropriate area of section (Bullock *et al., 1985*) *t* Trace • Very few •• few ••• Frequent/common •••• Dominant/very dominant.
Frequency class for textural pedofeatures (Bullock *et al., 1985*) *t* Trace * Rare ** occasional *** Many

Table 2.7 Höfðagerði home field. Summary thin section description, profile 2.

Profile 4, 20 m down slope from Profile 3, very few fine bone fragments are also found in the equivalent part of the stratigraphic sequence, their limited occurrence suggesting little cultural amendment. Above the 1300 tephra, coarse mineral material and light brown fine mineral materials organized as porphyric granular and intergrain microaggregate microstructures predominate, which in the absence of organic material in thin section, suggests a devegetated and destabilized landscape.

Summary

In upland environments, soil accumulation rates and thin section micromorphology have provided complementary spatial and temporal evidence of contrasting occurrences and intensities of soil movement and stability in the Mývatnssveit region. Where soil accumulation rates are low and the landscape is stable there is greater accumulation of organic materials, or their siliceous remains, and evidence of biological activity; conversely, where accumulation rates are high, silt and coarse sand accumulations with low organic content are more prevalent. From this soils-based evidence the distinctiveness of the Hofstaðir estate emerges. Stability is consistently evident at what became the Hofstaðir estate prior to *landnám*, back to the deposition of the Hekla-3 tephra. This locality does not exhibit cycles of stability and soil movement evident elsewhere (generally, at higher altitudes) in Mývatnssveit, implying an inherent resilience to land degradation. *Landnám* impacts are discernable at Hofstaðir as they are at other locations in Mývatnssveit, although the impact is delayed at Sandfell. Landscape recovery is evident at Hofstaðir after 1477, as a result either of improved management of grazing livestock on the estate or a reduction in their numbers. This is in contrast to the return to cyclical erosion observed at Arnarvatnssel, and threshold-crossing to continuously accelerating degradation at Sandfell, serving to highlight marked contrasts in landscape responses within grazing areas. In comparing homefield areas, Hofstaðir's is found to be predominantly on imperfectly drained soils, which would encourage enhanced productivity compared to the well drained soils of the other two sites considered. Evidence of *landnám* impacts exhibit their greatest intensity at Hofstaðir in the distinctive occurrence of silt and fine sand accumulations as microhorizons. From prior to 1104 through to 1477, cultural soil amendment occurs with an intensity not seen elsewhere in the region, interpretable as a major effort to maintain and enhance soil fertility and hence vegetation productivity. Evidence from both upland and homefield areas thus points to the distinctiveness of Hofstaðir in terms of its relative inherent resilience to soil degradation and in terms of the effort put into land management. This ensured that the estate was spared from substantial erosion, remaining relatively intact and productive to the present day.

Freshwater environments

(MJC, KJE, FJGH, ITL)

Preliminary archaeofaunal data from Viking Age assemblages from Hofstaðir, Sveigakot and Selhagi showed intriguing patterns. At all three sites, wild freshwater fish appear to have been important in the first century or so of settlement, but became less important relative to domestic mammals after AD 1000; this change was particularly striking at Hofstaðir. Where data are available, at Sveigakot and Selhagi, the abundance of charr (*Salvelinus alpinus*) relative to trout (*Salmo trutta*) increased over time. At all three sites marine fish were present from the earliest phases of settlement onwards, and at Selhagi they became much more important after AD 1000. This raised questions: why did communities apparently reduce their use of local freshwater fish, when these resources today

Oddastaðir Profile 3

Thin Section sample	Micro-horizon	COARSE MINERAL MATERIAL >63µm: TEPHRA															FINE MINERAL MATERIAL	COARSE ORGANIC MATERIAL				FINE ORGANIC MATERIAL			PEDOFEATURES					MICROSTRUCTURE	COARSE MATERIAL ARRANGEMENT	GROUNDMASS b FABRIC	RELATED DISTRIBUTION
		Vö 1477	Hekla 1300	Katla 1262	Hekla 1104	Landnám 871	Hekla (H3)	Brown	Pale brown	Grey	Black	Igneous rock	Phytoliths	Diatoms	Bone	Rubified mineral		Charcoal	Charcoal (with inclusions)	Parenchymatic	Fungal Sclerotia	Cell residue	Amorphous (black)	Amorphous (brown)	Silt coatings	Amorphous crypto - crystalline (reddish brown)	Depletion	Excremental (mammillate)	Excremental (spheroidal)				
32 - 40	a							••	•	•	••		•	•			•• Light Brown; Organo mineral			•			•	••		•				Granular	Random	Speckled	Porphyric
	b	••••																												Single grain	Random		
	c							••	•	•	••		•	•			•• Light Brown; Organo mineral			•	•		•	••		•				Intergrain microaggregate	Random	Speckled	Porphyric
	d		••••																											Single grain	Random		
	e							••	•	•	••		•	•			•• Light Brown; Organo mineral			•	•		•	••		•				Intergrain microaggregate	Random	Speckled	Porphyric
38 - 47	a							•	•	•	•		•	•			••• Light Brown and Grey; Organo mineral	•		•	•		•	••	•	•				Intergrain microaggregate Lenticular	Random	Speckled	Porphyric
	b							•	•	•	•		•	•			••• Greyish and Light Brown; Organo mineral			•			•	•						Lenticular	Random	Slightly Speckled	Enaulic
	c				•••												••• Grey (Hekla 1104)						•	•						Lenticular		Speckled	
	d							•	•	•	•		•	•			••• Light Brown and Grey; Organo mineral			•			•	••		•				Intergrain microaggregate Lenticular	Random	Speckled	Porphyric
46 - 54	a							••			••			•	•		••• Light Brown; Organo mineral			•	•		•	•••		•				Intergrain microaggregate	Random	Speckled	Enaulic
	b							••			••			•	•		•• Light Brown and Greyish; Organo mineral			•	•		•	•						Lenticular	Random	Speckled	Enaulic
	c							•			•			••	•		••• Grey; Mineral													Lenticular	Random	Speckled	Enaulic
	d							•	••		•						•• Light Brown; Organo mineral			•	•		•	••		•		•		Intergrain microaggregate	Random	Speckled	Enaulic
56 - 61	a							•	••		•						•• Light Brown; Organo mineral			•	•		•	••	•	•		•		Single grain granular	Random	Speckled	Enaulic
	b				••••												• Grey; Mineral				•		•	•		•				Single grain	Random	Speckled	Monic
69 - 77	a				••••												• Grey; Mineral													Single grain	Random	Speckled	Monic
	b							•	•		••						••• Reddish Brown; Organo mineral			•	•		•	•••		•				Granular	Random	Speckled	Porphyric

Frequency class refers to the appropriate area of section (Bullock *et al., 1985)* *t* Trace • Very few •• few ••• Frequent/common •••• Dominant/very dominant.
Frequency class for textural pedofeatures (Bullock *et al., 1985)* *t* Trace * Rare ** occasional *** Many

Table 2.8 Oddastaðir home field. Summary thin section description, profile 3.

are abundant and relatively easy to exploit? And why did they go to the trouble of importing marine fish from the coast, 50 km away?

One possibility is that this was forced by changes in the abundance of these resources in the environment. This was tested as far as possible by a review of the available evidence for change in the freshwater environments (Lawson *et al.* 2006). One conclusion of this study was that there is no evidence that the productivity of Mývatn, the main freshwater resource in the region, has declined over time. Sedimentation in Mývatn has been extremely rapid throughout its history (Einarsson *et al.* [1993, 2004] cite rates of 1.5–2.7 mm yr^{-1} for one tephrochronologically-dated core, with rates highest after *landnám*) due to high biogenic sedimentation resulting from high biological productivity. Twentieth century catches of fish from Mývatn (mostly charr with some trout; the former is preferentially found in lake habitats) ranged between 15,000 and 40,000 individuals per year (Gudbergsson 2004). The productivity of Mývatn governs that of the Laxá downstream, which thus is likely also to have remained an abundant source of trout.

Lawson *et al.* (2006) found that, at the small oligotrophic lake Helluvaðstjörn, 3.5 km south-southwest of Hofstaðir, the palaeolimnological record indicates a large increase in the productivity of aquatic algae (*Pediastrum*), macrophytes (*Myriophyllum alterniflorum* in particular), and chironomids between landnám and *c*. AD 1200. This pattern of change has subsequently been replicated in its essentials at Vestmannsvatn, though there *Potamogeton* and *Nymphaea alba* are added to the list of aquatic macrophytes that expand, and the productivity of chironomids does not seem to increase so markedly as at Helluvaðstjörn. Vestmannsvatn is a much larger lake than Helluvaðstjörn and is fed by the Reykjadalsá, the next river system to the west of the Laxá, so trophic conditions in this lake probably reflect land use changes integrated over a much larger area. Thus, assuming that Helluvaðstjörn and Vestmannsvatn are representative of the oligotrophic lakes and rivers in the region, there is no evidence that the productivity of these systems declined over the first few centuries of the settlement; on the contrary, palynological and chironomid evidence points to a large and sustained increase in nutrient supply beginning with the settlement, possibly in relation to reworking of organic soils, cultivation and manuring, or a more direct input of nutrients from watering cattle. Both lakes remain more productive today than they were before the settlement.

On the other hand, some parts of the aquatic ecosystem may have responded in the opposite direction. For instance, the Kráká has likely seen a drop in productivity between the initial settlement and the present day as the surrounding landscape has been desertified, and many of the small lakes in the Framengjar will have become smaller and shallower, or even disappeared entirely, as sedimentation proceeded.

In conclusion, the decline in the importance of freshwater fish at some Viking Age and early medieval sites, and the inclusion of marine fish in the diet of the people of Hofstaðir, Sveigakot and Selhagi from the outset, seem in balance not to reflect environmental degradation; as far as we are able to tell from the present data, these features of the archaeofaunal datasets are better explained through cultural explanations than as a result of a decline in the productivity of aquatic ecosystems.

Discussion

The development of Hofstaðir, its economy, and the dynamics of its relationship with other farms in the area, require consideration within the context of an environment which was both different from today's, and constantly changing. In a situation as marginal for agriculture as Mývatnssveit, environmental change could *a priori* be expected to have great importance for these aspects of the site's evolution. The available palaeoenvironmental data indicate that caution is required before developing theories based on environmental determinism, and that cultural factors may be equally or more important in determining the changing socio-economic status of a farm, and its relationship with its neighbours, in space and time.

The first settlers of Mývatnssveit encountered a varied landscape with a rich diversity of resources. For practitioners of a typical 'Norse' pastoral economy, it may have seemed a potentially productive environment, apart perhaps from the difficulty of growing crops other than hay, which the simulation studies presented here suggest may have been less restrictive at the peak of the Medieval Warm Period. The indications are also that year-to-year climate was more predictable than it was to become during the Little Ice Age (Dugmore *et al.* 2007).

Environmental change since initial settlement in the North Atlantic region is frequently considered as a story of human impact and ecosystem degradation (e.g. Dugmore *et al.* 2000, 2005; Simpson *et al.* 2001; Diamond 2005), and elements of this narrative certainly hold true for Mývatnssveit. Although the details remain to be worked out, it is clear that birch woodland was progressively and, sometimes, rapidly diminished in extent over much of the landscape. Other aspects of vegetation change, such as the loss of a lush ground storey of shrubs and tall herbs in favour of the current heavily-grazed and grazing-tolerant vegetation communities, or soil acidification and related expansion of *Empetrum*, *Sphagnum* and other acidophiles, could also be interpreted as degradation of the natural resource base. There are indications that here, as elsewhere in Iceland, attempts were made to preserve diminishing vegetation resources. The recent discovery of extensive wall systems throughout the region (Einarsson *et al.* 2002) perhaps constitutes further evidence of an attempt to preserve the remaining woodland by excluding livestock. Vegetation change and soil erosion are almost certainly closely linked, and soil erosion has certainly become a more serious issue over time as desert areas have expanded, swallowing up early farms such as Sveigakot and Oddastaðir.

This narrative of degradation needs to be qualified in three ways. Firstly, not all of the changes to the Mývatnssveit environment during the last twelve centuries are necessarily due to human impact. Ólafsdóttir and Guðmundsson (2002), working on pre-settlement soil erosion, found that the soil system was naturally dynamic and prone to cycles of erosion, especially in the uplands; further evidence for this has been presented here. Palaeoecologists working in other parts of Iceland have long noted a considerable prehistoric variability in, for example, woodland cover and mire hydrology (e.g. Einarsson 1963; Bartley 1973; Wastl *et al.* 2001), which has often been attributed to climatic change. The transition from the Medieval Warm Period to the Little Ice Age may therefore have brought about substantial changes to landscapes and ecosystems even if Iceland had never been settled by humans. Disentangling anthropogenic from climatic effects is likely to be difficult, but certainly much work remains to be done on understanding pre-settlement ecosystem dynamics and documenting in detail the climatic history of recent centuries.

Secondly, a straightforward narrative of ecosystem degradation would ignore the numerous changes described in this chapter which could be counted as 'improvements' (depending of the perspective of the observer). Thus, initially at least, deforestation is likely to have improved grass yields for grazing animals, and certainly will have made the landscape easier to traverse and to manage. Cleared and cultivated hayfields are arguably more usefully productive than birch woodland. At Hofstaðir itself, the investigation of soils discussed above has revealed the extent to which intensive amendment of the homefield soils and careful management of winter grazing areas contributed to maintaining and improving the productivity of the farm. Certain aquatic ecosystems may also have become more valuable economic resources over time as a result of perturbation of their natural nutrient dynamics.

Thirdly, spatial variability is important: different parts of the landscape have changed in different ways. Hofstaðir itself has remained economically viable throughout the last millennium and the land around it has remained intact and productive. In part this is may be a consequence of management practices; for example, micromorphological evidence suggests that amendment of homefield soils was more thorough here than at some other sites. However, consideration of the climatic analysis and the behaviour of the prehistoric soil systems at Hofstaðir and elsewhere suggests that this was a well-chosen location for settlement. At a lower altitude than many neighbouring farms, and perhaps sheltered by the Laxá valley, it was situated far enough from critical climatic and ecological boundaries to be able to withstand the more difficult conditions brought on by the Little Ice Age. Perhaps for related reasons, the site itself was characterized by a lower inherent susceptibility to soil erosion, as shown by the contrasting patterns in prehistoric soil accumulation rates at Hofstaðir and elsewhere. The local topography was also favourable: the gently sloping area which became the homefield offered better drainage conditions for hay production than was typical for the region. Not all of the early farms in Mývatnssveit were as successful in the long term. The evidence presented here certainly suggests that environmental factors beyond the immediate control of people had a part to play in determining Hofstaðir's sustained relative prosperity, but the choices made by early farmers as they organized and managed the landscape were also of vital significance.

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