

# Expensive errors or rational choices: the pioneer fringe in Late Viking Age Iceland

ORRI VÉSTEINSSON\*  
MIKE CHURCH\*\*  
ANDREW DUGMORE^  
THOMAS H. MCGOVERN°  
ANTHONY NEWTON^

\* University of Iceland, Department of Archaeology.  
Corresponding author.

\*\* University of Durham, Department of Archaeology.

^ University of Edinburgh, Department of Geography.

° Hunter College, CUNY, Department of Anthropology  
and Northern Science and Education Center

Just as the colonies established on the North Atlantic islands in the Viking Age were peripheral to Europe, so these islands had their own peripheral areas. In Iceland the highland margins have long been a focus of archaeological research and the prevailing view has been that highland settlement failed because people had made unrealistic assessments of carrying capacity. This paper presents a case study of the northern highland valley of Krókdalur and argues that the dating and pattern of settlement in that valley indicates that its settlers were keenly aware of its limitations. It also suggests explanatory frameworks that can make sense of this marginal settlement without resorting to environmental determinism.

**Keywords:** Iceland, Viking Age, highland, settlement, abandonment

*Così come le colonie vichinghe nel nord Atlantico erano periferiche rispetto all'Europa, anche queste isole avevano le loro zone periferiche. In Islanda, secondo la ricerca archeologica, sulle alture l'insediamento fallì poiché gli abitanti fecero irrealistiche previsioni sulle capacità di sostentamento. Questo articolo presenta un caso studio nella valle di Krókdalur che dimostra che gli abitanti di questo insediamento erano consapevoli delle limitazioni. Suggerisce anche una cornice teorica che può spiegare l'insediamento in zone marginali senza ricorrere al determinismo ambientale.*

**Parole chiave:** Islanda, epoca vichinga, alture, insediamento, abbandono

## 1. Introduction

The colonization of the North Atlantic islands, the Faroes, Iceland and Greenland, in the 9<sup>th</sup>-10<sup>th</sup> centuries AD is a classic case of human optimism fuelling bold endeavours (Jones 1986; Vésteinsson 2013). For the first time in European history the open seas were traversed deliberately and repeatedly without having sight of land for days and weeks. And although it was no doubt reckless adventurers who first demonstrated that a North Atlantic crossing was possible, they were soon followed by thou-

sands of colonists (Vésteinsson, McGovern 2012), confident (enough) that contact would be maintained over distances and obstacles which only a few decades earlier had been considered unthinkable.

The aftermath has also been seen as a classic demonstration of the consequences people are likely to suffer when caution is thrown to the wind. As time passed the descendants of the pioneers found themselves increasingly isolated and marginalized; what had once been an exciting and vibrant frontier became an overlooked and poverty-stricken backwater. A toehold in America was abandoned almost as soon as it was established - as if the explorers themselves already suspected that theirs was a case of overreach. The farthest permanent outposts, the two settlements of Greenland, came to an end in the 14<sup>th</sup> and 15<sup>th</sup> centuries, providing a sombre end-note to the tale of intrepid Vikings sailing into the sunset.

Although Icelandic scholars of the 12<sup>th</sup> to 14<sup>th</sup> centuries regarded the exploration of the North Atlantic and the colonization of its islands as a perfectly reasonable undertaking – the protagonists of the stories they told were perhaps colourful and quarrelsome but they are depicted as essentially sensible farmers out to make a decent living – the irrationality of this episode was not lost on outside observers. Adam of Bremen in the earliest written account of the Icelanders from the late 11<sup>th</sup> century describes them as miserably poor, living in underground holes where they share not only roof but also beds with their livestock. Their poverty is caused by the barren, nearly treeless, environment where it is too cold to grow grain. Despite this the inhabitants are, according to Adam, happy and content with their wretched existence; they share everything with each other and any visitors, and obey their bishop as if he was their king (Adam of Bremen, *Gesta* IV, 36). To Adam only monastic ideals could explain why anybody might want to live in such distant and horrible places. The same views are echoed a little more than a century later by Saxo Grammaticus, who speaks of the “meanish dwellings” of the Icelanders and explains that: “... since the barrenness of their native soil offers no means of self-indulgence, [the Icelanders] pursue a steady routine of temperance and devote all their time to improving our knowledge of others’ deeds, compensating for poverty by their intelligence.” (Saxo, *Historia*, prefatio 5; transl by Fisher in Davidson (ed) 1978, p. 5, 7). Saxo could also add some hair-raising details about the natural wonders of Iceland: steam from hot-springs which turned everything it touched into stone, a volcano spewing endless fire, the incredible noise made when the sea ice touches the shore and a glacier that returns the bodies of those who fall into its crevasses (Saxo, *Historia*, prefatio 7-8). These themes were to be reworked, embellished, twisted and turned down the centuries (Ísleif-

sson 2011) but the basic element is a constant: the North Atlantic environment was hostile and inhospitable and the communities established there were poor and simple compared to “old” Europe. And this is true however the story is told: the North Atlantic islands are barren, their soils are poor and the climate is cold compared to the lands which the colonists came from. The crucial fact, which the medieval commentators got right – if nothing else – was that although barley could be grown it was not a meaningful component of the subsistence strategy, with the exception of the Faroes (Debes, *Faroæ*, II, p. 106; Brøgger 1937, pp. 59-60). The North Atlantic climate is too cold and the growing season too short for grain to be grown as a staple (Pórarinnsson 1958). This is reflected in low population densities and dispersed settlement patterns (Vésteinsson 2006), and in a subsistence economy based on animal husbandry subsidized, often to a large degree, by hunting, gathering and fishing. The economic strategies could be seasonally labour-intensive but productivity was on the whole low, creating only a limited surplus to support a small elite, and, from the 11<sup>th</sup> century onwards, the Church (Vésteinsson *et al.* 2002; McGovern *et al.* 2007). Wealth creation in the North Atlantic can only be described as modest and assertions to the contrary – both medieval and modern – are based on low expectations: the environment is so bleak that a stone-church here or an illuminated manuscript there seems like evidence for remarkable prosperity. There was some prosperity in the North Atlantic but it was remarkable mainly for its limitations: when colonists sailed into the North Atlantic in the 9<sup>th</sup> and 10<sup>th</sup> centuries they were occupying environments that were substantially poorer, which had significantly less potential for wealth creation, than the lands which were being left behind.

This is by no means the only case in human history of less productive environments being occupied by people who were used to better conditions. The colonization of New Zealand in the late 13<sup>th</sup> century AD is another instance of people sailing long distances to occupy new lands which were climatically and environmentally marginal for their economic strategies (Walter *et al.* 2010) and the colonization of islands in general is recognized as involving a reduction in diversity of flora and fauna, creating more circumscribed opportunities for subsistence and wealth creation (Keegan, Diamond 1987). At smaller scales this kind of behaviour is ubiquitous: there are always some parts of any given region or country which are less desirable than others; where the environment does not support the same intensity of occupation and production. These can be areas which are colder (e.g. mountains), drier (deserts), wetter (marshes) or they may be too small, inaccessible and isolated to support the same de-

gree of economic sophistication as the core with which it is associated. Such areas we call margins or peripheries and the long recognized dichotomy of core and periphery has provided useful insights into many aspects of human societies, their economic, social and political organization (Rowlands *et al.* 1987). Yet it remains difficult to understand what drives people to occupy lands which are less suited to support the way of living, the social organization, which they are accustomed to.

There are four basic explanations for how this can happen:

It can be through **error**: people do not initially realize that the new environments are marginal in ways that significantly differ from their former homelands, and when they do it is too late, they have left everything behind and cannot return. Traditional Ecological Knowledge (TEK) is of course not available to pioneers, and its acquisition and application is expensive. Many initial European colonial attempts in the 16<sup>th</sup>-17<sup>th</sup> centuries were outright failures or eventual successes only at staggering human cost (Rockman 2010). The error may lie in initial assessments but it may also enter later when decisions are made based upon false analogy to familiar homeland ecosystems that turn out to be unsustainable over the longer term.

It can be through **manipulation**: people are forced to occupy the margins by some interests back in the core. This can take the form of penal-colonies or military colonies but can also involve the forced migration of slaves, deportees, poorhouse inmates and others who do not chose to go, or, possibly most commonly: find themselves without other options.

It can be a result of **speculative resource extraction**: where settlements are tied to a wider social and economic system based in other environmental zones it may be fully rational for some settlers to occupy environmentally marginal zones in order to exploit resources not available in the homelands. When specialized (and perhaps initially temporary) resource extraction colonies become permanent communities the original special benefits of the location may come with significant drawbacks for a more generalized economy and wider society.

Or it can be a consequence of **relative deprivation**: despite its circumscribed potential the peripheral area may nevertheless be appealing to segments of the population in the core, those whose prospects are limited; those who are not benefiting from the good conditions in the core and for whom the margins would represent an improvement in their quality of life. Warfare, violence, and intense competition from other groups can limit options and provide strong motivation to escape immediate danger through migration, despite potential long term consequences for prosperity.

In reality these explanations are likely to overlap and any given case of marginal settlement may contain elements of all four. The information available to settlers is rarely so comprehensive or accurate that no mistakes are made, and those who are relatively deprived are inherently vulnerable to manipulation.

In this paper we present the results of recent fieldwork in the highland valley Krókdalur in northern Iceland. It serves as a case study to assess why marginal environments were occupied and why they were abandoned. The scale of this study is small, involving less than 10 farms, but it provides evidence for settlement dynamics which can be related to the larger-scale and longer-term processes involving the human settlement of the North Atlantic and of marginal areas in general. We begin by outlining the debate about marginal settlement in Iceland before describing the study area, its archaeological sites and palaeo-environmental evidence.

## **2. Marginal archaeology in Iceland**

Settlement in Iceland is essentially coastal with inhabitable plains and valleys rarely stretching more than 50 kilometres inland. The centre of the island is a highland plateau, effectively a desert capped by several large glaciers. In many regions the transition from coastal lowland to interior highland is marked by steep mountainsides while in others there is a more gradual intermediate zone. This can take the form of narrow valleys cutting deep into the mountains but there are also low-lying parts of the plateau where the vegetation is sufficient to support farming. Records going back to the 18<sup>th</sup> century describe numerous remains of pre-modern habitation in this intermediate zone and since the late 19<sup>th</sup> century it has been a particular focus of archaeological fieldwork in Iceland. The sustained interest in the archaeology of the margins stems in part from the fact that archaeological remains from the Viking Age and medieval times are more accessible there than in the lowland areas where most early remains are buried under large farm mounds (Vésteinsson 2010), but it was also recognized early on that the margins could hold the keys for understanding the course of Icelandic history; the ebb and flow of settlement in marginal areas could be seen as a measure of prosperity; such areas would be particularly sensitive to human impacts on the environment, and the reverse, environmental impacts on society. It was the issue of how volcanism had destroyed highland settlements that dominated the debate for much of the 20<sup>th</sup> century (Pórarinnsson

1943; Vilhjálmsson 1989; Dugmore *et al.* 2007) but slowly the idea also gained currency that farm abandonment in the highland margins could have been caused by soil erosion triggered by intentional deforestation and overgrazing.

A turning point came with the research of geologist Sigurður Þórarinnsson published in 1977 where he demonstrated that there was a high number of abandoned farms in the highland margins, and that they had as a rule been abandoned very early, in the 11<sup>th</sup> or 12<sup>th</sup> centuries. Ruling out climate – as the abandonments predated the onset of the cooling trend after 1200 AD – and volcanism – as abandoned farms were found as much in regions far away from volcanoes as in those directly impacted – Þórarinnsson argued that the principal reason for the retreat of settlement from the “pioneer fringe”<sup>1</sup> was its environmental fragility. The vegetation and soils of the highland margins were so vulnerable to farming that soil erosion soon set in, making the pioneer fringe uninhabitable in a few generations. Þórarinnsson had dug a number of soil profiles and in them he observed an increase in sediment accumulation rates (SeAR) – evidence for soil erosion – associated with the archaeological deposits (Þórarinnsson 1977, p. 36).

Þórarinnsson's logic cannot be faulted. Although he did not elaborate, it makes good sense that when humans occupy a marginal ecosystem for the first time it will be difficult for them to know where the limits of the inhabitable zone lie exactly. In particular this will be difficult where the transition from habitable to uninhabitable is gradual, where e.g. vegetation may have a lowland character but still be much less robust than at lower altitudes. In such areas the pioneers could only find out by trial and error, and the ruins of the abandoned farms then tell us that the limits were tested, but perhaps not much else. The withdrawal from the pioneer fringe is in Þórarinnsson's interpretation essentially a technical issue; it is landscape-learning the hard way (Rockmann, Steele 2003), but does not necessarily have any other significance. His work however raised the question of whether the human induced erosion evident in the soil profiles was a matter of continuous over-exploitation and mismanagement or whether the introduction of humans and their livestock into the ecosystem in the Viking Age was such a shock that it triggered an irreversible process of escalating erosion which the scaling back from the pioneer fringe was unable to check. This issue and the possible impact of climate change on the pace and scale of the erosion has proved a fruitful area of research (Dugmore

<sup>1</sup> ÞÓRARINSSON uses “settlement frontier” in his English summary (pp. 37-38) but “pioneer fringe” more closely translates his Icelandic term “frumbyggjajaðar” and has become accepted in the literature, e.g. DUGMORE *et al.* 2006.

*et al.* 2009; Streeter, Dugmore 2014), but Þórarinnsson's work also resulted in two major follow-up projects which added significantly to the archaeological understanding of the pioneer fringe.

In the 1980s archaeologists Guðrún Sveinbjarnardóttir and Sveinbjörn Rafnsson investigated a number of areas of abandoned highland settlements, including two of the largest concentrations of abandonment: Austurdalur and Vesturdalur in Skagafjörður in northern Iceland (Sveinbjarnardóttir 1992) and Hrafnkelsdalur and Brúardalur in eastern Iceland (Rafnsson 1990). Their research confirmed Þórarinnsson's principal finding that all such areas had evidence of widespread initial settlement which was abandoned early on. Rafnsson and Sveinbjarnardóttir also found that many of the sites on the pioneer fringe seem to have been occupied for only a matter of years; that there was considerable variation – some settlements were occupied into the 13<sup>th</sup> century while others had been abandoned as early as the 10<sup>th</sup> – and also that the story was in most regions made more complex by later reoccupation and reuse. Many farms abandoned in the 11<sup>th</sup> or 12<sup>th</sup> centuries were later used as shielings (summer-farms), suggesting that the change might have been more about the nature and intensity of exploitation than complete withdrawal as Þórarinnsson had supposed. They also recorded cases of abandoned farms being reoccupied or new farms being established in regions of abandonment at different times in later centuries, suggesting that the environmental damage had at least not in all cases been irreversible and that the margins could sometimes recover sufficiently to allow resettlement. Intriguing complexities aside the extensive and thorough fieldwork of Rafnsson and Sveinbjarnardóttir, as well as subsequent smaller-scale studies (including the one reported here, see below) have substantiated Þórarinnsson's initial impression: Iceland's highland plateau is ringed by a pioneer fringe where farms were established in the Viking Age but mostly abandoned by the 12<sup>th</sup> century AD.

By and large explanations for this continue to invoke Þórarinnsson's reasoning and only two major alternatives have been aired. The most radically different is Rafnsson's hypothesis which relates the abandonment of the highland margins to a shift from wool to fish as Iceland's principal export commodity in the 13<sup>th</sup> and 14<sup>th</sup> centuries (Rafnsson 1990, pp. 98-100). Rafnsson thought that volcanic eruptions might have sped up such processes but that the underlying causes were essentially economic: the highland settlements made economic sense as long as there was a demand for their products on foreign markets, but when demand shifted towards fish their *raison d'être* disappeared and abandonment be-



came a foregone conclusion. This hypothesis has problems with chronology: the abandonments seem to be happening 1-2 centuries before there is evidence for marketing of Icelandic fish abroad (Vésteinsson forthcoming) and it makes hard-to-support assumptions about market dependency which go against current ideas about economic relations in medieval Iceland (Porláksson 1991; Vésteinsson *et al.* 2011). The thinking that the abandonment could have to do with factors unrelated to environmental changes is however valid; it is a reminder that the coincidence of abandonment and an increase in erosion is not sufficient evidence to conclude that the former was caused by the latter.

The other explanation that has emerged is based on environmental and historical research suggesting that the margins had not necessarily become uninhabitable when they were abandoned in the 11<sup>th</sup>-13<sup>th</sup> centuries although soil erosion may have made them vulnerable (Simpson *et al.* 2003; Vésteinsson, Simpson 2004; Dugmore *et al.* 2006, 2007; Mairs *et al.* 2006; Church *et al.* 2007). The fact that many of these same areas later became important woodland reserves – when practically all woodlands had been cleared in the lowlands the highland margins often were the only areas where wood for charcoal making remained – suggests that the abandonments may have had more to do with land management. This is made more likely by the fact that the marginal areas were as a rule owned – by the late Middle Ages at least – by large ecclesiastical institutions and other major landowners in whose interest it could have been to give up the income from rents of small mountain farms in order to preserve woodlands. Large landowners had to provide their lowland tenants with access to woodlands to make charcoal, which is essential for ironworking. The abandoned fringe areas frequently also have evidence for the smelting of bog-iron and would in addition have continued to be useful for summer grazing of livestock, both free-range grazing and controlled grazing from shielings. This explanation works better for the 13<sup>th</sup> century abandonments – when the existence of large landowners can more easily be supported from historical records, but similar conditions and considerations could also have applied earlier.

To explore these matters in more detail we have studied an area in northern Iceland which was briefly visited by Pórarinnsson in the 1970s but is one of few highland margin areas which had not been the subject of a full archaeological survey until we undertook fieldwork there in 2004 and 2005. Our objectives were to obtain a fuller understanding of regional settlement patterns in relation to the Landscapes of Settlement project which has been ongoing in nearby Mývatnssveit since the mid-1990s (McGovern *et al.* 2007).



### 3. Krókdalur

The study area is called Krókdalur, a highland stretch of the very long valley through which one of Iceland's longest rivers, Skjálfandafljót, runs (fig. 1). The lower section of the valley, called Bárðardalur has been continuously settled from the Viking Age to this day, but south of the innermost farms, Litlatunga and Stóratunga, the valley floor rises sharply and is filled with a barren lava-field (Suðurárhraun) on the east side. Krókdalur is considered to begin at the south side of this lava-field, at an elevation of ca. 320 m.a.s.l. rising to c. 500 m some 20 kilometres further south. Valleys of tributaries of Skjálfandafjót, which drain into it in the area just north of where the two valley sections meet, have comparable elevations and indications of early habitation of the same kind as Krókdalur. These side-valleys have not been systematically surveyed but we include their early sites in our discussion to present as comprehensive a picture of this area as possible.

Krókdalur is mentioned as an uninhabited area already in 13<sup>th</sup> century sources (Vésteinsson 2004, pp. 5-6) and unlike many other highland margin areas in Iceland there is no evidence of re-occupation or transhumance in the valley. It was used for summer grazing by farms much further north and in the early 18<sup>th</sup> century at least two long-abandoned farm sites were known, Helgastaðir and Hafursstaðir (*Jarðabók* 1943, p. 144). In the late 19<sup>th</sup> century soil erosion exposed artefacts, some of which were donated to the National Museum. These included weapons of Viking Age types and pieces indicative of habitation, like spindle whorls. The weapons included a sword and a spear found together suggesting that they might come from a pagan burial (Eldjárn 2000, p. 197) but the exact location is unknown. The earliest description of the site undir Sandmúla is from 1880 when it was already eroding but in 1909 a hoard of hack-silver was found there along with a number of other artefacts. This is one of only four sizeable silver-hoards found in Iceland and includes a piece of a Hiberno-Norse brooch (Pórðarson 1909; Eldjárn 2000, pp. 373-75, 426). In 1897 antiquarian Daniel Bruun recorded three sites on either side of Krókdalur proper: Hrauntunga (fig. 5), Fiská (fig. 3) and Horngarðar (fig. 2) (Bruun 1898), but the valley itself was not investigated archaeologically until 1972 when Sigurður Pórarinsson explored a part of it. Pórarinsson revisited two of the sites described by Bruun and obtained tephra and C14 dates demonstrating that both are from the Viking Age. He also published a Viking Age date associated with an iron smelting site in Smiðjuskógur at the southern end of the valley.

In 2004 an archaeological survey of the valley was carried out, followed by limited excavation at three of the sites in 2005. What follows

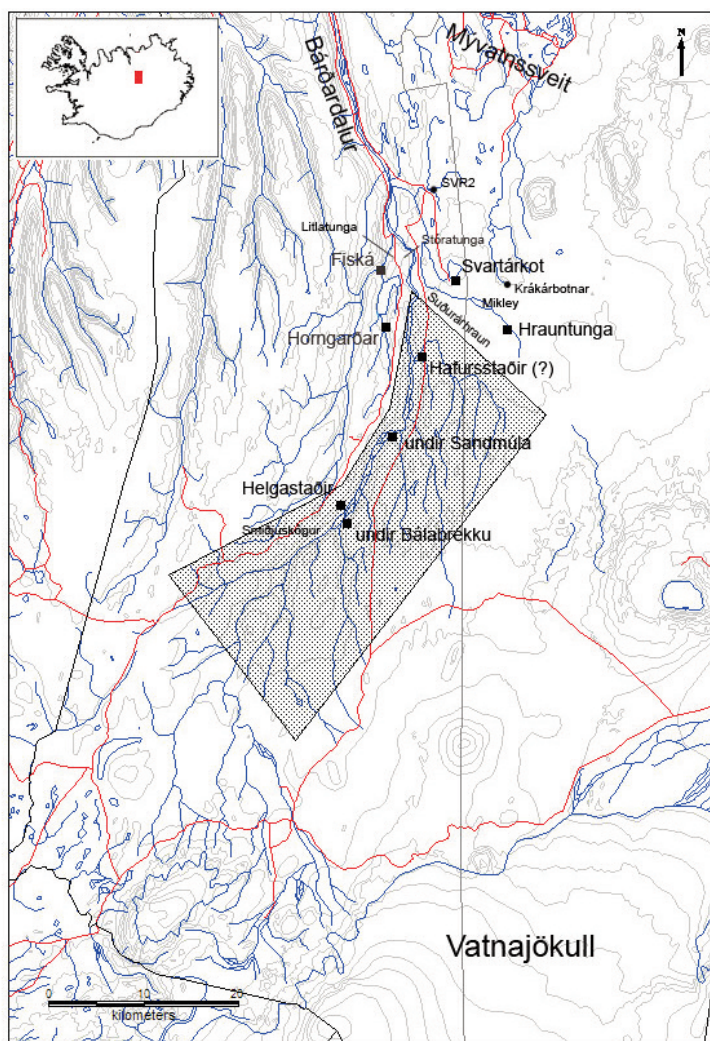


Fig. 1. Map of Krókdalur showing the sites discussed in the text. The shaded area indicates the area surveyed in 2004 and 2005. Black squares are archaeological sites, black circles tephra profiles.

is a brief summary of the evidence found at each of the likely or confirmed Viking Age farm-sites in Krókdalur and adjacent areas, the locations of which can be seen on fig. 1 (for details see Vésteinsson 2004; Vésteinsson (ed) 2010, 2011; Church *et al.* forthcoming). The catalogue begins with sites outside Krókdalur proper, in the side-valleys of the aforementioned tributaries, with the sites listed clockwise.

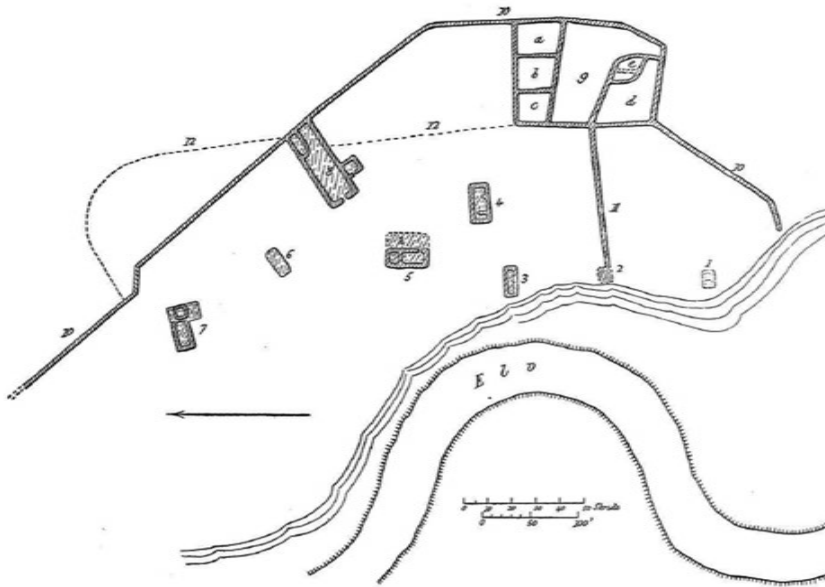


Fig. 2. Horngarðar, plan from 1897 by Daniel Bruun. No 5 is the dwelling in Bruun's estimation, the other structures are interpreted as animal stalls and pens. No 12 is traces of an earlier infield boundary suggesting more than a single generation occupation of this site. Features comparable to the small enclosures a-g have been interpreted as cultivation plots at other sites.

**Horngarðar:** this site was recorded by Daniel Bruun in 1896 (fig. 2) and is the only one in the area not damaged by erosion. Judging from Bruun's plan this was a small to average-sized farm and indications of a re-alignment of its homefield boundary suggest that it must have been occupied for more than a few years. Sigurður Pórarinnsson examined two soil profiles in 1972 observing the H-1104 tephra above floor layers, providing a firm *terminus ante quem*.

**Fiská:** Bruun picked up a few artefacts at this badly eroded site (fig. 3), including a bead of a Viking Age type. Bruun's plan shows a scatter of small buildings and the bead and a spindle-whorl suggests that this was a dwelling but no further information is available for this site.

**Svartárvatn:** this site is at the northern limit of the study area and is the only one with evidence for re-occupation in later centuries. An arrow head of a Viking Age type was found in the 19<sup>th</sup> century but a long section (fig. 4) exposed by rising water levels in the lake Svartárvatn suggests that this site was occupied between V~940 and H-1104, with clear signs of building activity also between H-1104 and H-1158, and

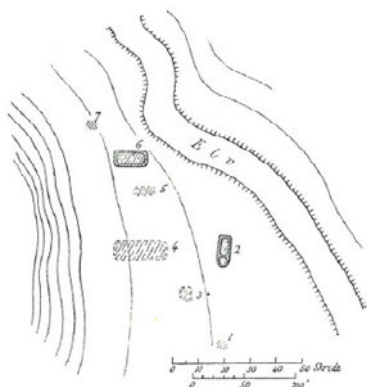


Fig. 3. Fiská, plan from 1897 by Daniel Bruun. Ruins 2 and 6 were identified as dwellings from artefacts and fire-places.

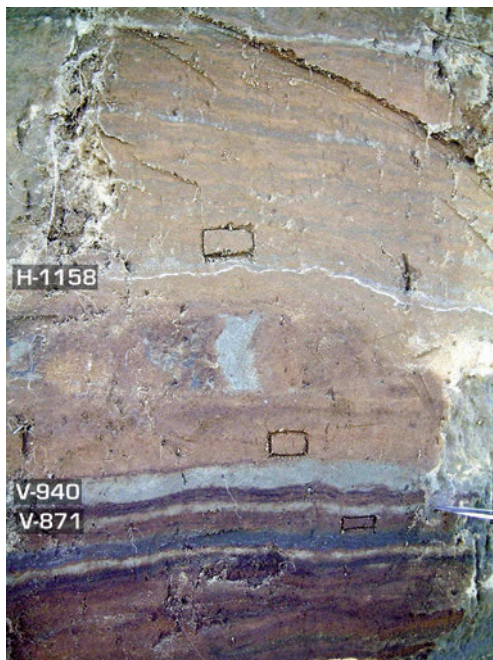


Fig. 4. Svartárkot. Part of eroding section showing turf-structures between tephras from c. 940 and 1158 AD.

some human presence datable to the 14<sup>th</sup> or 15<sup>th</sup> centuries. The site was reoccupied c. 1670 and is still a functioning farm.

**Hrauntunga:** this is the third site recorded by Daniel Bruun (fig. 5) and was judging from his plans a considerably smaller farm than Horn-garðar. He collected some iron artefacts and bones of cattle, sheep, goats and horses. Þórarinnsson collected birch twigs from this site and a radiocarbon determination gave the result 995 or 1020 ± 100 uncal BP (St-4396), broadly suggesting a Viking Age date. Survey in 1996 found that the site is more or less completely denuded.

Human bones and a variety of artefacts have been found in several places (mostly not accurately defined) in and around the island Mikley in the river Suðurá between Hrauntunga and Svartárkot. The evidence is not sufficient to decide whether there was a farm here.

**Hafursstaðir:** the site is mentioned in 1712 but its location is uncertain. Hafursstaðahlíð is a prominent and well-known place-name describing the east side of Krókdalur north of Sandmúli and at the northern end of this stretch Þórarinnsson observed building remains. These are now covered with soil and vegetation and no archaeological date is available.

Midway between the suggested location of Hafursstaðir and the site of undir Sandmúla the badly eroded remains of a human burial were discov-

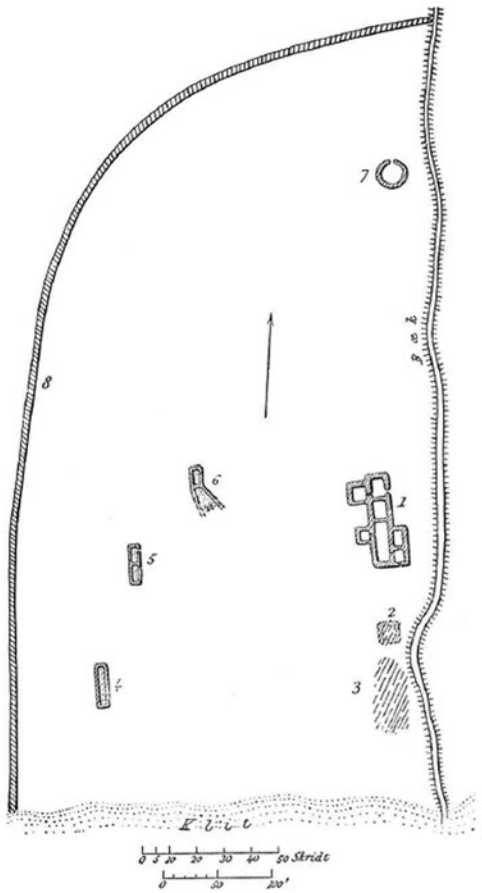


Fig. 5, Hrauntunga, plan from 1897 by Daniel Bruun. N. 1 is the dwelling and n. 3 a midden sampled by Þórarinnsson in 1972. By 1996 it was the only anthropogenic feature remaining at the site.

ered in 2004. The location is typical for pagan burials (on boundaries between farms) but the site is too badly damaged to confirm its age or type.

**Undir Sandmúla:** in addition to an artefact assemblage with definite Viking Age characteristics, two radiocarbon dates were obtained from the same undisturbed archaeological context excavated in 2005. The dates were produced from two unburnt cow phalanx bones [ $920 \pm 35$  uncal BP (SUERC-11548) and  $1040 \pm 35$  uncal BP (SUERC-11549)]. The two calibrated calendrical dates overlap in the early 11<sup>th</sup> century AD and although a firm terminus ante quem cannot be given there are no indications that settlement here lasted beyond the 12<sup>th</sup> century. Archaeological deposits overlie the V~940 tephra suggesting that this farm was established in the mid to late 10<sup>th</sup> century. Judging from the size of the buildings (represented only by scatters of stone – fig. 6) this was a small



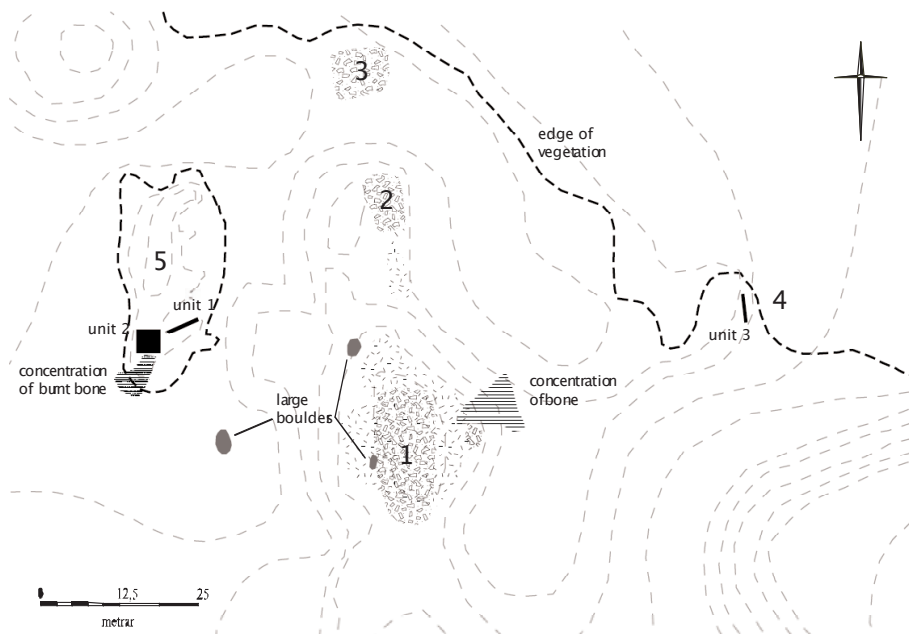


Fig. 6. Plan of the remains at undir Sandmúla in 2005. Unit 2 was the main excavation area where undisturbed deposits were still remaining but 1-3 represent dense scatters of building stone where buildings had once stood.

to average sized farm. A sizeable animal bone assemblage includes cattle, sheep, goats, pig and horse, some freshwater fish and clams from the sea 90 kms away. The cattle to sheep ratios are similar to assemblages in Mývatnssveit suggesting that this was not a specialized sheep station but a conventional farming operation. A small archaeobotanical assemblage was also recovered, dominated by carbonised birch roundwood charcoal and no presence of barley grains. Some smelting slag was found on the site but a large scatter is also present a kilometre or so further south.

**Undir Bálabrekku:** the site is completely denuded and only represented by scatters of stone and some smelting slag (fig. 7). Judging from the scatters the buildings were comparable to those at undir Sandmúla. A surface collection of animal bone suggests that this was a farm, with cattle, sheep, goats and horse. No dating evidence is available.

The skeletons of a human and a horse on a low rise south of this site may represent the remains of a pagan burial but this is unverifiable.

**Smíðjuskógur:** the place name indicates iron-smelting and Sigurður Þórarinnsson collected pieces of charcoal from a deposit full of slag and iron-smelting debris. A radiocarbon determination gave the result  $970 \pm 60$  or  $995 \pm 60$  uncal BP (U-2517) suggesting a 10<sup>th</sup> or 11<sup>th</sup> cen-

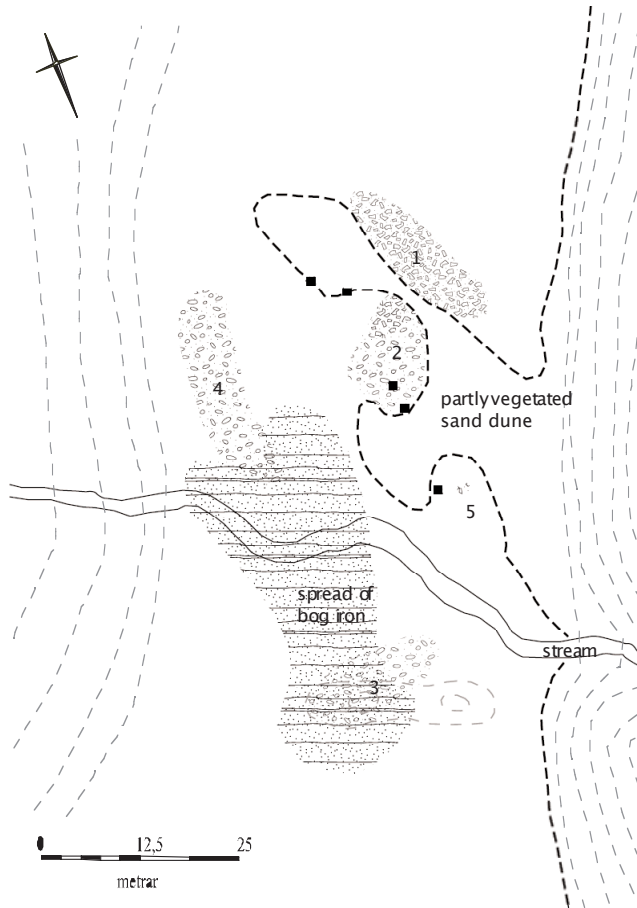


Fig. 7. Plan of the remains at undir Bálabrekku in 2005. 1-4 are scatters of building stone, no 1 being the proposed dwelling.

tury date. This site is now completely denuded.

**Helgastaðir:** buried under a thick layer of soil accumulation an eroding section shows extensive archaeological deposits formed between 940 and 1104 AD (fig. 8). The deposits consist of ash midden and upcast, presumably from sunken featured buildings. A small animal bone collection includes bones of cattle, goat and sheep. Scatters of smelting slag are found close by.

In all eight likely farm sites have been recorded in Krókdalur and adjacent valleys. Although the dating evidence is variable in quantity and quality it consistently suggests occupation between the 10<sup>th</sup> and 12<sup>th</sup> centuries AD.



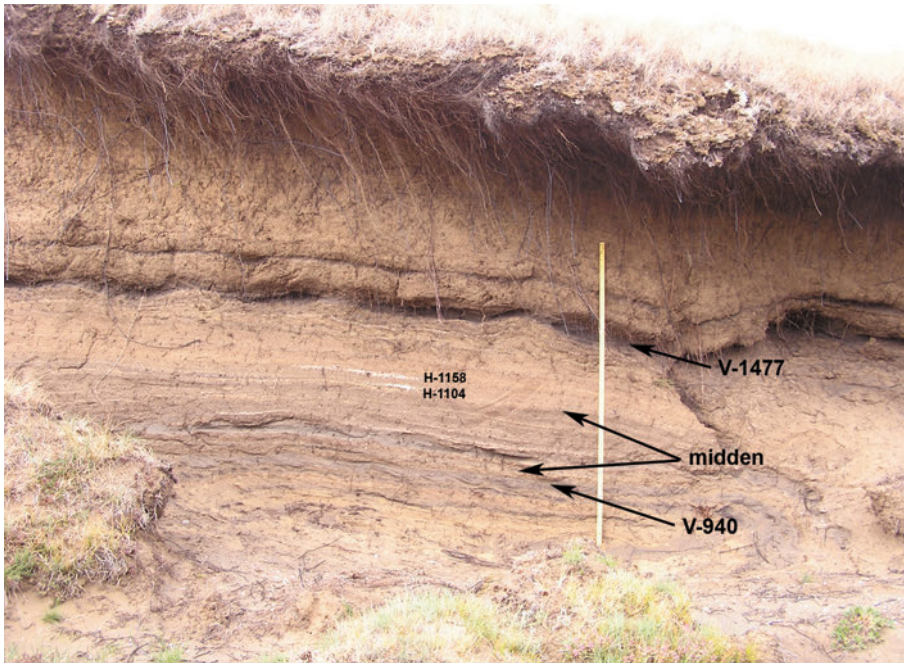


Fig. 8. Helgastaðir. Eroding section photographed in 2004. The midden, visible on a 30 m long stretch, is sandwiched between tephras from 940 and 1104.

#### 4. Soil erosion and the abandonment of Krókdalur

Examination of the soil sections which Sigurður Pórarinnsson exposed at Horngarðar led him to conclude that soil erosion was already in full swing by 1104 AD<sup>2</sup>. His thinking was that it was this soil erosion, triggered by deforestation and overgrazing in the vulnerable highland margins, which had decided the fate of the highland farms. This is a reasonable argument but it is not conclusive. Evidence for soil erosion is not in of itself evidence for the farms facing problems – and there are some rather different possible explanations for changing soil accumulations around Horngarðar about 1100 AD. Rates of land cover loss are not

<sup>2</sup> Our estimates of the soil accumulation rates evident in Pórarinnsson's published profile 1 at Horngarðar (PÓRARINSSON 1977, p. 20) do not quite support his interpretation. They indicate little change in long term rates of c. 0.1mm/yr accumulation from c 7Ka BP to the early 12<sup>th</sup> century; accumulation rates jump by an order of magnitude in the 12<sup>th</sup> and 13<sup>th</sup> centuries (to c. 3.7mm/yr) before reducing by an order of magnitude 1300-1477 (c.0.9mm/yr 1300-1362; c.0.4mm/yr 1362-1477) to rise again by an order of magnitude to reach all-time highs after 1717 (1717-1977 c.7.1mm/yr).

necessarily related to sediment accumulation rates (SeAR) because loss of a small area of deep soil will generate greater related SeAR than the loss of a large area of shallow soil cover (Dugmore *et al.* 2009). Sediment may have been blowing in from far away; alternatively (or in addition) the vegetation cover may have been breached and soil was eroding closer by, but even if it was within the pastures used by the farm, it is difficult to judge the scale of this problem and how it affected the high-land farms from a few sections only.

At the northern end of the study area our profile SVR2 (fig. 9) shows that long term rates of accumulation between 4-3,000 years ago were very low (0.06-0.07 mm/yr) but they rise somewhat between 3,000 years ago and the settlement of Krókdalur (0.11-0.12 mm/yr). These rates double with settlement, but range between 0.2-0.3 mm/yr through to the early 18<sup>th</sup> century when they increase by an order of magnitude (to 2.5mm/yr). This picture is reinforced by data from Krákárbotnar (fig. 9) which also shows an order of magnitude increase in SeAR post 1717. One thing is clear: the problem of soil erosion while developing early was limited around 1100 compared to what it became later on. In some parts of Iceland there are early peaks in SeAR following initial settlement in the late 9<sup>th</sup> century that can be related to the onset of erosion in vulnerable upland areas (Dugmore, Buckland 1991) or the scale of local ecological change (Mairs *et al.* 2006). This is also shown by the poorly defined tephra layers in many soil profiles of the Landnám and V-Sv tephra layers (Sigurgeirsson *et al.* 2012), reflecting the landscape disturbance of settlement. In general, however, the highest rates of accumulation both for individual sections and in terms of absolute rates tend to occur in recent centuries (Dugmore *et al.* 2009, Streeter *et al.* 2012). Locally this is exemplified by the very high post 1717 rates observed by Þórarinnsson and profile SVR2 reported here. There are significant regional and local variations but overall the picture of landscape change is one of generally noticeable to locally pronounced erosion throughout the middle ages, becoming dwarfed by post 16<sup>th</sup> century rates and reaching unprecedented levels in the 19<sup>th</sup> and 20<sup>th</sup> centuries. In the upland areas, such as around Krókdalur, detail is difficult to add because now so many areas have been completely stripped of their soil cover – and with it the local record of sediment accumulation. To the north of Krókdalur (fig. 10) there were clearly significant but variable local increases in erosion in the 12<sup>th</sup> century, with some sites showing comparatively little early change compared to pre-Settlement times and others showing unprecedented change. In some cases early peaks subside during the 14<sup>th</sup> and 15<sup>th</sup> centuries only to rise again

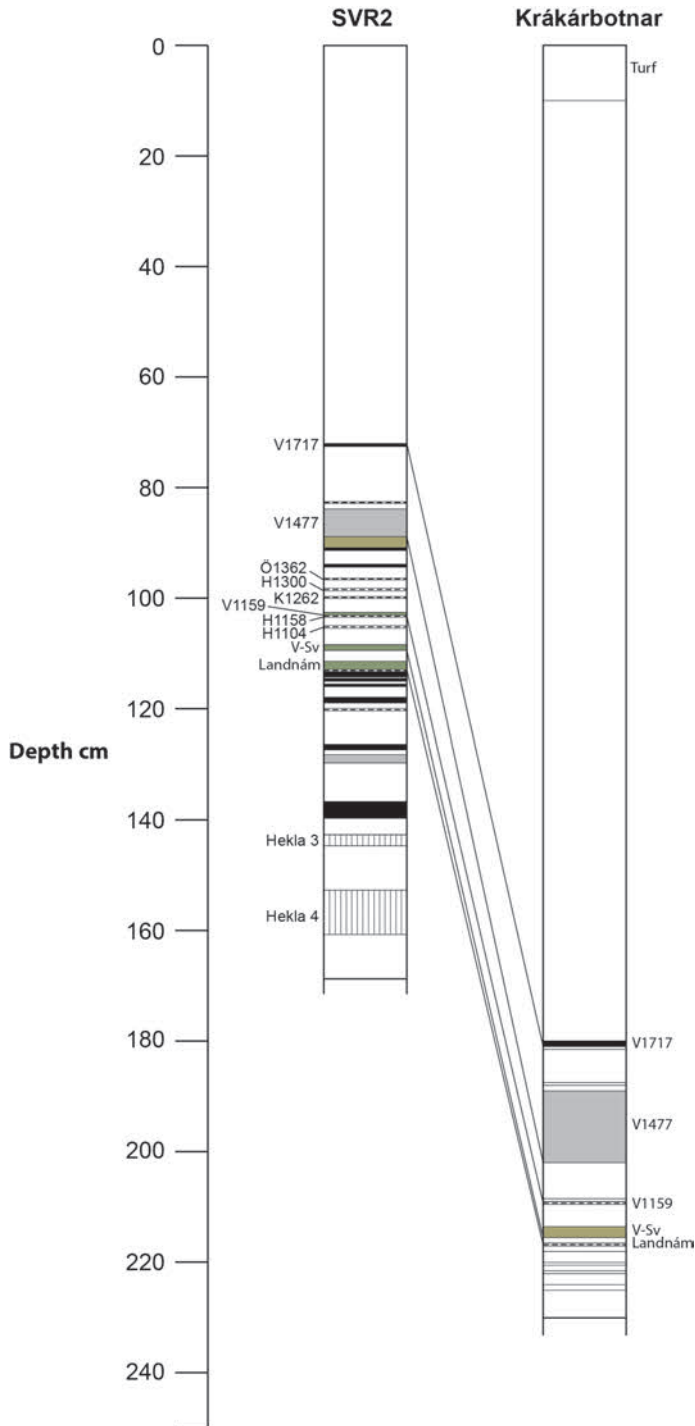


Fig. 9. Soil profiles from sites north of Krókdalur. For location see fig. 1.

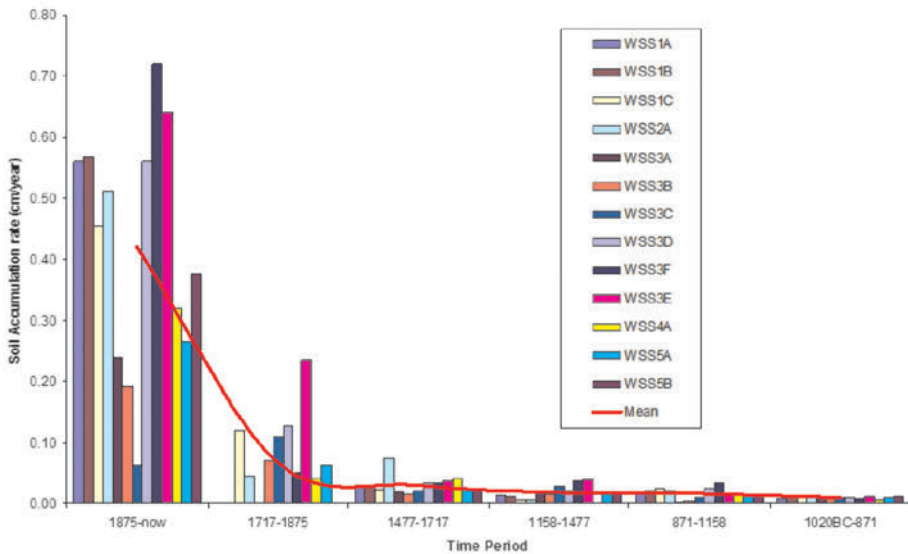


Fig. 10. Soil accumulation rates from the Viking Age to the present. The codes refer to soil sections in the lower lying areas north of Krókdalur but south of Mývatnssveit.

later. A lake core from Helluvaðstjörn in nearby Mývatnssveit (Lawson *et al.* 2007), demonstrates the other side of the coin to increasing erosion – a gradual decline in birch pollen from Settlement until c AD 1300. It could be that the easing of landscape pressures in Krókdalur in the 14<sup>th</sup> century, implied by Þórarinnsson's work, was a direct consequence of the valley being abandoned and no longer being used for grazing year round (this kind of argument has been made for Þjórsárdalur in southern Iceland, Dugmore *et al.* 2007) but it does not follow from this that the abandonments were caused by the environment having deteriorated to the degree that it could no longer support these eight farms. The decrease in soil erosion can easily have been a positive side-effect of abandonments, themselves caused by something entirely unrelated to environmental degradation. Even if there is a causal relationship between the abandonments and erosion, it may also be more complex: it is possible that the erosion was primarily taking place in the summer pastures around the valley, pastures used not primarily by the valley farms but by lowland farmers. Once those pastures started to degrade it will have created pressure on the highland farms. Because they were few and hardly rich or powerful they might have been pushed out of the

commons (increasing the grazing-pressure on their home-pastures) and, perhaps more likely, they would have become targets for acquisition by lowland interests. Being small and marginal, these properties would also be cheap, and buying them to close down the farms and use the land for grazing of livestock from the lowlands would make good economic sense, more so because there would also be other valuable resources, like iron and woodlands which might have become scarce in the lowlands. This kind of acquisition strategy would make sense even if degradation of the summer pastures had not been a concern. Lowland acquisition of highland properties could have been a consequence simply of economic growth in the lowlands, larger herds needing more pastures, and increasing needs for iron and charcoal.

Such options are only hypothetical. We point them out merely to make clear that it is not only possible but easy to suggest a series of alternative explanations for highland abandonments. Clearly more research is needed. In particular it is imperative to develop analytical tools to assess what sort of actual environmental impact is represented by a given amount of soil accumulation (Streeter, Dugmore 2014). Research could also be aimed at trying to understand where the erosion was taking place: were the home-lands being threatened or was the erosion mostly ravaging faraway summer pastures? And was there such abundance of these pastures that even a large reduction in the vegetated area made little or no difference for the grazing economy?

## **5. Discussion**

Although the Krókdalur sites are poorly preserved and research into what does remain has been limited in scope, a comprehensive picture has emerged which allows several important observations.

One is that none of the sites seems to have been occupied before the middle of the 10<sup>th</sup> century. Three of the sites, Svartárkot, undir Sandmúla and Helgastaðir were established after ~940 and the rest have no firm terminus post quem. This is in contrast to nearby Mývatnssveit where there are several pre-940 sites, many but not all of low social status, and where full occupancy of the whole inhabitable area was achieved within a generation from the inception of settlement (Vésteinsson, McGovern 2012). This suggests to us that Krókdalur was not settled in the first wave of colonization, and that its settlement in the mid to late 10<sup>th</sup> century must be understood in the context of societal developments two or three generations after initial settlement.

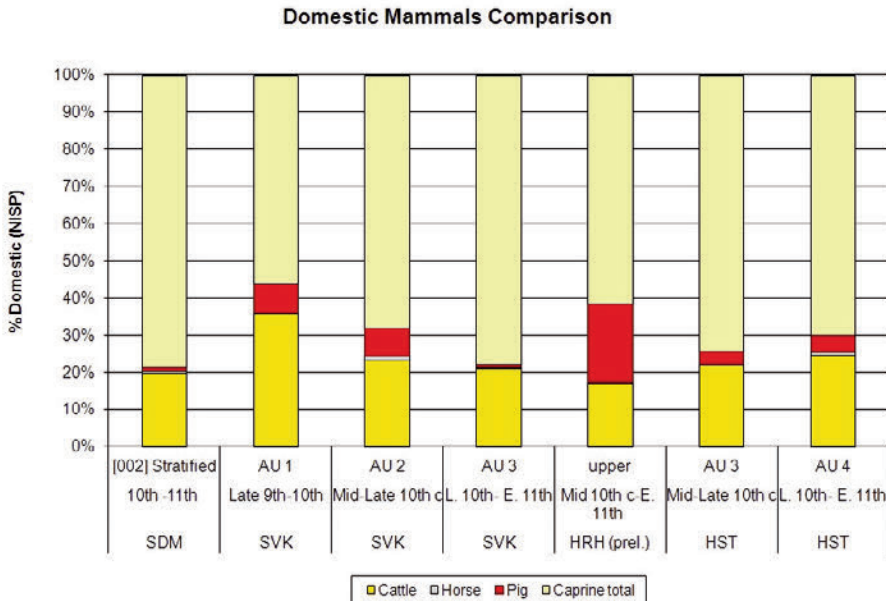


Fig. 11. Comparison of domestic mammal proportions at undir Sandmúla (SDM) and sites in nearby Mývatnssveit, Sveigakot (SVK), Hrísheimar (HRH) and Hofstaðir (HST). Caprine refers to sheep and goat.

In addition, while the zooarchaeological data is limited in size and only the undir Sandmúla collection can be reasonably quantified, the Krókdalur archaeofauna include the full range of Viking Age/early Medieval species, including the pigs and goats which become rare or absent after the 12<sup>th</sup> century. As figure 11 indicates, the undir Sandmúla collection has a ratio of cattle to sheep and goat bones similar to roughly contemporary sites in the Mývatn region, suggestive of a normal full-scale farm of the Viking Age or early medieval period rather than a specialized sheep station or shieling. Midden tests at sites known to be specialized shielings in other highland margin areas (e.g. Þorvaldsstaðasel – Gísladóttir *et al.* 2013, pp. 83-86, and Pálstóftir – Lucas 2008) normally produce little or no bone refuse. While there is not currently the same zooarchaeological evidence for import of marine fish and mammals into Krókdalur as there is for contemporary Mývatnssveit, the clam shells serve to hint at wider provisioning strategies connecting these deep inland sites with the coast. Individual farms were the basic unit of settlement, but these were clearly interconnected economically and socially to each other and to the es-



tablished lowland communities. The zooarchaeological evidence thus suggests intent to establish a permanent network of settlement in the valley, potentially an extension of similar highland fringe settlements in nearby Mývatnssveit. It is therefore safe to rule out a strategy of specialized herding or other form of *speculative resource extraction*, though the smelting debris at Smiðjuskógur might parallel intensive but short term iron production at sites like Háls in Hálsasveit (Smith 2005). The nature of the artifact finds in the valley and what we can reconstruct of the scale of the ruins does not indicate an impoverished forced settlement of exclusively low status people. The silver hoard at undir Sandmúla, weapons finds, and indications of relatively high status pagan burials all indicate that at least some of the Krókdalur settlers were comparatively well off and at least initially capable of providing deceased kinfolk with an expensive burial ritual. While we can never assume that all members of all the initial Krókdalur households were enthusiastic about their new homes, it thus also appears that *manipulation and coercion* are not likely to be sufficient explanations for the post-940 highland settlement initiative.

On current evidence the initial settlement seems to have effectively filled the landscape of nearby Mývatnssveit by c. 940 (Vésteinsson, McGovern 2012), providing a potential clue to the post-940 Krókdalur second wave settlement effort. If we assume that a high percentage of the original settlers, arriving in the late 9<sup>th</sup> century, were young adults in peak fertility years, the potential rate of increase during the first two generations would be high. Some seventy years after the first generation settled in, the third generation of young Icelandic farmers might be starting to experience *relative depravation* reflected i.a. in increasingly restricted opportunities for setting up independent households. Given the choice of permanent celibacy as an unpaid farm-hand or the chance to become a fully reproductive household head as part of a new settlement, one can see a situationally rational willingness to take some chances to better one's social and biological opportunities.

Although, as Sigurður Pórarinsson noted, the occupation and abandonment of Krókdalur took place well before the onset of the general cooling trend after 1200 AD it is still possible that climatic fluctuations are a part of the story. Multi-proxy climate data (Mann *et al.* 2009) allow reconstructions of temperature variations which suggest that the period c. 930 to 1110 AD was particularly mild in northern Iceland. Not only was the annual temperature 0,3-0,7 degrees C warmer than the 20<sup>th</sup> century baseline mean temperature but the period was unusually stable with few cold years relative to warm years. The onset of a lengthy period of stable relatively warm conditions in the mid 10<sup>th</sup> century pos-



sibly helps explain why such a project as the occupation of Krókdalur was conceived and executed; risky decisions are more easily made when conditions are good. It is possible that the more variable conditions after c. 1110, with more frequent cold years, also impacted the Krókdalur farms (if, that is, they were still in occupation; Helgastaðir was already out of business by that date). Highland settlements are more vulnerable to changes in climate impacting the length of the growing season and the number of days of snow-cover prohibiting grazing. We would however caution against drawing simplistic inferences from temperature curves; it is always tempting but experience warns us that such relationships are invariably more complicated and subtle than meets the eye.

Although the post-940 occupation of Krókdalur can be seen as a logical continuation of the initial settlement, there is an important difference reflected in the long distances between the Krókdalur farms. The mean distance to nearest neighbour was 5 km (8.6 when the river Skjálfandafljót was impassable), which was much greater than the Icelandic norm, typified regionally by Mývatnssveit with 1,5 km. Krókdalur in fact surpasses all other marginal areas in this regard, compared e.g. to 3,25 km in Hornstrandir, another peripheral region with sparse settlement which topped the scale in a study of settlement dispersal in eight areas in Iceland (Vésteinsson 2006, p. 93), and Hvalseyjarfjörður in Greenland at 4,1 km (Vésteinsson 2009, pp. 152-153). This suggests that the people who planned the Krókdalur settlements were concerned about carrying capacity. Spacing the farms much more widely than would be considered normal in an Icelandic countryside, they were clearly taking account of the quality of the land and the harsher upland climate. Although we cannot know whether they got it right, this concern suggests at the very least an awareness of environmental limitations and possibly quite realistic assessments.

This was thus an optimistic settlement attempt, but not irrational or based on unreasonable expectations of potential landscape productivity. As noted above, while erosion impacts and temperature declines from the 10<sup>th</sup> century maxima may have had a role in eventual abandonment of this highland community, it does seem to have endured for more than a century (three to five human generations) which would be more than enough time to validate the rationality of the original objectives. Farms ran profitably for a time, silver was hoarded, kin solidarity was enhanced, and a number of couples otherwise doomed to un-reproductive biological oblivion ended their lives as honoured ancestors afforded the best available burial ritual. So their choices were neither irrational nor unsuccessful in their particular environmental and social contexts.

Why then did these optimistic but realistic settlers' descendants choose to abandon these farms? While environmental change is certainly part of the explanation, erosion and climate impacts need to be seen in a wider and more dynamic social context. Following Cronon (1992), we can conceive of community viability as based upon the interplay of *natural capital* (stocks of productive vegetation, minerals, animals, water, soil fertility), *social capital* (population size, health/age/gender balance, social cohesion and solidarity, general morale), and *economic capital* generated by a favourable or endurable balance of production and consumption of vital resources (both subsistence and exchange products). In this case, we suggest that rapid draw-down of natural capital of vegetation and soils through overgrazing is now less credible than hypothesized by Pórarinnsson. Climate change rather than foolish human expenditure of natural capital would appear to have been the most important environmental challenge to sustained permanent farming in Krókdalur. However, as noted above the worst shocks of climate and soil erosion significantly post-date the abandonment of these farms, and the region continued to be used for grazing by farms further down the valley. Simple natural capital depletion or climatic determinism does not convincingly explain the 12<sup>th</sup> century abandonment.

Even if the highland farms were intended to be permanent and were occupied for generations the same as any other farms, their eventual demise may have a variety of explanations. As research continues and our understanding of developments in Viking Age and Medieval Iceland increases more such explanations suggest themselves. One possibility is that this relates to the increase in sheep numbers evident from the 12<sup>th</sup> century onwards. Whereas 9<sup>th</sup>-11<sup>th</sup> century animal bone assemblages have cattle to sheep ratios between 1:2 and 1:6, already by the 12<sup>th</sup> century sites like Steinbogi in Mývatnssveit have ratios in excess of 1:20 (McGovern *et al.* 2007, p. 41). This increase in sheep numbers will have put greater pressure on the summer pastures in the highlands. The home-range of Steinbogi was tiny compared to other farms in its neighbourhood and it is difficult to account for its high sheep numbers unless it had access to summer pastures elsewhere. If Steinbogi is a part of a broader pattern then this will have had consequences relevant to this inquiry: increased grazing of lowland sheep in the highlands will have contributed to the erosion and may even have undermined the sustainability of the farms of the margins. It can have done so directly, by contributing to the degradation of the land, but also indirectly by increasing the value of the highland pastures and making them too valuable for small-scale farming. The increasing economic importance of sheep would have

exposed the highland farms to competition, introducing incentives to close them down.

It is important to note that the chronological relationship here remains unproven. It is quite possible that the highland farms were long abandoned when sheep numbers started to increase. The case should rather serve as a demonstration that it is possible to construct hypotheses which account for the abandonments in a more sophisticated way than Þórarinnsson's pioneer-fringe concept.

Perhaps more central is the issue of maintaining and enhancing *social capital* in such a dispersed settlement pattern, especially at high altitudes where the households can be expected to have been snow-bound for months each winter. Even if these farms were economically and environmentally viable they may not have been socially viable: living in such isolation in harsh conditions is a security issue and the inhabitants' quality of life will have been significantly poorer than in lowland areas. Social interaction between the farms will have been on a much reduced scale compared to the lowlands and poor access to social events and religious services will have become a greater disadvantage as such services became more regular at lowland churches in the course of the 11<sup>th</sup> and 12<sup>th</sup> centuries (Vésteinsson 2000). If nothing else this will have affected the value of these properties, making them cheaper. Cheap means they may have become easy targets for acquisition by outside interests, but it also means they will have been more easily abandoned, whether by their farmers, if they were the proprietors, or by distant landlords who were only forsaking small sums of rental income. The very social and biological imperatives that may have contributed to the initial success of the post-940 Krókdalur settlement effort may have worked against its long term survival, as isolated households provided fewer options for social and biological reproduction and the alleviation of relative deprivation. People in Krókdalur had less access to collective labour, potential mates and actual kin, impressive church rituals, and all the benefits of an expanding network of human interaction and communication. By 1100 Krókdalur had become a place of relative deprivation to be avoided rather than the promising frontier it had been only a few generations previously.

## 6. Conclusions

We conclude that the case for error is far from proven and not only that: it is simply not the most likely one. It is demonstrable that the early

colonists did not blindly occupy the margins expecting them to sustain the same quality of life as the lowlands. On the contrary the settlement of marginal areas like Krókdalur was delayed by up towards a century after the initial settlement, suggesting there were reservations about their capacity to sustain settlement, and when farms were built there they were spaced so widely that it can only be considered extreme. It is still possible that even such wide dispersal of farms was over-optimistic and that it triggered or exacerbated the erosion which led to the farms' abandonment, but the conclusion that the occupation of the margins was not a seamless continuation of the initial colonization process but a separate process starting in the mid to late 10<sup>th</sup> century calls for explanations which take into account societal developments in the post-colonization period.

One parallel process that suggests itself is the colonization of Greenland from the 980s onwards. The emigration of what must have been at least several hundred people suggests something about population levels and opportunities in late 10<sup>th</sup> century Iceland. It seems that there were substantial numbers of people willing to take considerable risks to establish a life for themselves in new places. Although manipulation cannot be ruled out it seems that this is an issue of relative deprivation; people responding to prospects becoming increasingly limited as society became more fixed and set in its ways. Greenland would have offered a no-turning-back answer for a part of this cohort but places like Krókdalur may have represented opportunities to establish a family and quickly increase capital (no doubt mainly in livestock although the silver hoard from undir Sandmúla clearly indicates capital savings) as a shortcut to respectability – respectability which would only be realized by moving back to the lowlands. Occupying the margins as a short-term status-enhancing strategy makes sense and is consistent with the evidence. At many of the sites occupation may have been very short-lived, perhaps only a few years – and rather than seeing this as failure it may be the very mark of success: leaving behind a hard life of isolation and danger is a positive step.

The image of the colonization of the North Atlantic as something of a blunder is deep-rooted. When information is scarce it is easy to suspect people of ignorance, or even crass stupidity. We do not deny that some very unreasonable and unsustainable behaviour went down in the North Atlantic, but we do not think the evidence suggests that it was particularly prevalent there. Examination of a marginal area like Krókdalur suggests that its settlement and abandonment can be explained by people making rational and reasonable decisions. This case complements other

evidence from Iceland indicating that in so far as their traditional ecological knowledge permitted, people attempted to sustainably manage the environment and its resources (Simpson *et al.* 2001; McGovern *et al.* 2006). Where Adam of Bremen saw holy paupers, and where Sigurður Pórarinsson saw babes in the woods, we see people making informed decisions about how best to make use of the available resources.

## **Acknowledgements**

This research was made possible by generous grants from the National Geographic Society, RANNIS, Social Sciences and Humanities Research Council of Canada, the Leverhulme Trust, the Wenner-Gren Foundation for Anthropological Research, the Leifur Eiriksson Fellowship Program, the American Scandinavian Foundation, the US National Science Foundation (grants 0732327, 1140106, 1119354, 1203823, 1203268, 1249313 & 1202692), the Icelandic Archaeology Fund and the University of Iceland Research Fund. We would also like to send our warmest thanks to our host communities and the Akureyri 4x4 club which generously provided the expedition with accommodation in the field.

## References

### Historical sources

- Magistri Adam Bremensis, *Gesta Hammaburgensis ecclesiae pontificum*, B. SCHMEIDLER (ed), MGH, SRG, Hannover 1917.
- Lucas Jacobsøn Debes, *Færoæ et Færoa reserata. Det er: Færaernis, de Færaeske Indbyggeris Beskrivelse*, Copenhagen 1673.
- Jarðabók Árna Magnússonar og Páls Vídalíns XI. Þingeyjarsýsla, Copenhagen 1943.
- Saxo Grammaticus, *The History of the Danes, books I-IX*, H.E. DAVIDSON (ed), P. FISHER (trans), Cambridge 1979.

### Studies

- J. ARNERBORG, B. GRØNNOW (eds) 2006, *Dynamics of Northern Societies, Proceedings of the SILA/NABO Conference on Arctic and North Atlantic Archaeology* (Copenhagen, May 10<sup>th</sup>-14<sup>th</sup>, 2004), Copenhagen.
- D. BRUUN 1898, *Gjennem affolkede bygder paa Islands indre høiland. Undersøgelser foretagne i 1897*, "Árbók hins íslenska fornleifafélags 1898. Fylgirit", pp. 4-46.
- A.W. BRØGGER 1937, *Hvussu Føroyar vórðu bygdar. Inngongd til løgtingssøgu Føroya*, Tórshavn.
- M.J. CHURCH, A.J. DUGMORE, K-A. MAIRS, A.R. MILLARD, G.T. COOK, G. SVEINBJARNARDÓTTIR, P.A. ASCOUGH, K.H. ROUCOUX 2007, *Charcoal production during the Norse and Early Medieval Periods in Eyjafjallahreppur, Southern Iceland*, "Radiocarbon", 49, pp. 659-672.
- M.J. CHURCH *et al.*, forthcoming, *Surviving on the frontier: excavations at an early inland site at undir Sandmúla, Iceland*, "Archaeologia Islandica", 11 (2014).
- W. CRONON 1992, *Nature's Metropolis. Chicago and the Great West*, New York.
- A.J. DUGMORE, P. BUCKLAND 1991, *Tephrochronology and late Holocene soil erosion in Southern Iceland*, in J.K. MAIZELS, C. CASELDINE (eds), *Environmental Change in Iceland. Past and present*, Dordrecht, pp. 147-159.
- A. DUGMORE, M.J. CHURCH, K-A. MAIRS, T.H. MCGOVERN, A.J. NEWTON, G. SVEINBJARNARDÓTTIR 2006, *An over-optimistic pioneer fringe? Environmental perspectives on medieval settlement abandonment in Þórsmörk, South Iceland*, in ARNERBORG, GRØNNOW 2006, pp. 335-346.
- A. DUGMORE, M.J. CHURCH, K-A. MAIRS, T.H. MCGOVERN, S. PERDIKARIS, O. VÉSTEINSSON 2007, *Abandoned farms, volcanic impacts and woodland management. Revisiting Þjórsárdalur, the "Pompeii of Iceland"*, "Arctic Anthropology", 44, pp. 1-11.
- A.J. DUGMORE, G. GÍSLADÓTTIR, A.J. NEWTON, I.A. SIMPSON 2009, *Conceptual models of 1,200 years of soil erosion reconstructed using tephrochronology*, "Journal of the North Atlantic", 2, pp. 1-18.
- K. ELDJÁRN 2000, *Kuml og haugfé úr heiðnum síð á Íslandi*, 2<sup>nd</sup> rev. ed. by A. FRÍÐRIKSSON, Reykjavík.
- G.A. GÍSLADÓTTIR, J.M. WOOLLETT, U. ÆVARSSON, C. DUPONT-HÉBERT, A. NEWTON, O. VÉSTEINSSON 2013, *The Svalbard project*, "Archaeologia Islandica", 10, pp. 69-103.
- S. ÍSLEIFSSON 2011, *Islands on the edge. Medieval and early modern national images of Iceland and Greenland*, in S. ÍSLEIFSSON, D. CHARTIER (eds), *Iceland and Images of the North*, Sainte-Foy, pp. 41-66.
- G. JONES 1986, *The Norse Atlantic saga. Being the Norse Voyages of Discovery and Settlement to Iceland, Greenland, and North America*, 2<sup>nd</sup> ed., London.
- W.F. KEEGAN, J. DIAMOND 1987, *Colonization of islands by humans. A biogeographical perspective*, in M. SCHIFFER (ed), *Advances in Archaeological Method and Theory* 10, New York, pp. 49-92.
- I.T. LAWSON, F.J. GATHORNE-HARDY, M.J. CHURCH, A.J. NEWTON, K.J. EDWARDS, A.J. DUGMORE, Á EINARSSON 2007, *Environmental impacts of the Norse settlement: palaeoenvironmental data from Mývatnssveit, northern Iceland*, "Boreas", 36, pp. 1-19.
- G. LUCAS 2008, *Pálstóftir. A Viking Age shieling in Iceland*, "Norwegian archaeological review", 41(1), pp. 85-100.

- K.A. MAIRS, M.J. CHURCH, A.J. DUGMORE, G. SVEINBJARNARDÓTTIR 2006, *Degrees of Success: evaluating the environmental impacts of long term settlement in South Iceland*, in ARNEBORG, GRØNNOW 2006, pp. 365-373.
- T.H. MCGOVERN, S. PERDIKARIS, Á. EINARSSON, J. SIDELL 2006, *Coastal connections, local fishing, and sustainable egg harvesting: patterns of Viking Age inland wild resource use in Mývatn district, Northern Iceland*, "Environmental Archaeology", 11, pp. 187-205.
- T.H. MCGOVERN, O. VÉSTEINSSON, A. FRÍÐRIKSSON, M. CHURCH, I. LAWSON, I.A. SIMPSON, Á. EINARSSON, A. DUGMORE, G. COOK, S. PERDIKARIS, K.J. EDWARDS, A.M. THOMSON, W.P. ADDERLEY, A. NEWTON, G. LUCAS, R. EDVARDSSON, O. ALDRED, E. DUNBAR 2007, *Landscapes of settlement in Northern Iceland: Historical ecology of human impact & climate fluctuation on the millennial scale*, "American Anthropologist", 109, pp. 27-51.
- M.E. MANN, Z. ZHANG, S. RUTHERFORD, R.S. BRADLEY, M.K. HUGHES, D. SHINDELL, C. AMMANN, G. FALUVEGI, F. NI 2009, *Global signatures and dynamical origins of the Little Ice Age and Medieval climate anomaly*, "Science", 326(1256), DOI: 10.1126/science.1177303
- S. RAFNSSON 1990, *Byggðaleifar í Hrafnkelsdal og á Brúardblum*, (Rit hins íslenska fornleifafélags 1), Reykjavík.
- M. ROCKMAN 2010, *New World with a new sky. Climatic variability, environmental expectations, and the historical period colonization of eastern North America*, "Historical Archaeology", 44(3), pp. 4-20.
- M. ROCKMAN, J. STEELE (eds) 2003, *Colonization of unfamiliar landscapes. The archaeology of adaptation*, London.
- M.J. ROWLANDS, M.T. LARSEN, K. KRISTIANSEN (eds) 1987, *Centre and periphery in the ancient world*, Cambridge.
- M.Á. SIGURGEIRSSON, U. HAUPTFLEISCH, A. NEWTON, Á. EINARSSON Á 2013, *Dating of the Viking Age landnám tephra sequence in Lake Mývatn sediment*, "Journal of the North Atlantic", 21, pp. 1-11.
- I.A. SIMPSON, A.J. DUGMORE, A. THOMSON, O. VÉSTEINSSON 2001, *Crossing the thresholds: human ecology and historical patterns of landscape degradation*, "Catena", 42, pp. 175-192.
- I.A. SIMPSON, O. VÉSTEINSSON, W.P. ADDERLEY, T.H. MCGOVERN 2003, *Fuel resource utilisation in landscapes of settlement*, "Journal of Archaeological Science", 30, pp. 1401-1420.
- K.P. SMITH 2005, *Ore, fire, hammer, sickle: iron production in Viking Age and Early Medieval Iceland*, in R.H. BORK (ed), *De Re Metallica: Studies in Medieval Metals*, Aldershot, pp. 183-206.
- R.T. STREETER, A.J. DUGMORE 2014, *Late-Holocene land surface change in a coupled social-ecological system, southern Iceland: a cross-scale tephrochronology approach*, "Quaternary Science Reviews", 86, pp. 99-114.
- R.T. STREETER, A.J. DUGMORE, O. VÉSTEINSSON 2012, *Plague and landscape resilience in premodern Iceland*, "Proceedings of the National Academy of Sciences", 109(10), pp. 3664-3669.
- G. SVEINBJARNARDÓTTIR 1992, *Farm abandonment in Medieval and Post-Medieval Iceland: An interdisciplinary study*, Oxford.
- O. VÉSTEINSSON 2000, *The Christianization of Iceland. Priests, power and social change 1000-1300*, Oxford.
- O. VÉSTEINSSON (ed) 2003, *Fornleifarannsókn á Steinboga í Mývatnssveit 2002*, Reykjavík.
- O. VÉSTEINSSON 2004, *Krókdalur. Fornleifaskráning 2004*, Reykjavík.
- O. VÉSTEINSSON 2006, *Communities of dispersed settlements. Social organization at the ground level in tenth to thirteenth-century Iceland*, in W. DAVIES, G. HALSALL, A. REYNOLDS (eds), *People and Space in the Middle Ages, 300-1300*, Turnhout, pp. 87-113.
- O. VÉSTEINSSON 2009, *Parishes and communities in Norse Greenland*, in J. ARNEBORG, G. NYEGAARD, O. VÉSTEINSSON (eds), *Norse Greenland. Selected papers from the Hvalsey conference 2008*, (Journal of the North Atlantic. Special volume 2), pp. 138-150.
- O. VÉSTEINSSON 2010, *On farm-mounds*, "Archaeologia islandica", 8, pp. 13-39.
- O. VÉSTEINSSON (ed) 2010, *Archaeological investigations in Krókdalur 2005*, Reykjavík.
- O. VÉSTEINSSON (ed) 2011, *Archaeological investigations in Mývatnssveit, Reykjadalur and Svartárkot 2010*, Reykjavík.



- O. VÉSTEINSSON 2013, *North Atlantic Migrations in the Viking Age*, in I. NESS (ed), *The Encyclopedia of Global Human Migration*, Malden, DOI: 10.1002/ 97814443 51071.wbeghm396.
- O. VÉSTEINSSON forthcoming, *Commercial fishing and the political economy of medieval Iceland*, in J. BARRETT, D. ORTON (eds), *Cod and Consequences: the Archaeology and History of Medieval Sea Fishing*, Oxford.
- O. VÉSTEINSSON, T.H. MCGOVERN 2012, *The peopling of Iceland*, "Norwegian Archaeological Review", 45(2), pp. 206-218.
- O. VÉSTEINSSON, T.H. MCGOVERN, C. KELLER 2002, *Enduring impacts: Social and environmental aspects of Viking Age settlement in Iceland and Greenland*, "Archaeologia Islandica", 2, pp. 98-136.
- O. VÉSTEINSSON, I.A. SIMPSON 2004, *Fuel utilisation in pre-industrial Iceland. A micro-morphological and historical analysis*, in G. GUÐMUNDSSON (ed), *Current Issues in Nordic Archaeology*, Proceedings of the 21<sup>st</sup> Conference of Nordic Archaeologists (Akureyri, September 6<sup>th</sup>-9<sup>th</sup> 2001), Reykjavík, pp. 181-87.
- O. VÉSTEINSSON, S. ÞORGEIRSDÓTTIR, H.M. ROBERTS 2011, *Efniviður Íslandssögunnar. Vitnisburður fornleifa um einokun og neyslu*, in O. VÉSTEINSSON, G. LUCAS, K. ÞÓRSDÓTTIR, R.G. GYLFAÐÓTTIR (eds), *Upp á yfirborðið. Nýjar rannsóknir í íslenskri fornleifafræði*, Reykjavík, pp. 71-93.
- V.Ö. VILHJÁLMSOHN 1989, *Stöng og Þjórsárdalur-bosættelsens ophor*, "Hikuin", 15, pp. 75-102.
- R. WALTER, C. JACOMB, S. BOWRON-MUTH 2010, *Colonisation, mobility and exchange in New Zealand prehistory*, "Antiquity", 84, pp. 497-513.
- H. ÞORLÁKSSON 1991, *Vaðmál og verðlag í utanríkisviðskiptum Íslendinga*, Reykjavík.
- S. ÞÓRARINSSON 1943, *Þjórsárdalur og dess föröðelse*, in M. STENBERGER (ed) *Fortida Gårdar i Island*, Copenhagen, pp. 9-52.
- S. ÞÓRARINSSON 1958, *Iceland in the Saga Period. Some geographical aspects*, in K. EL-DJÁRN (ed), *Third Viking Congress. Reykjavík 1956*, (Árbók hins íslenska fornleifafélags 1956, Fylgirit), Reykjavík, pp. 13-24.
- S. ÞÓRARINSSON 1977, *Gjósulög og gamlar rústir. Brot úr íslenskri byggðasögu*, "Árbók hins íslenska fornleifafélags 1976", pp. 5-38.
- M. ÞÓRÐARSON 1909, *Merkur fornmenjafundur. Fundið fornt gangsilfur*, "Árbók hins íslenska fornleifafélags 1909", pp. 24-31.