A VIKING AGE POLITICAL ECONOMY

FROM SOIL CORE TEPHROCHRONOLOGY

A Thesis Presented

by

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ABSTRACT

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FROM SOIL CORE TEPHROCHRONOLOGY

June 2011

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Saga accounts describe Viking Age Iceland as an egalitarian society of independent household farms. By the medieval period, the stateless, agriculturally marginal society had become highly stratified in exploitative landlord-tenant relationships. Classical economists place the origin of differential wealth in unequal access to resources that are unevenly distributed across the landscape. This irregularity is manifested archaeologically as spatial variations in buried soil horizons, which are addressed through thousands of soil cores recorded across Langholt in support of the Skagafjörður Archaeological Settlement Survey. Soil accumulation rates, a proxy for land quality, are derived from tephrochronology and correlated with archaeological and

historical data to describe relationships between local environmental conditions, farm size, and farm settlement order. Spatial variations in soil accumulation rate are inherent, persistent, and magnified by environmental decline. Settling early on high-quality land leads to long-term success, while farmers who settle later, or on more marginal land, can maintain high status by leveraging alternate sources of wealth to gain control over more productive agricultural land. Subtle differences in the rate of soil accumulation lead to large differences in the wealth of farmsteads during the Viking Age on Langholt in Skagafjörður, Iceland.

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I am profoundly grateful to my family and friends, especially my mother, Kathy Catlin, and my sister, Sally Catlin, who accepted my return to higher education with good humor and invaluable support.

To be a successful farmer
one must first know the nature of the soil.

Xenophon
Oeconomicus
ca. 360 B.C.

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CHAPTER 1

INTRODUCTION

Small differences in the rate of soil accumulation lead to large differences in the success of farmsteads during the Viking Age on Langholt in Skagafjörður, Iceland. Classical economic theory places the origins of social stratification in the enforcement of unequal access to scarce resources that are unevenly distributed across the landscape (Ricardo 1817; Gilman 1995; Hunt 1998). By extension, then, if the first settler into a newly opened frontier takes advantage of the opportunity to claim and protect the most productive land, he will ultimately become the wealthiest landowner in the region. Social stratification emerges when differences in this landed wealth are institutionalized and passed on from one generation to the next (Johnson and Earle 2000).

Rent, a concept foundational to political economy, was defined by David Ricardo (1817) as the difference in the amount of grain that can be produced on a good farm and a poor farm of the same size in the same region with the same amount of labor (i.e., the difference in the productivity of the land) . As progressively more marginal land is put into cultivation by new arrivals and younger generations, these rents increase. Stratified political economies are characterized by the mobilization and manipulation of rents, in the form of surplus production, by members of an elite class (Earle 2002).

The rapid settlement of uninhabited Iceland during the Viking Age is an ideal case study for exploring how small differences in rent may institutionalize social stratification. Iceland was settled by wealthy farmers and displaced chieftains from Scandinavia, who brought with them an ideology of self-sufficiency that laid the foundation for a nascent democracy. However, over 350 years the chieftains began to amass power and wealth until several major families controlled the majority of the island by the 13th century. Most farms were tenant-occupied by the end of the 14th century (Bolender and Steinberg 2010), and by the early 18th century, tenancy had progressed to the point of 95% land alienation, while disease, famine, economic marginalization from Europe, and climatic changes further contributed to the impoverishment of the peasantry (Magnússon and Vídalín 1930; Karlsson 2000; Byock 2001).

What was the basis of wealth that drove the emergence of an elite class in this previously uninhabited landscape? On an island where all land is marginal by the standards of mainland Northern Europe, is the difference between poor land and only slightly better land sufficient to create the degree of social stratification that enabled the emergence of such profound inequality? What is the relationship between primacy, rent-seeking, and alternate sources of wealth and status, and how do they interact with changing environmental conditions? Iceland's settlement is the only historically documented example of a transition from unsettled frontier to fully propertied agricultural landscape – an anomalous event that provides a unique opportunity to observe the evolution of a society from household autonomy to exploitative stratification, embedded within a complex and shifting field of social and environmental relationships

(Smith 1995; Amorosi et al. 1997; McGovern et al. 2007). Socially speaking, Iceland was a blank slate before ca. A.D. 870, and by using one of Iceland's other unique archaeological resources – tephrochronology – changes and continuities in patterns of soil accumulation can be traced from the prehistoric period though the anthropogenic landscapes of the Viking Age. Iceland therefore presents a singular opportunity to truly seek the origins of wealth and social stratification in inherent differences in the landscape, to test this most fundamental principle of anthropology and economics.

The Skagafjörður Archaeological Settlement Survey (SASS) was initiated to address these and other questions about Iceland's early settlement and political economy (Steinberg and Bolender 2005; Bolender and Steinberg 2010; Steinberg, Bolender et al. [2011]). The Langholt region has experienced a series of volcanic ash falls that have resulted in distinct tephra layers of known age, relatively evenly spaced through the Viking Age and later Norse period. It is therefore possible to date fairly precisely both cultural deposits and the massive amounts of anthropogenic erosion and aeolian-andic deposition that have occurred between the tephra isochrons (Guðbergsson 1996). Significant change and variability in soil accumulation rates between tephra layers is observed in thousands of soil cores. While the correlation is complex, there is long-term advantage to settling early on high-quality land with deep soils. I argue that rent, made possible by thicker and more fertile soils, is the base of the institutionalization of social stratification on Langholt.

There may be multiple pathways to securing the wealth and status that ultimately resides in the land. Archaeological interpretations of the relict landscape have the potential to address the controversies that arise from ambiguities in the sagas, and provide a vital counterpoint to historical and literary analyses. The current study, an analysis of the first extensive regional-scale soil core survey in Iceland, represents one of few attempts to address the role of inherent land quality in the initial partitioning of the landscape and the development of social stratification.

Political Economy of Viking Age Iceland

Because the goal of this research is to describe the role of soil accumulation rates and farm productivity in the development of social stratification in Viking Age Iceland, it is important to first understand Iceland's early history and the structure of its political economy. The first settlers in Iceland arrived from Scandinavia ca. A.D. 870 (Buckland et al. 1995). According to the sagas, the settlers were independent farmers, chieftains, and their retinues, who were fleeing state consolidation in Norway. Soon thereafter, this rapid settlement was called *landnám* (land-taking) (Pálsson and Edwards 1972), and this term has also been adopted to describe other such colonizations in the archaeological record (e.g. Iversen 1941, Oldfield and Statham 1963, Lowe et al. 2000, Caseldine and Fyfe 2006). The *landnám* began with large, dispersed land claims, settled by one or more related households. From the time of these early land claims to the traditional end of the settlement in 930 (Þorgilsson 1930), independent farmers settled on the empty land between the initial farmsteads, with or without the permission of the original claimants. The households of chiefs and large, independent farmers were characterized by internal stratification, consisting of family members, retainers and followers, and servants and slaves, as well as the livestock and material goods necessary for their support, all of which had to be transported across the ocean (Vésteinsson 2000; Bolender, Steinberg et al. 2008).

Our knowledge of early Icelandic social structure is derived largely from historical and anthropological readings of the Sagas of Icelanders (Durrenberger 1998, Byock 2001), a body of oral traditions that were set down in writing by church scribes and officials starting in the late 12th century. The saga authors were therefore not contemporaries of most of the events and relationships they describe, and the events of the first years after *landnám* are open to multiple interpretations. Early Icelandic society has been described as essentially a classic Germanic chiefdom, with assemblies, loosely hereditary chieftaincies, and autonomous households as the basic unit of production (Engels 1884; Gilman 1995; Steinberg 2006). This early society subscribed to an ideology of egalitarian individualism among the land-owning elite; the chieftains (*goðar*, sing. *goði*) had very limited roles including arbitration (suits tended to be over killings related to ownership of land or livestock), temple maintenance, and participation in local and national assemblies – notably, not explicitly including management of productive resources or surplus (Gilman 1995; Bolender and Steinberg 2010). An early territorial administrative unit was the *hreppur* (pl. *hreppar*), or commune, which was jointly administered by the local farmers for mutual welfare, support, and management of communal pastures (*affrétur*). The origins of the *hreppar* are uncertain, but the borders of these areas appear to be of considerable antiquity. The relationship of each *goði* to the *hreppur* in which he resided is likewise unclear and debatable (Sigurðsson 1999). The office of *goðorð* was non-territorial, heritable, alienable, and often for purchase; any farmer could grant his allegiance to any *goði* in the quarter and could aspire to become one himself (Byock 2001, Steinberg 2006). These scenarios occur repeatedly in the sagas in concert with an emphasis on hospitality and gift-giving as markers of wealth and status (Steinberg and Bolender 2010), but the ultimate source of the capital to create the wealth and status of the *goðar* is unclear (Sigurðsson 1999; Byock 2001).

Institutionalized stratification in the form of direct control over non-household labor is usually described as a later development, beginning in the early 12th century as ambitious chieftains exploited the legal system to gain more and more wealth in the form of land and taxes (Karlsson 2000; Byock 2001). An alternate reading of these early years suggests that stratification arose much earlier, out of the social dynamics of the initial settlement and subsequent land division practices. In particular, if the origins of wealth lie in differential resource distribution, interhousehold social stratification based on differential rents will emerge when land becomes scarce, or about the time that settlement is complete (Bolender and Steinberg 2010). Recent multidisciplinary studies have suggested that settlement was more complex than the sagas imply (McGovern et al. 2007; Steinberg, Bolender et al. [2011]), which tends to support the latter view of an early start to tenancies and exploitative coercion in at least some instances. Most likely there was considerable regional variability in initial settlement patterns and social practices, as well as temporal variation in the structure of land subdivision, rent collection, and labor distribution.

From the Viking Age through to the late modern period, the economic organization of Icelandic society has been transhumant pastoralism. The harsh northern climate is not conducive to cereal production, though some contexts do show evidence that barley was sometimes successfully cultivated (Vésteinsson 2000; Vésteinsson et al. 2002; Steinberg 2007; Sveinbjarnardóttir et al. 2007; Trigg, Bolender, Johnson et al. 2009). Instead, the meat and dairy produce of sheep and cattle herds became dietary staples, in some areas supplemented by harvesting wild birds and seafood (McGovern et al. 2007). During the summer months, herds were sent to distant common pastures in the uplands, tended from small temporary dairy camps (*shieling*). In winter, especially in the north, the weather was often too harsh for dairy stock to survive outdoor grazing; herds were brought back to the farmstead and kept warm and dry in barns (*fjarhús*) when they could not be let out to graze, fed instead on hay that had been gathered and stored during the summer. Households were therefore dependent for survival on their ability to harvest and store sufficient hay from their homefields and outfield areas in the summer months to support their herds of sheep and cattle through the winter (Friðriksson 1972; Durrenberger 1998; Vésteinsson et al. 2002; Bolender 2006; McGovern et al. 2007). This agricultural bottleneck meant that more productive homefields could support larger herds. A bad year could spell starvation; access to productive fields in summer and viable pastures in winter could minimize bad years (Halstead and O'Shea 1989; Thomson and Adderley 2007). Economic success – and simple survival – was tied to field productivity at this most basic level. As property institutions emerged to take advantage of productive land, ownership was constrained by the choices of the initial settlers in partitioning the landscape. Analysis of buried soil horizons implies potential links between land quality and settlement patterns, suggesting that later social developments in Iceland were structured by the consequences of these early choices and practices of land division and use (Smith 1995; Amorosi et al. 1997; Vésteinsson, McGovern, et al. 2002; Bolender, Steinberg et al. 2008).

This transplantation of Northern European agricultural practices to Iceland was not environmentally sustainable, despite many outward similarities to the contemporary pastoral landscapes of Scandinavia. Initial forest clearing to create pastures and hayfields and unrestricted consumption of wood for charcoal, construction, and ship repair, coupled with intensive upland grazing by ruminants and swine, very quickly reduced the tree cover of the island (Amorosi et al. 1997; Vésteinsson 2000; Dugmore et al. 2006; Church et al. 2007). Current forest cover is estimated to have declined by 90% since *landnám*, with an accompanying 40% rate of soil loss to erosion (McGovern et al. 2007). This rampant environmental degradation did not escape the notice of the *landnámsmen* and their children, experienced farmers that they were. Pigs and goats, the more damaging of foragers, almost disappear from the archaeological record during the 10th century, and there is evidence that management of the remaining forest cover began very early in certain locations (Amorosi et al. 1997; Vésteinsson 2000; Dugmore, Church et al. 2007; McGovern et al. 2007). These measures were too little, too late: the island would never recover its pre-*landnám* highland pastures and forest cover, or return to prehistoric levels of erosion.

By 930, the traditional end of the Settlement period and beginning of the Icelandic Commonwealth (Þorgilsson 1930), tephrochronology makes it clear that destructive erosion was already rampant in localized areas (Dugmore, Gísladóttir et al. 2009). The human population rose as environmental degradation proceeded. Icelanders appear to have dealt with population pressure by altering their production strategies in two ways. First, they further subdivided their properties (Bolender and Steinberg 2010; Steinberg, Bolender et al. [2011]), pushing ever more marginal land into hay production by exploiting the labor of extra-household tenants and dependents. Second, they became increasingly transhumant, grazing sheep in more distant upland pastures year-round when possible, and in some cases possibly limiting the size of high-consuming cattle herds (Bolender 2006; McGovern et al. 2007).

Faced with the problem of feeding more people on increasingly marginal land, most societies through history have avoided starvation by intensifying agricultural production through new, creative land use practices (Johnson and Earle 2000). Intensification via the application of additional labor usually operates in diseconomies of scale, in which the productive efficiency of a plot of land rises while its marginal output decreases: if one worker can produce 2 bushels of grain in a day, two workers on the same land can produce 3.8. In early Iceland, intensification does seem to have created diseconomies of scale. Analysis of homefield productivity has shown that despite enrichment strategies, most farms were not able to produce a surplus of hay beyond subsistence level (Adderley et al. 2008). Furthermore, individual laborers were unable to produce substantially more than they consumed, effectively limiting farmstead size and providing an economic incentive for farmers to free their slaves (Durrenberger 1998). By granting land on the unused margins of their claim to former slaves or to adult children of first-generation settlers, farmers could increase their land area under cultivation. It is unclear whether the farmsteads that resulted from this initial round of subdivision were institutionally subordinate or nominally independent, but if familial ties were present there was probably some degree of mutual interdependence. Later periods of subdivision created a class of smaller tenant and dependent farms (*hjáleigur*), from which the parent farm could benefit by demanding produce and labor at no cost to their own resource base (Durrenberger 1998; Bolender and Steinberg 2010; Steinberg, Bolender et al. [2011]). The practice of putting ever more marginal lands into cultivation increased the productive divide between the best and worst farmland (i.e., rent), while the increasing extent of sheep grazing further damaged the environment.

Timing the appearance of tenancies with respect to environmental change therefore has the potential to address two major interrelated questions about the development of early Icelandic society: when did institutionalized social hierarchies develop, and what was the basis of the wealth that structured these institutions? By correlating spatiotemporal variations in land quality with farm status and farm establishment date, we can test the proposition that long-term social and economic success lies in inherent differences in the land, and we can determine whether any economic advantages accrue to the earliest settler. As the overall environment declines, the first settlers and their descendants may be able to maintain their status if they control land that proves to be consistently highly productive – whether they farm that land directly or extract its wealth as rent. Medieval and early modern records of land ownership and tenancy tie early land division practices and soil accumulation rates to later farm status. These multiple lines of evidence, taken together, suggest relationships between the rise of exploitative stratification, the institution of dependencies, and the expanding differences in land quality that result from environmental change.

Tephrochronology in Iceland

Icelandic archaeology benefits from the presence of tephra layers that are unevenly distributed at known temporal intervals through the stratigraphic record. By examining the nature and thickness of the deposits between known tephra at multiple locations across the landscape, we are able to explore both temporal and spatial variation in environmental conditions. These glassy, silicate-rich sediments blanket the downwind landscape during a volcanic eruption, and the resulting layers are visually distinct in profiles and in cores, distinguishable from one another by color, texture, and thickness. Tephra layers may be up to 50 cm thick immediately after the eruption, which can have an extremely deleterious effect on human and agricultural health, sometimes leading to temporary (or permanent) abandonment of farms in the affected area. Tephra horizons as they appear in soil profiles are generally $^1/_3$ to $^1/_2$ the thickness of the layer at the time of deposition (Þórarinsson 1971). Analysis of Greenlandic glacial ice cores supplemented by historical documentation has allowed these layers to be precisely dated – to the year, and sometimes, to the day (Zielinski, Meyewski et al. 1994; Grönvold et al. 1995; Zielinski, Meyewski et al. 1997). Tephra horizons are therefore used as isochrons – timeparallel markers corresponding to the boundary between the layer and the underlying soil (Larsen and Eiríksson 2008) – that allow sedimentary and aeolian-andic deposits to be quickly and easily assigned date ranges in the field. The speed and direction of prevailing winds at the time of each eruption determined the land area that would ultimately be covered in tephra, and so each region of Iceland therefore has its own distinctive tephra sequence (Þórarinsson 1944; Larsen and Eiríksson 2008).

The tephra sequence of Skagafjörður is spaced at intervals through the Viking Age, making the region particularly attractive for archaeological research. These layers have been dated to the eruptions of 1766 (Hekla), 1300 (Hekla), 1104 (Hekla H1), 1000 (Grimsvotn), and ca. A.D. 871 (Vatnaöldur, the *landnám* layer), over two prehistoric layers from ca. 1000 and 3000 B.C. (Hekla H3 and Hekla H4) (Figure 1) (Sigurgeirsson 2001; Sigurgeirsson 2009).

The Hekla volcano has two distinct types of eruptions. Pure explosions occur once every few centuries, producing light-colored, rhyolitic tephra layers (the H sequence). Hekla H2 has not been identified in Skagafjörður, and Hekla H5 (ca. 5000 BC) was often quite literally beneath our notice since it is standard procedure to stop digging or coring when the H3 and/or H4 layers are recognized. Hekla's more common mixed eruptions are not assigned H numbers; these produce lava flows as well as darker, basaltic to andesitic tephra (Þorarinsson 1971; Guðbergsson 1975; Larsen and Eiríksson 2008).

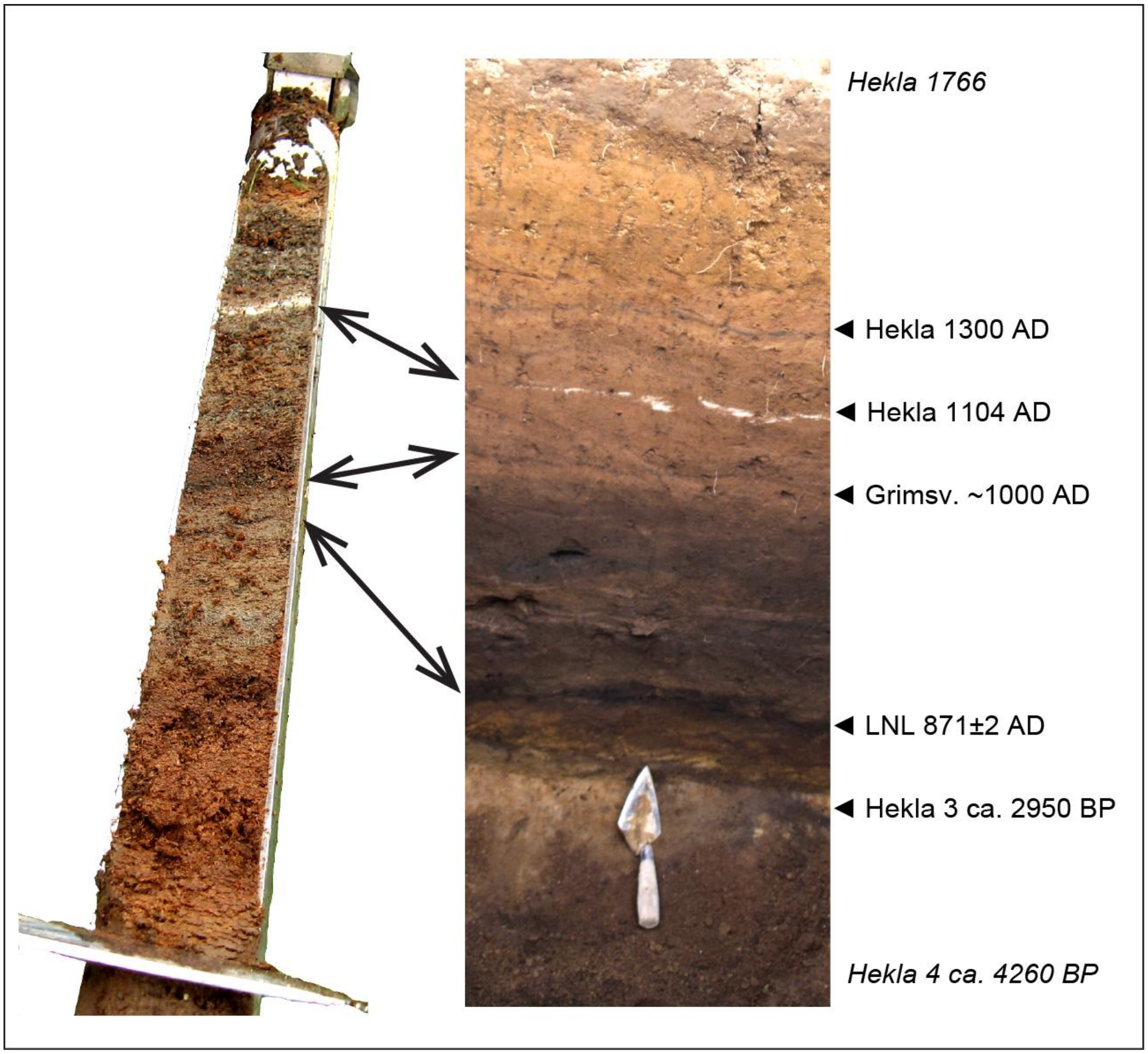


Figure 1. Tephra Layers in a Core and a Profile
(modified from Bolender et al. 2009)

The H3 layer has a sandy, light greyish yellow color, while H4 is finer-grained and tends more toward a very light grey. Both are quite thick, up to 10 cm in some cases, and they occur very close together when both are observed. The H3 layer, where present, serves in the current research as the start date for prehistoric soil accumulation measurements. The *landnám* sequence is a series of tephra often observed together with layers of extreme burning, dated to between about ±50 years of 870 (Guðbergsson 1996). The basaltic layer that corresponds to 871±2 (the *landnám* layer) (Grönvold et al. 1995) is the most common of these, and manifests as a very thin, distinctive iridescent dark green. The 1000 layer, the least common of the major tephra layers in Skagafjörður, appears as a thin black line. By far the most common of the historic tephra layers and the easiest to spot is the thick bright white layer of H1 (1104), which is usually about 0.5 cm thick but can be as thick as 2 cm in some cases. The sequence is capped by the 1300 and 1766 Hekla layers, both dark grey. 1766 is often darker and thinner and occurs within a few centimeters of the ground surface, while 1300 is deeper, lighter in color, and often somewhat thicker. The current study does not make use of the 1766 layer in favor of concentrating on landscape changes during the Viking Age, defined here as the Settlement (ca. 870-930) and Commonwealth (930-ca. 1260) periods, and due to known difficulties in distinguishing the layer in the field (Steinberg 2002).

In the study area, these pyroclastic strata are separated by thick accumulations of andosols, usually gleyic to brown depending on water content, which are formed from aeolian sediments of volcanic origin. Once deposited, these sediments weather in place to create andosols that are high in silica, iron, and residual organic carbon (Arnalds 2004). These silt loam soils are rough to the touch and distinctive in color and texture from the very dark or very light-colored, sharp-edged, grainy tephra layers. Soil profiles are usually not much more than one meter thick, atop sand, gravel, and basaltic bedrock. Peat bogs are also common and generally shallow (Jóhannesson1960). Although other soil formation processes are at work, such as alluvial and colluvial transport and cryoturbation, the dominant influence is redistribution, a process that includes soil erosion, aeolian deposition, and reworking (Arnalds 2010). By measuring redistribution in terms of soil accumulation rates between tephra layers, we can describe differences in land quality, and begin to suggest connections between land quality and social status.

Soil Accumulation and Land Quality

The Soil Science Society of America defines soil quality as "the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation" (Carter et al. 1997:8). This is a broad definition that applies to all soil types, environments, and applications; no single measure can fully characterize the quality of a particular soil. Instead, sets of soil attributes are examined together to assess a soil's suitability for a particular purpose. These attributes include pH, nitrogen content, soil organic carbon, and topsoil depth, among many others (Carter et al. 1997). Soil quality is itself an attribute of overall land quality, an assessment that also considers the effects of vegetation cover, water quality, climate, and topography on the land’s suitability for a given purpose (Carter et al. 1997; Arshad and Martin 2002). The notion of land quality "implies purpose, use, and value" (Carter et al. 1997:8), and is therefore firmly embedded in the ways in which people inhabit propertied landscapes: to speak of land quality is to make a claim about social utility, and does not imply value judgments of uninhabited ecosystems.

Decades of work by soil scientists and agricultural engineers have thus far failed to produce a single universal measure of soil or land quality that is applicable at all times and places (Carter et al. 1997; Karlen et al. 1997). However, topsoil depth is an important component of most suggested suites of quality assessments (Thompson et al. 1990; Warkentin 1995; Karlen et al. 1997; MacEwan 1997; Page-Dumroese et al. 2000; Arshad and Martin 2002; Troeh and Thompson 2005). Deeper soils can store more nutrients and water and provide more space for root growth than shallower soils, and experiments have shown that for two soils identical in every other way, the deeper soil tends to be the more productive (Thompson et al. 1990; Troeh and Thompson 2005). Above-ground vegetative biomass has been observed to increase with soil depth, and nutrient availability is proportional to soil volume (Bush and van Auken 1991; Belcher et al. 1995). Rhoton and Lindbo (1997) have further suggested that within an eroding environment of a single soil type, depth is a better index for productivity than soil organic carbon. Icelandic andosols that result from reworked aeolian deposition generally have high organic content through their full depth, and therefore the entire andic matrix can be considered A-horizon topsoil between the ground surface and the nutrient-poor subsoil layers of clay, gley, glacial till, and bedrock (Arnalds 2004; Óskarsson et al. 2004; Steinberg 2004; Troeh and Thompson 2005).

Soil redistribution is a complex process involving erosion, transport, redeposition, and reworking of both exposed subsoils and redeposited topsoils (Pennock 1997). Net soil accumulation rate is a measure of this dynamic redistributive process, distinct from (though clearly related to) static measurements of depth. All Icelandic andosols have experienced redeposition. Although redeposited soils are sometimes considered sediments (Goldberg and MacPhail 2006), an archaeological definition of soil that includes all biologically active layers capable of providing a "relatively stable surface for human activities" (Rapp and Hill 1998:32) would include redeposited Icelandic aeolian-andic soils through the Viking Age. In addition, scientific literature on soil quality refers to redistributed soils, and the current research follows these examples (e.g., Pennock 1997).

Two particular characteristics of redistributive environments should be emphasized. The first is a tendency for areas that experience high rates of soil redeposition to exhibit corresponding increases in independent measures of soil quality, including gains in nitrogen and soil organic carbon content (Pennock 1997). In Iceland, increased aeolian deposition rates of andosols with a high basaltic glass content lead to faster chemical weathering of the soil. Chemical weathering results in higher pH values and nutrient levels, increased microbial activity, faster rates of carbon decomposition, and formation of allophane and ferrihydrite clay minerals, all of which serve to increase the quality and fertility of the soil (Arnalds 2004; Sigfusson, Paton et al. 2004; Sigfusson, Gislason et al. 2008; Arnalds 2010).

The second important consequence of soil redistribution lies in its relationship to landscape topography, such that the range of variation in soil quality across a given region increases as redistribution proceeds. Redistribution may "create or exaggerate an overall spatial order within the ecosystem" that can be used to "stratify landscapes into distinctive response units" (Pennock 1997:168): areas with high soil quality increase in quality, while those with low quality decline as redistribution proceeds. This observation goes hand in hand with the tendency for stressful conditions (such as drought or erosion) to have more deleterious effects on the productivity of shallower soils (Thompson et al. 1990; Troeh and Thompson 2005).

Soil quality falls on a continuum between inherent and dynamic properties. The first are intrinsic to the soil, while the second refers to those qualities that can be adjusted via land management practices (Carter et al 1997; Herrick 2000). Quality is therefore directly related to "the cost of inputs required to change soils" (Warkentin 1995:226), which is to say, the difference in labor requirements to produce the same amount on plots of different inherent quality. Dynamic soil properties can therefore be harnessed to alter land productivity and Ricardian rent. When dynamic properties are dominant, management is low-cost and effective, and rents are low. On the other hand, when inherent properties dominate as they appear to do in Iceland, management strategies are high-cost and ineffective, and rents on productive land are very high. Where inherent soil properties are dominant and stable, high rents may also tend to stabilize – that is, if large differences in farm productivity do not substantially change year-to-year because inherent land quality is not susceptible to anthropogenic alteration, it is possible to imagine a scenario in which Ricardian rents remain relatively constant. When stable productivity makes it clear that some land is of inherently higher quality, there may be incentive to obtain this better land. The advantages to farming or controlling land with inherently high soil quality that requires relatively little management have been recognized since the beginnings of agricultural production (Childe 1951; Warkentin 1995; MacEwan 1997).

Soil depth and accumulation rate are the only criteria related to land quality that are available for the current study. Although this physical measure cannot, on its own, fully characterize relative land quality, the studies cited above suggest that as a proxy measure it is sufficient to sketch a rough approximation of landscape variability. In addition, this study may serve as a partial answer to Herrick's (2000) call for the development of landscape-scale approaches to soil quality analyses.

Previous studies in Iceland have used soil accumulation rates derived from tephrochronology to describe erosion rates from more distant areas with a particular interest in the character, extent, and distribution of the increases in anthropogenic or climate-driven erosion that occurred after *landnám* (Dugmore and Buckland 1991; Guðbergson 1996; Dugmore, Newton et al. 2000; Dugmore, Church et al. 2005; Dugmore, Church et al. 2006; Dugmore, Gísladóttir et al. 2009; Arnalds 2010). In a study that addressed the relationship between soil accumulation, farm quality, and social hierarchy in the Mörk and Dalur regions of south Iceland, high accumulation rates were equated with locally high erosion rates (landscape instability), and taken to represent poor locations for farming (Mairs et al. 2006). In contrast to the complex topography at the base of the Eyjafjallajökull glacier, landforms of Langholt tend to be flat or gently rolling, and so the current research takes an alternate perspective. Windborne aeolian-andic sediments have been found to travel more than a kilometer before coming to rest (Dugmore, Gísladóttir et al. 2009), and in the inhabited areas of Langholt the sum of deposition and erosion is positive, so the observable net effect is of soil accumulation. Although localized erosion is sometimes apparent, particularly where soils are thin and tephra layers are missing, massive erosion events resulting in areal loss to bedrock are not common on Langholt in current or historic fields or pastures, even where modern land management is demonstrably poor. The sum of both deposition into and erosion out of microenvironments (i.e., the net soil accumulation rate at sampled point locations) is arguably reflective of local land quality.

Langholt, Skagafjörður, Iceland

Langholt, a 6500-hectare region south of the modern town of Sauðarkrókur, today includes about 40 farms and cottages along the western side of the valley between the Héraðsvötn and Sæmundará rivers (Figure 2) (Pálsson 2001). Many of these farmsteads have occupied the same location since the Viking Age. Often, the modern farmhouses are located atop or near farm mounds, which are hillocks of building debris and garbage that have built up over centuries of habitation, elevating the structures above the surrounding terrain. Structures that comprise the buried archaeological landscape of a Viking Age farm include longhouses (*langhús*), ash middens (*öskuhaugar*), sheep and cow barns (*fjarhús*), and in some cases churches (*kirkja*), additional storage sheds, and pithouses. Large, high-status farms tended to have more structures; in particular, on Langholt, they are more likely to have a church (Bolender 2006; Steinberg 2009). In other parts of Iceland, some large, complex settlements have been found with multiple contemporary longhouses or pagan temples (Vésteinsson 2000), though none are yet known in the study region. Until the 20th century the land area that could be farmed was limited by household labor, and grass was harvested by hand from relatively small

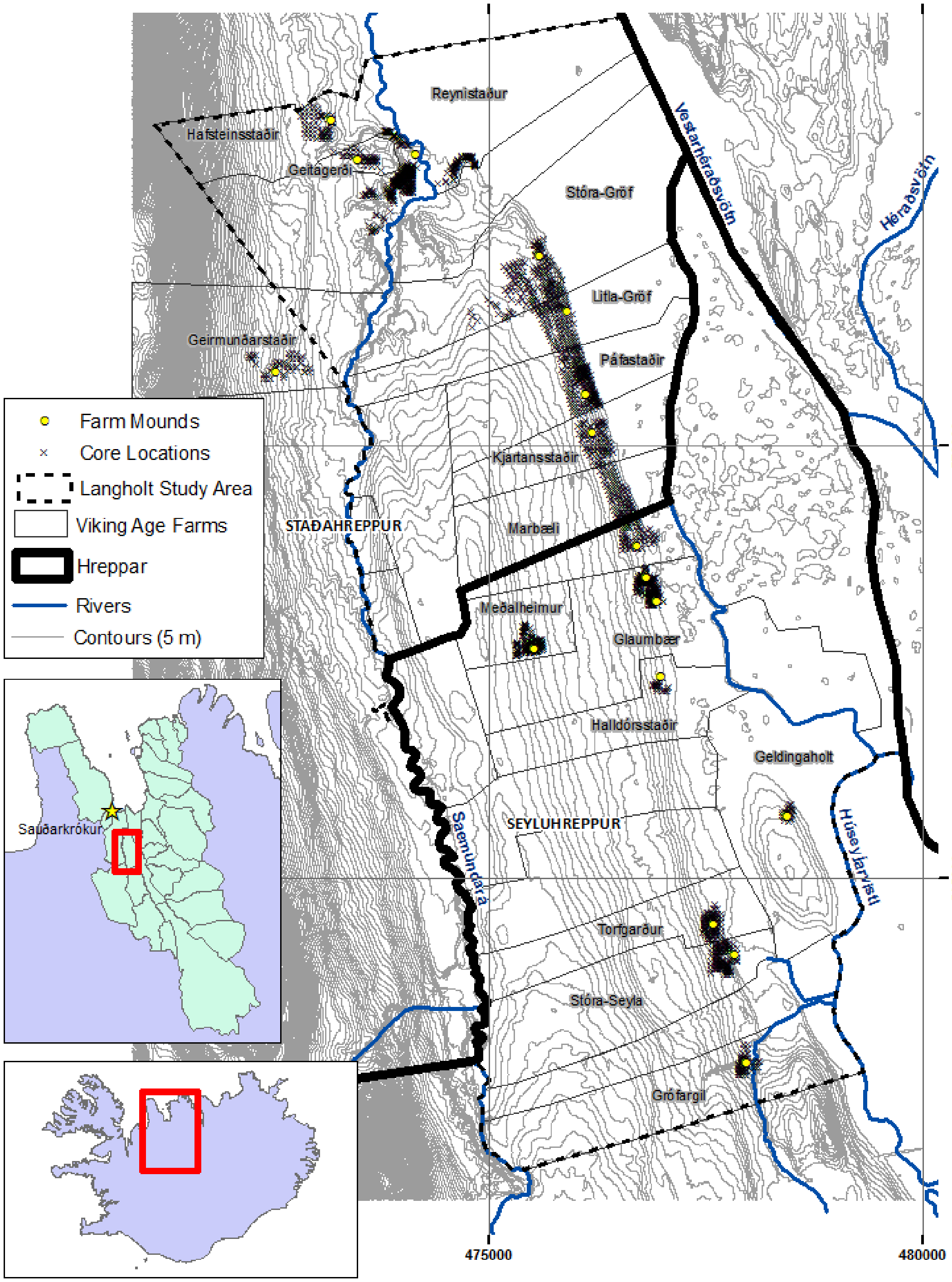


Figure 2. **Map of Langholt**
Langholt, Skagafjörður, Iceland, showing locations of soil cores included in the study. Viking Age farm boundaries correspond to modern property lines, except Meðalheimur, for which no records exist.

homefields (*tún*) around the farm structures, separated from the outfields by a turf-built fence (Figure 3) (Bolender 2006). Today, with the aid of modern equipment, the cultivated areas have significantly expanded.

Modern Langholt's farm properties are arranged in long lots, incorporating a range of environmental zones from east to west, from low-lying, wet peat bogs to drier, fertile, sloping hayfields and pastures (Bolender, Steinberg et al. 2008). At *landnám*, these areas may have included forested zones as well (Trigg, Bolender, Catlin et al. 2009). Bogs provided peat for fuel and turf for building materials, and hay was harvested from outfields to supplement the produce from the cultivated homefields. When not being harvested, these lands probably served as pasture, along with more distant communal rangelands. It is not known precisely how heavily the outlying areas were used for these practices during the Viking Age.

The current study focuses on the homefields and areas adjacent and topographically similar. The inhabited landscape slopes gradually upward from north to south: the lower, northern farms are nestled among small hills, while the southern farms are higher and more exposed to wind and weather (Figure 2). Farmsteads in the center of the region are located on or just above a small well-drained slope that extends from north to south above the river, giving most of them an excellent view of their lower outfields, the farms and mountains on the other side of the valley to the east, and the fjord to the north. In comparison to other parts of Iceland, Langholt's sub-regional variability is in fact quite small. Microenvironmental sampling strategies such as soil cores can

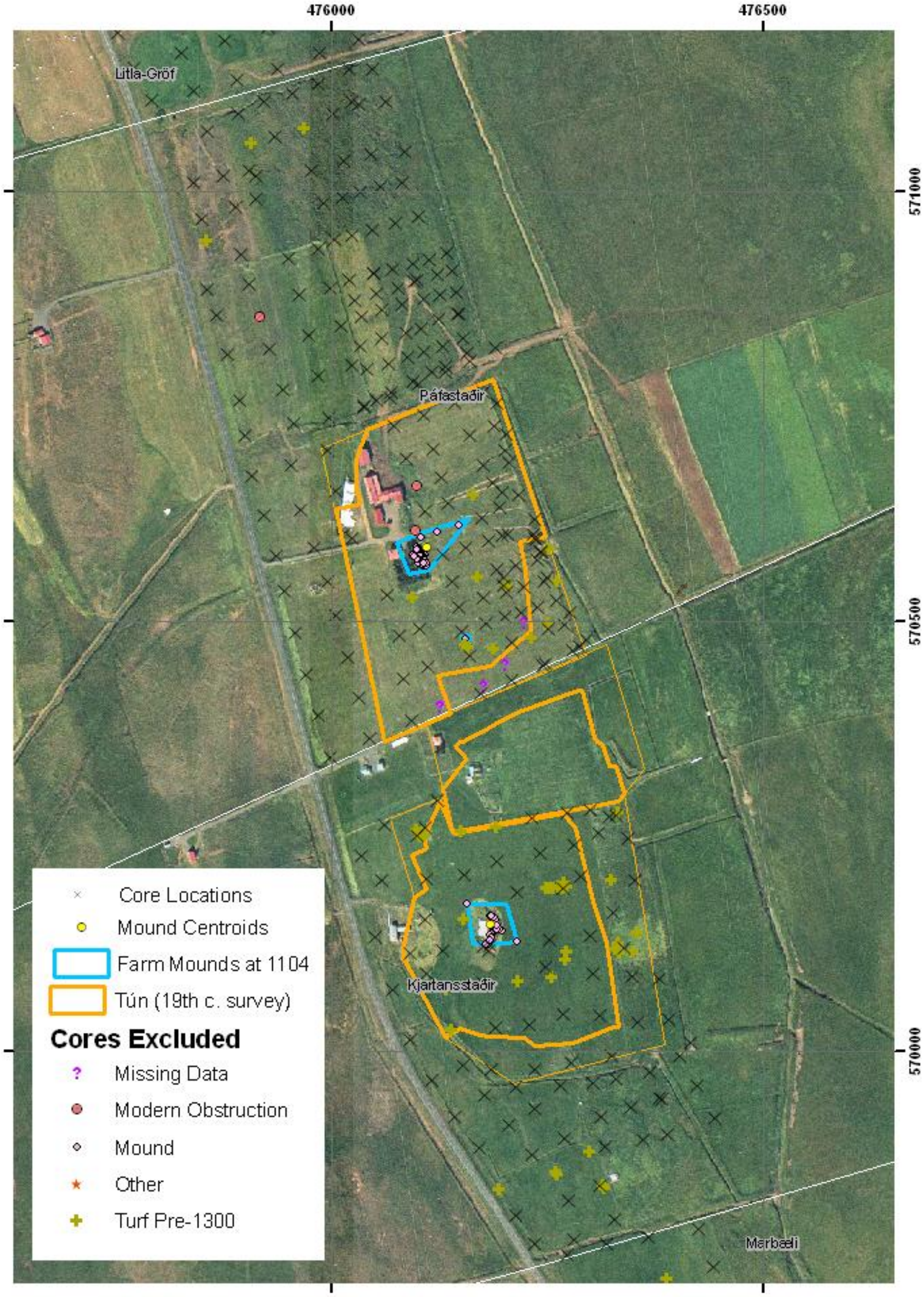


Figure 3. Farm Mounds and Homefields
Homefield boundaries from the 19th century survey (Magnússon and Vídalín 1930) are shown with farm mound boundaries derived from the coring survey, along with cores that were eliminated from the sample for the reasons shown. Grey lines correspond to modern farm boundaries.

nonetheless reveal subtle spatiotemporal variations within the largely homogeneous, agricultural landscape.

The Skagafjörður Archaeological Settlement Survey has used a combined approach of coring, remote sensing, test excavation, and environmental sampling to develop a settlement sequence and hierarchy for nineteen Viking Age farms on Langholt, in part by locating early farm structures that were abandoned during the Viking Age and are no longer visible on the surface (Bolender and Steinberg 2010; Steinberg, Bolender et al. [2011]). SASS's work has shown that the farmsteads of the region follow a convex rank-size curve by 1104 (two centuries after settlement), shifting to extremely primate by the 18th century (Figure 4). A few large, early farms become the wealthiest, eventually owning most of the many smaller, later farms that fill the remaining land in the region (Bolender et al. 2009). The two distant ends of the Langholt region were settled first, with large, wealthy farms, followed by two more large farms directly in the middle, and the remaining land area was slowly filled by smaller dependent and tenant farms through a process of land division (Figure 5, Table 1; also see Figure 13) (Bolender 2006; Bolender, Steinberg et al. 2008; Bolender and Steinberg 2010; Steinberg, Bolender et al. [2011]). Examined in light of this settlement sequence, differential soil accumulation rates through time can describe the role of landscape differences in long-term trajectories of wealth creation and social stratification.

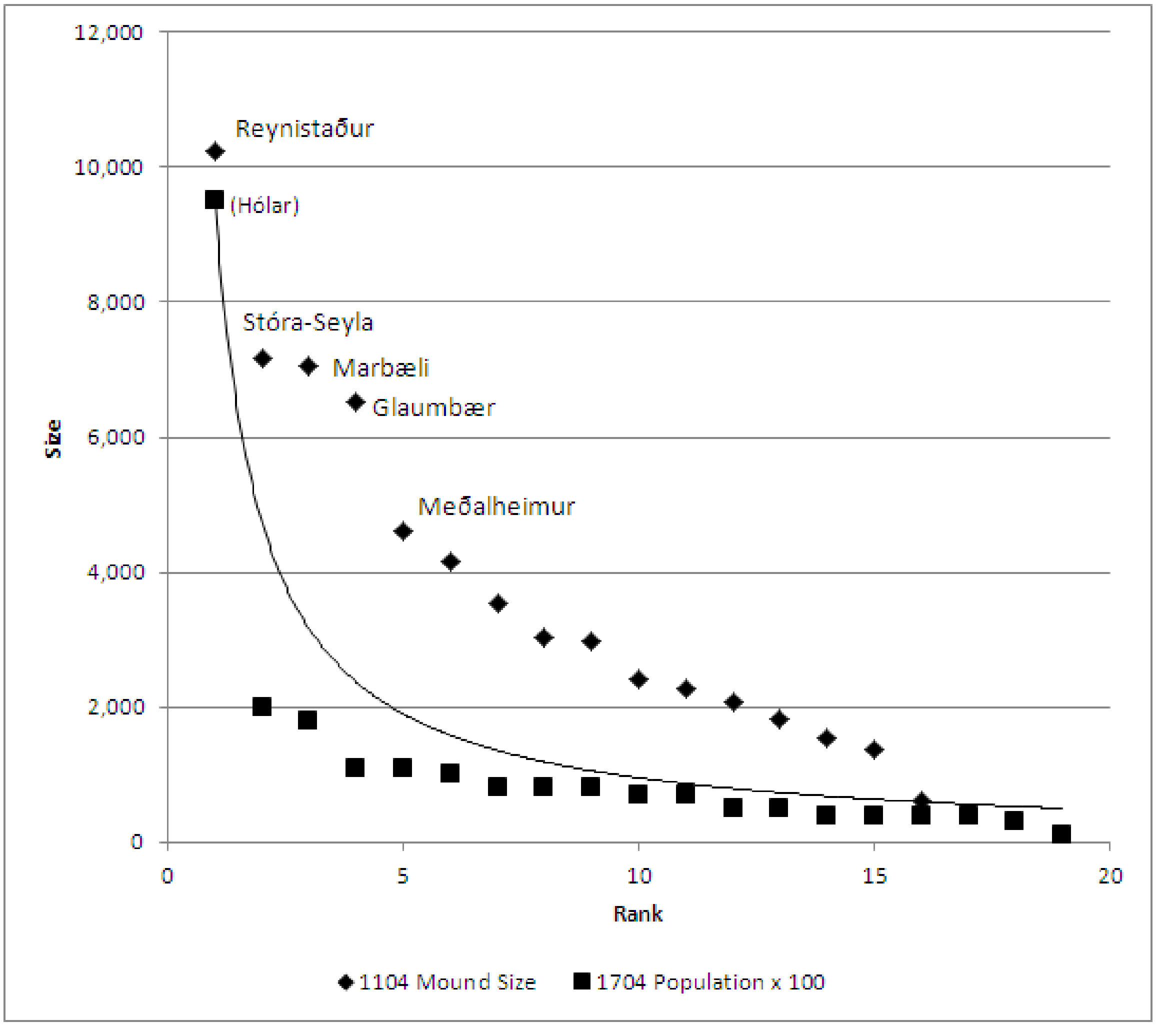


Figure 4. **Rank-Size Plots**
Data from the 1704 census is multiplied by 100 and includes Hólar. The log-normal line is shown for the 1704 data (Drennan and Peterson 2004; Steinberg et al. [2011]). The convex curve during the Viking Age becomes highly primate by the 18th century, when many of Langholt's farms have become subordinate to the distant, wealthy bishopric at Hólar.

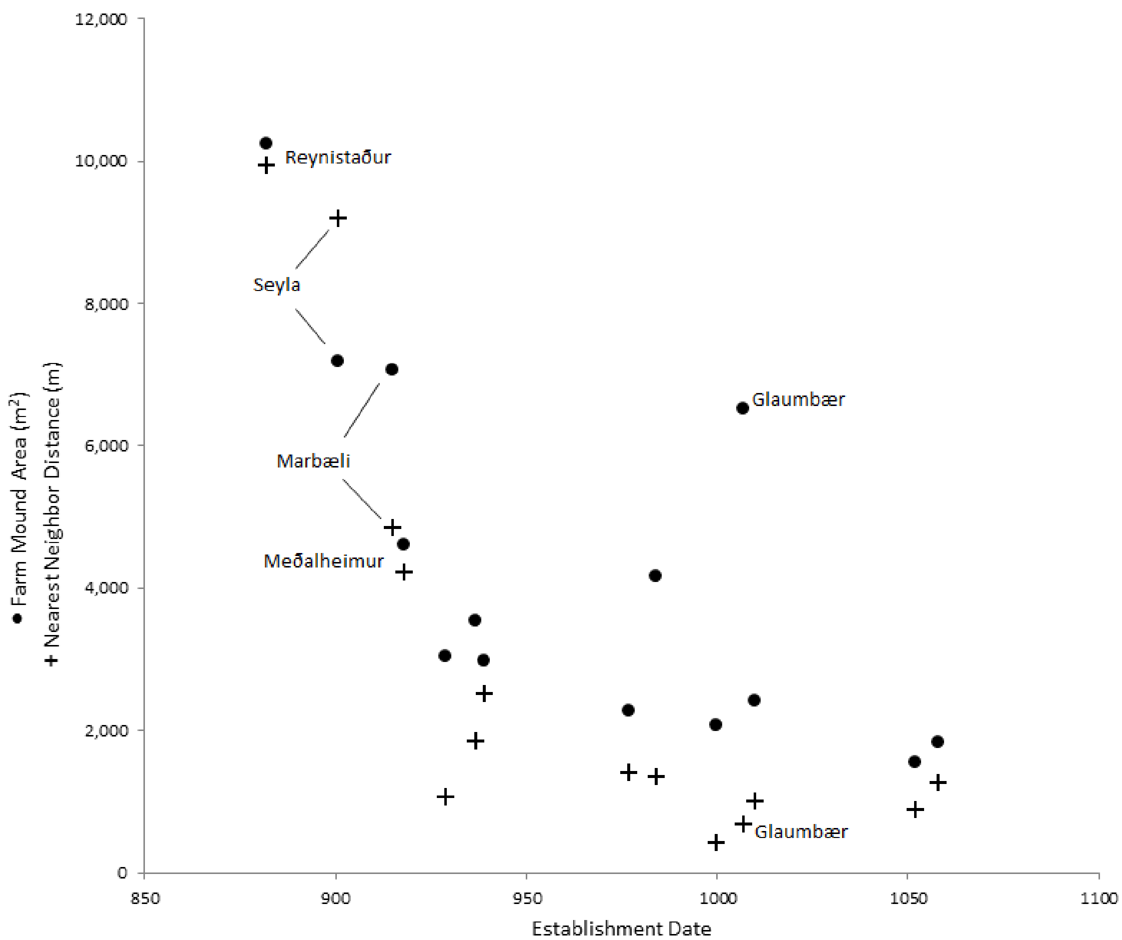


Figure 5. Establishment Date vs. Farm Mound Area and Nearest Neighbor Distance

Mound Area at 1104: R^2 linear=0.482, R^2 power series=0.576. Neighbor Distance: R^2 linear =0.561, R^2 power series=0.649. Early farms have larger mounds by 1104 and are located much farther from their neighbors. Glaumbær's large mound size is anomalous, suggesting that alternative sources of wealth should be considered. (Steinberg et al. [2011])

Table 1. Farm Data

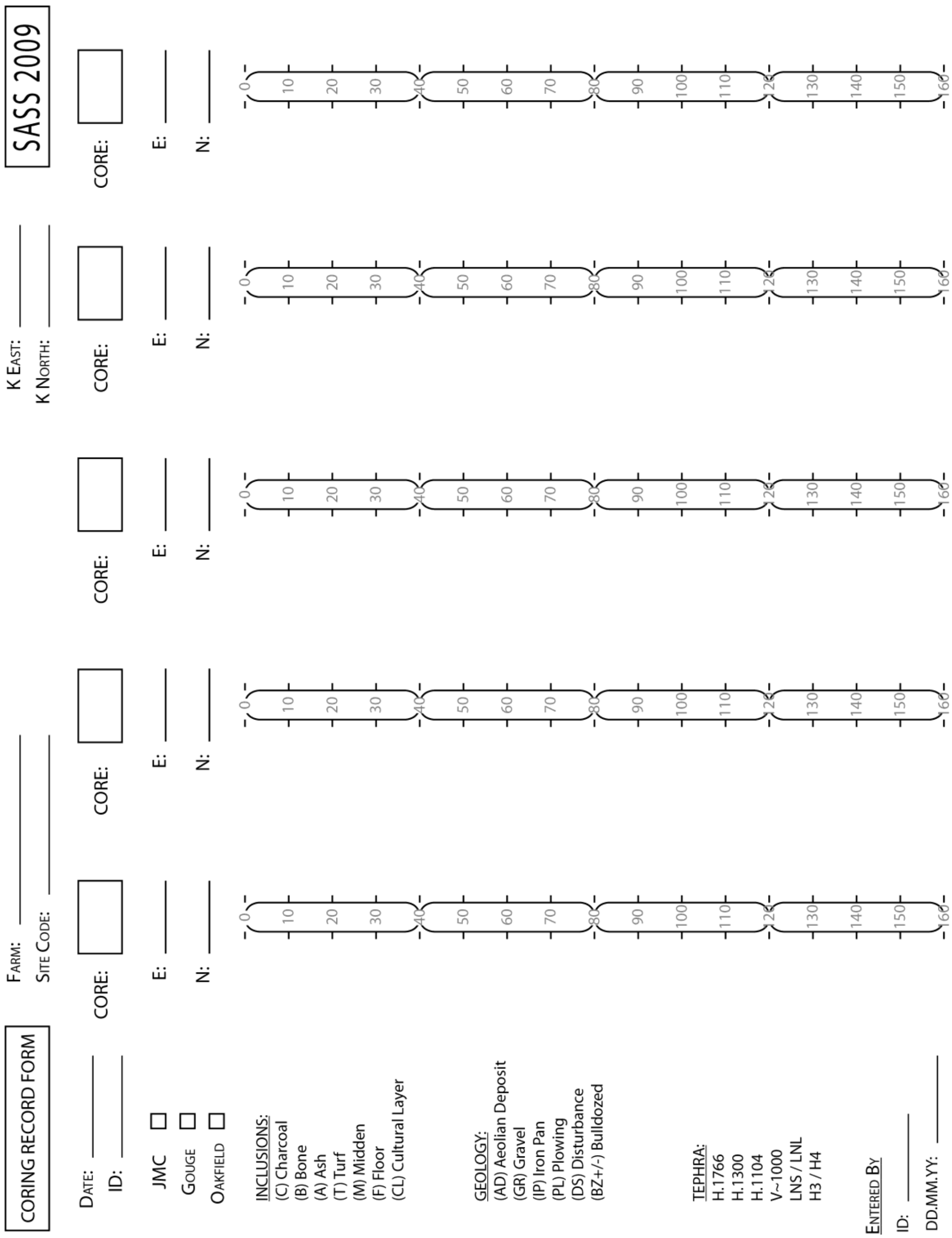
Farm+	Jónsbók ID	Date Established*	Distance to Nearest Neighbor (m)	Mound Size at 1104 (m^2)	Ábúðar**
Reynistaður	**63**	**882**	**9935**	**10243**	**84.5**
Geirmunðarstaðir	72	872	-	1364	33.2
Hafsteinsstaðir	71	929	1050	3021	28.1
Geitagerði	64	1300	566	-	10
Litla-Gröf	60	939	711	2962	14.2
Stóra-Gröf	61	937	1844	3532	39.4
Páfastaðir	59	1010	439	2402	17.6
Kjartansstaðir	57	977	1409	2271	14
Stóra-Seyla	**104**	**901**	**9182**	**7179**	**31.5**
Grófargil	89	1058	1257	1817	19.9
Glaumbær	**111**	**1007**	**680**	**6512**	**45.7**
Meðalheimur	**1006**	**918**	**1675**	**4596**	**-**
Halldórsstaðir	109	1052	869	1537	17.1
Hólar	249	1106	-	-	-
Marbæli	**115**	**915**	**1675**	**7052**	**22.8**
Geldingaholt	102	984	1332	4154	32.3
Torfgarður	106	1000	421	2064	5.1

+ Landlords at 1704 are grouped with their tenant farms.
*Approximate establishment dates are derived from tephrochronology and supported by radiocarbon. Geirmunðarstaðir, a very early farm technically located in Sæmundarhlið, is extrapolated from the sagas.
** *Ábúðar* (lease value), averaged values between 1882-1896. No data for Meðalheimur.
- Unknown or no data.

CHAPTER 2

METHODS

Soil cores can provide a great deal of information about the nature of buried landscapes and cultural remains at low cost and in a very short time. Coring is therefore employed as an early prospection tool in SASS's suite of remote sensing technologies. Core surveys are carried out on an approximate fifty-meter sampling grid with closer-spaced judgmental sampling near mounds and other cultural deposits, and all core locations are recorded with a differential GPS (Figure 2). The JMC backsaver cores employed in 2009 are used to extract soil columns at successive 40-cm depths until either the terminal H3 tephra layer or impenetrable glacial till is reached (Figure 1). Field forms (Figure 6) are used to record the depth and character of all subsurface strata including tephra layers. Tephra sequences observed in cores in association with cultural deposits suggest farm settlement dates and farm mound sizes at successive times though history, while unusually deep deposits suggest possible locations for buried structures and are flagged for potential remote sensing survey. Complete sequences guide placement of 1x1-meter test excavations to confirm settlement dates via tephrochronology and radiocarbon, and to extract samples for palaeoethnobotanical analysis (Steinberg 2001; Steinberg 2002; Steinberg 2007; Steinberg, Damiata et al. 2008; Steinberg 2009).


CORING RECORD FORM

FARM: ______
SITE CODE: ______

K EAST: ______
K NORTH: ______

SASS 2009

DATE: ______
ID: ______

JMC ☐
GOUGE ☐
OAKFIELD ☐

CORE: ☐ E: ______ N: ______
CORE: ☐ E: ______ N: ______
CORE: ☐ E: ______ N: ______
CORE: ☐ E: ______ N: ______
CORE: ☐ E: ______ N: ______

0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160

INCLUSIONS:
(C) Charcoal
(B) Bone
(A) Ash
(T) Turf
(M) Midden
(F) Floor
(CL) Cultural Layer

GEOLOGY:
(AD) Aeolian Deposit
(GR) Gravel
(IP) Iron Pan
(PL) Plowing
(DS) Disturbance
(BZ+/-) Bulldozed

TEPHRA:
H.1766
H.1300
H.1104
V~1000
LNS / LNL
H3 / H4

ENTERED BY
ID: ______
DD.MM.YY: ______

Figure 6. Coring Field Form
This version of the form was developed for the 2009 field season.

A total of 3265 cores across Skagafjörður, of which 1865 (60%) fit the selection criteria for the present analysis (Figure 3, Table 2), comprises a bulk sample size large enough to draw broad, generalized conclusions, by simplifying some of the complexities of multivariate settlement pattern analysis while recognizing the limitations of the data (e.g., Steinberg 1996). These selection criteria meant that only sixteen of the nineteen farms in the full settlement survey had coring data sufficient for inclusion in the present analysis. Because the aim of this research is environmental reconstruction, cores in the farm mounds were omitted from the study to avoid artificially inflating soil accumulation rates with anthropogenic trash deposition. Cores that contained layers of identifiably cultural turf or midden below the 1300 tephra layer were excluded from the sample for the same reason. In areas without such cultural deposits, progressively deeper cores should, on average, reflect proportionally lower past rates of erosion. Lower erosion rates means that tephra layers are unlikely to have been removed by wind or water, and so deeper cores should contain proportionately more tephra layers. The core selection criteria was therefore validated by plotting the number of historic tephra layers in a core against the mean total depth of cores in each group, for an R^2 of 0.938 (p=0.001).

Data from several other sources are correlated with the coring data to characterize the relationship between farm status and soil accumulation (Table 1). The area of the farm mound at 1104 was derived from the coring survey data by defining a polygon in GIS to encircle all cores near the mound that contain turf or midden below the 1104 tephra layer (Figure 3). These areas are used as a proxy for wealth; farms with large mounds supported large, internally stratified populations that required high rates of food

Table 2. Summary of Cores by Farm

Viking Age Farm / Modern Farm	Jónsbók ID	Total Cores	Omitted: Farm Mound	Omitted: Turf Pre-1300	Omitted: Other**	**Cores Studied**	Home-field Cores	Out-field Cores
Farms in the Study Area								
Geirmunðarstaðir	72	59	3	11	2	**43**	43	0
Geitagerði	64	43	0	0	1	**42**	7	35
Geldingaholt	102	59	29	5	0	**25**	25	0
Glaumbær	**111**	**191**	**86**	**5**	**0**	**100**	**152**	**35**
Jaðar*	**114**	**111**	**18**	**3**	**3**	**87**	-	-
Grófargil	89	55	3	0	2	**50**	28	22
Hafsteinsstaðir	71	71	6	1	2	**62**	31	31
Halldórsstaðir	109	35	12	3	1	**19**	8	11
Kjartansstaðir	57	139	22	33	0	**84**	25	59
Litla-Gröf	60	137	35	3	4	**95**	14	81
Marbæli	**115**	**188**	**29**	**13**	**0**	**146**	**20**	**126**
Meðalheimur	**1006**	**238**	**78**	**5**	**2**	**153**	**88**	**65**
Páfastaðir	59	250	42	14	9	**185**	49	136
Reynistaður	**63**	**348**	**17**	**3**	**5**	**323**	**241**	**165**
Hvammskot+	**1005**	**55**	**0**	**0**	**2**	**53**	-	-
Melur+	**1015**	**13**	**0**	**0**	**0**	**13**	-	-
Holtsmúli++	**62**	**33**	**16**	**0**	**0**	**17**	-	-
Stóra-Gröf	61	260	54	34	5	**167**	21	146
Stóra-Seyla	**104**	**179**	**62**	**4**	**1**	**112**	**75**	**37**
Torfgarður§	106	194	73	8	24	**89**	31	58
Totals		2658	585	145	63	**1865**	858	1007

Omitted Farms		
Syðra-Skörðugil§†	107	174
Ytra-Skörðugil†	108	17
Litla-Seyla‡	105	57
Hof¥	250	105
Hólar¥	249	111
Keldudalur¥	450	14
Melkot¥	1004	45
Steinsstaðir¥	167	42
Viðimýri¥	92	42
Total Cores		3265

** Other reasons for omission include missing data, modern landscape features such as driveways, and corrupted or questionable tephra sequences.

* Jaðar is located inside Glaumbær's historic homefield and split from its parent farm after the end of the study period.

+ Cores at Hvammskot and Melur were collected inside the historic homefield boundary of Reynistaður.

++ Cores at Holtsmúli are inside the mound or adjacent to Reynistaður's outfields.

§ Coring in 2005 (151 at Syðra-Skörðugil and 21 at Torfgarður) recorded only total depth and location data.

† Cores with data at Syðra- and Ytra-Skörðugil are all in the mounds.

‡ Litla-Seyla's historic homefield boundaries and farm mound have not been identified.

¥ Indicates farms located outside the study region.

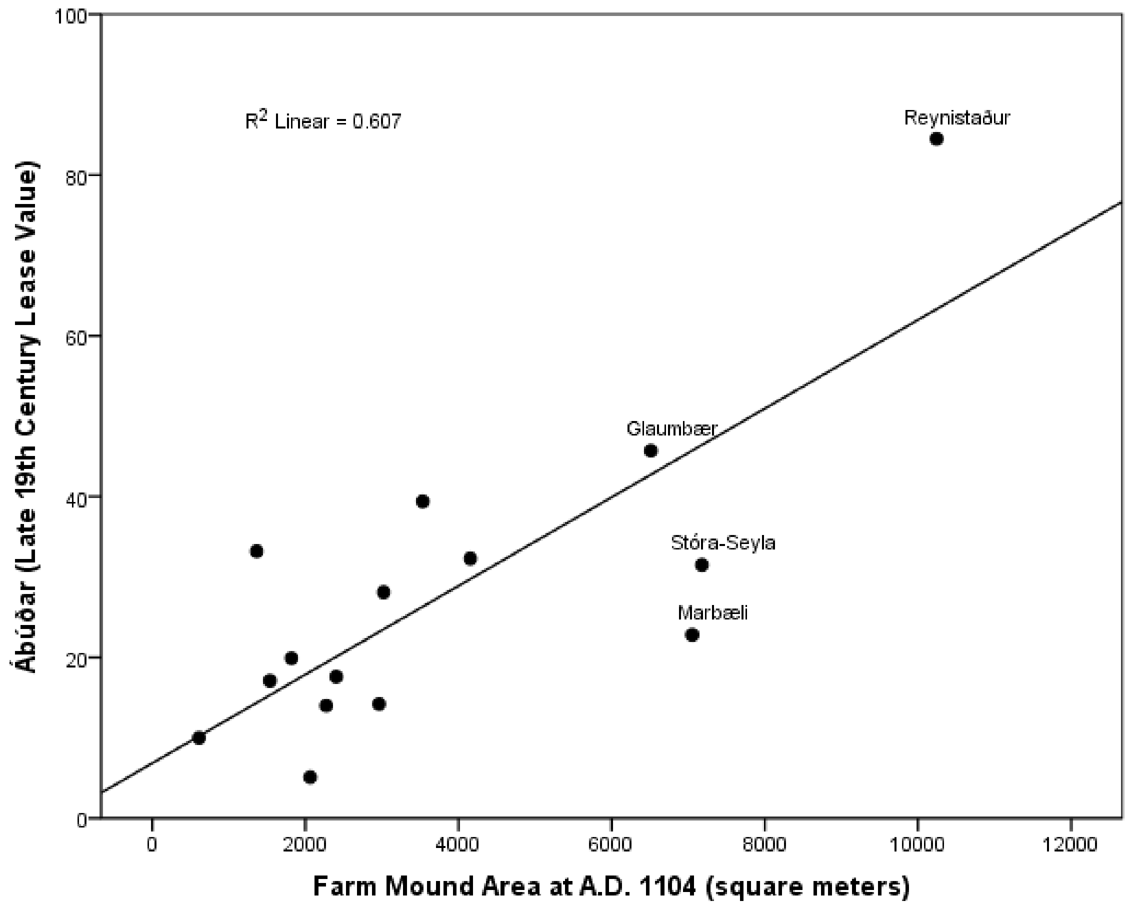


Figure 7. Farm Mound Area vs. Ábúðar
Farm mound area at 1104 is well correlated with 19th century valuations, indicating that there is continuity in farm status, and that mound size is a reasonable proxy for wealth. No data is available for Meðalheimur, which was abandoned by the 1880s-1890s when the records were collected.

production for support, and will tend to be higher on the social scale than farms with smaller populations and correspondingly smaller mounds. A correlation (R^2=0.607, p=0.002) between mound size at 1104 and 19th century property value (Figure 7) suggests a relationship between mound size and long-term farm productivity. Farm establishment date, derived from radiocarbon analysis and supported by tephrochronology, is used to characterize the advantages that accrue to the earliest settlers (Steinberg 2009; Damiata and Southton 2010). SASS's work has shown a direct relationship between settlement order, nearest neighbor distance, and mound size at 1104. Farms settled before ca. 930 tend to be much larger than later farms by several thousand square meters. Later farms are located much closer to their nearest neighbors, suggesting interdependent relationships (Figure 5, Figure 13, Table 1) (Bolender and Steinberg 2010; Steinberg, Bolender et al. [2011]). Additional information about the specific history of each farm is derived from the Danish census of 1702-1714 (Magnússon and Vídalín 1930), recent volumes describing the farm-by-farm history of Skagafjörður (Pálsson 2001; Pálsson 2004), and from the saga literature.

Detailed Field Methods

The main body of the JMC backsaver core, used during the 2009 season, consists of a polished stainless steel tube forty centimeters long and 1.5 inches in diameter. As the core is inserted into the ground, the sharpened base slices through the root mat and underlying layers, loosening a column of soil. Upon removing the core from the ground, the 40-centimeter soil column is available for inspection and documentation through the window that spans the length of the tube. Slicing lengthwise through the core with a clean knife or sharpened trowel edge allows for clear visual and tactile examination of the layered profile (Figure 1). The sides of the tube are notched every 10 cm, permitting easy determination of layer depth. The addition of extensions allows the core to penetrate as deep as 280 cm below ground surface if necessary, as it was in several of the farm mounds. Few of the cores examined for the present study required depth beyond 120 cm, the total depth the core can reach without extensions.

Between consecutive readings at a single point location, the core was cleared and a handful of grass placed into the hole. Because the motion of the core against the side walls tends to dislodge soil from higher layers, inserting a grass layer visually separates the new data from remnants of the higher (now removed) column, increasing the accuracy of measurements below 40 cm. The local andosols are not generally susceptible to measurement error caused by soil compression, although in deep cores where the soils are boggy, up to 20 cm of compression has been observed.

Core locations were recorded with a Trimble GeoXH differential GPS receiver in ISNET93 coordinates to sub-decimeter post-processed accuracy. Elevations were recorded to sub-meter accuracy during the 2009 season, but are not always available for previous years. ISNET (Icelandic Land Survey Network), the national Icelandic geodetic coordinate system, uses a network of ground stations around the nation's perimeter to accurately account for the horizontal change of several centimeters each year as the North Atlantic Rift widens the middle of the island, ensuring that our point locations are reproducible year-to-year. Locations recorded in UTM coordinates for the first few field seasons were subsequently converted to ISNET.

In addition to depth of tephra, the depth and thickness of other soil strata were also recorded. These included root mat/plow zone, aeolian deposit, clay, gley, sand, gravel, iron pan, and bog/natural turf, as well as cultural strata including midden, low density cultural deposits, floors, and cultural turf (Figure 6, Figure 8). Cultural turf is distinguished from natural turf by color, texture, moisture, and out of order tephra sequences. Inclusions such as charcoal, peat ash, and diatoms were noted, along with any observed disturbances, ranging from bulldozing to cryoturbation.

Core survey strategies were developed to best support the goals of each individual field season between 2001 and 2010. While earlier surveys concentrated in localized areas near mounds and homefields, the 2009 survey also covered a near-continuous 4-by-0.5 km strip through five farms in the north and a full-landscape survey of two other major farms (Reynistaður and Meðalheimur) (Figure 2) (Steinberg 2009). The large number of people involved in the field survey inevitably comprised a wide range of recording techniques (from precisely descriptive to highly interpretive), sampling strategies, skill levels, and even equipment: data collected with backsaver cores, Oakfield peat cores, hand augers, and electric augers were all included in the analysis (Steinberg 2001; Steinberg 2002; Steinberg 2007; Steinberg, Damiata et al. 2008; Steinberg 2009). To pull together the data from so many disparate surveys, the variations in collection were reconciled into a common scheme to develop a single large database of low-precision, low-accuracy data at very high resolution. Descriptive colors and textures from previous years were interpreted into the 2009 categories: for example, "brown loam" was reinterpreted as "aeolian deposit." A large enough sample size, which 1865 cores comprises, can overcome these limitations to suggest meaningful trends.

Simulating Tephra Isochrons

Complete tephra sequences in cores are the exception rather than the rule in an agricultural landscape such as Langholt, which has been actively modified by humans and animals over the last 1100 years as well as subject to natural processes including aeolian sedimentation, erosion, cryoturbation, and other soil formation processes. The most common tephra layer, 1104 (H1), occurred in 616 (33%) of the 1865 cores, while the 1000 layer was observed in only 85 cores (4.5%) (Table 3). Only 25 cores, or 1.3%, contained both any member of the *landnám* sequence *and* the 1000 tephra, and nine of the sixteen farms contained no such cores at all. Characterizing soil accumulation during the 10th century on the basis of such a small or nonexistent sample size is infeasible. This posed a serious problem for estimating soil accumulation rates on a landscape scale.

In the absence of other temporal markers in the core stratigraphy, an interpolation algorithm was developed to simulate isochron depths for the 1300, 1104, 1000, and *landnám* tephra layers for each core in the study that lacked those layers (Table 4). The depth of each core is measured from ground surface to the H3 tephra layer or (in absence of H3 or H4) to the underlying gravelly glacial moraine or bedrock. The depth of each existing tephra layer is measured from the ground surface, and the distance between all existing tephra layers is calculated by subtracting their respective depths. Each of these depths and distances is expressed as a percentage of the total core depth, and the average of these percentages is calculated among all the cores for which the tephra layers in question exist. The depth of a missing tephra layer can then be simulated by calculating its expected position with respect to the depth of the existing tephra layers that bound it.

Table 3. Summary of Tephra by Farm

Farm Name	ID	Cores Studied	Tephra Incidence													
			Hekla 1766		Hekla 1300		Hekla 1104 (H1)		Grimsvotn Vj~1000		Landnám Sequence		Hekla H3		Hekla H4	
			Count	%	Count	%	Count	%	Count	%	Count	%	Count	%	Count	%
Kjartansstaðir	57	84	6	7.1	8	9.5	36	42.9	3	3.6	20	23.8	38	45.2	28	33.3
Páfastaðir	59	185	14	7.6	23	12.4	62	33.5	7	3.8	56	30.3	88	47.6	48	25.9
Litla-Gröf	60	95	5	5.3	7	7.4	24	25.3	2	2.1	3	3.2	28	29.5	15	15.8
Stóra-Gröf	61	167	15	9.0	17	10.2	42	25.1	5	3.0	13	7.8	49	29.3	31	18.6
Reynistaður	63	406	60	14.8	73	18.0	174	42.9	24	5.9	37	9.1	88	21.7	22	5.4
Geitagerði	64	42	0	0.0	6	14.3	18	42.9	1	2.4	0	0.0	14	33.3	0	0.0
Hafsteinsstaðir	71	62	7	11.3	13	21.0	16	25.8	0	0.0	0	0.0	4	6.5	0	0.0
Geirmunðarstaðir	72	43	0	0.0	7	16.3	15	34.9	3	7.0	0	0.0	15	34.9	0	0.0
Grófargil	89	50	1	2.0	4	8.0	7	14.0	1	2.0	1	2.0	11	22.0	2	4.0
Geldingaholt	102	25	3	12.0	8	32.0	17	68.0	6	24.0	6	24.0	15	60.0	6	24.0
Stóra-Seyla	104	112	7	6.3	8	7.1	17	15.2	3	2.7	1	0.9	23	20.5	2	1.8
Torfgarður	106	89	5	5.6	10	11.2	19	21.3	1	1.1	4	4.5	24	27.0	5	5.6
Halldórsstaðir	109	19	0	0.0	1	5.3	1	5.3	0	0.0	0	0.0	5	26.3	0	0.0
Glaumbær	111	187	6	3.2	23	12.3	70	37.4	11	5.9	18	9.6	95	50.8	29	15.5
Marbæli	115	146	6	4.1	14	9.6	38	26.0	2	1.4	21	14.4	63	43.2	42	28.8
Meðalheimur	1006	153	46	30.1	47	30.7	60	39.2	16	10.5	24	15.7	54	35.3	27	17.6

For example, to calculate the expected depth of the 1000 layer in a core for which both the 1104 and *landnám* layers are present, the average distance between *landnám* and 1000 expressed as a percentage of the average distance between *landnám* and 1104 (that is, the ratio of the average percentages of distances between *landnám* to 1000 and *landnám* to 1104) is multiplied by the observed distance between *landnám* and 1104, and the calculated distance from *landnám* to 1000 is subtracted from the observed depth of the *landnám* layer to arrive at a simulated depth for the 1000 layer. In this manner simulated isochron depths can be calculated for any core, regardless of the number and distribution of extant layers. When no tephra layers are present, simulated layers are placed with respect to the total depth of the core. Simulated distances between tephra layers tend to be smaller than observed distances ($3.5 < t < 12.8$, $p < 0.001$), because cores that lack layers are on average shorter (R^2=0.938, p<0.001).

This method therefore implicitly allows erosion to be modeled as soil loss where tephra layers have been removed, though only as part of the constant background levels of aeolian deposition and erosion. Momentary erosion events cannot be modeled, though their effects will be averaged over the years for which tephra layers are lacking. The power of this method lies in its ability to extract specificity from generalizations: landscape-scale averages allow simulations to be generated at the appropriate temporal depth, while the unique structure of each individual core preserves its particular erosional environment with respect to the isochrons. The general homogeneity of Langholt supports this strategy, although the results of the analysis suggest that subregional average depths might increase the fidelity of the simulation.

To validate the algorithm, its predictions were tested against the actual depth of tephra layers for cases in which two sequential layers are present. The average (absolute) error is 7.4 cm with a standard deviation of 8.2 cm and median 4.7 cm. These errors are large when considered against the expected human error range of 2 cm when reading depths from the core. The average total error (not absolute value) is -0.4 cm with a standard deviation of 11 cm and median 0.16 cm. The implication here is that in terms of the aggregate values with which we are ultimately concerned, positive and negative errors in reporting and calculating will tend to cancel one another out. Errors of up to 0.5 cm in tephra depth result in errors of less than 0.05 mm/year in accumulation rate during the Viking Age, or 10%. In short, the range of error in observing, recording, and calculating tephra depths leads to potentially large errors in estimating accumulation rates. However, these errors apply to all farms, and the unambiguous trends visible in the median values inspire confidence that while errors may shift the numerical values, they will not significantly alter the ultimate conclusions that can be drawn from the data.

The median accumulation rate at each farm during each time period, incorporating both simulated and observed values, is therefore characteristic and representative of the microenvironments that comprise the landscape of the farm. Comparing the data from each individual farm rather than lumping them into groups elides some of the biases that result from the inconsistencies in sampling strategies employed. To estimate a fairly continuous profile of accumulation change over time, sufficient to draw some conclusions about very broad trends and correlations, median rates are taken to correspond to the midpoint of their associated date range: i.e., the rate shown in Figure 9 and Figure 10 for A.D. 1202 reflects the calculated accumulation rate between the 1104 and 1300 tephra layers. Figure 8 shows cores near the median depth for each of the five major farms, including both real and simulated isochrons. Table 4 summarizes the calculated and observed heights above end-of-core for each tephra layer by farm, while Table 5 summarizes the accumulation rates.

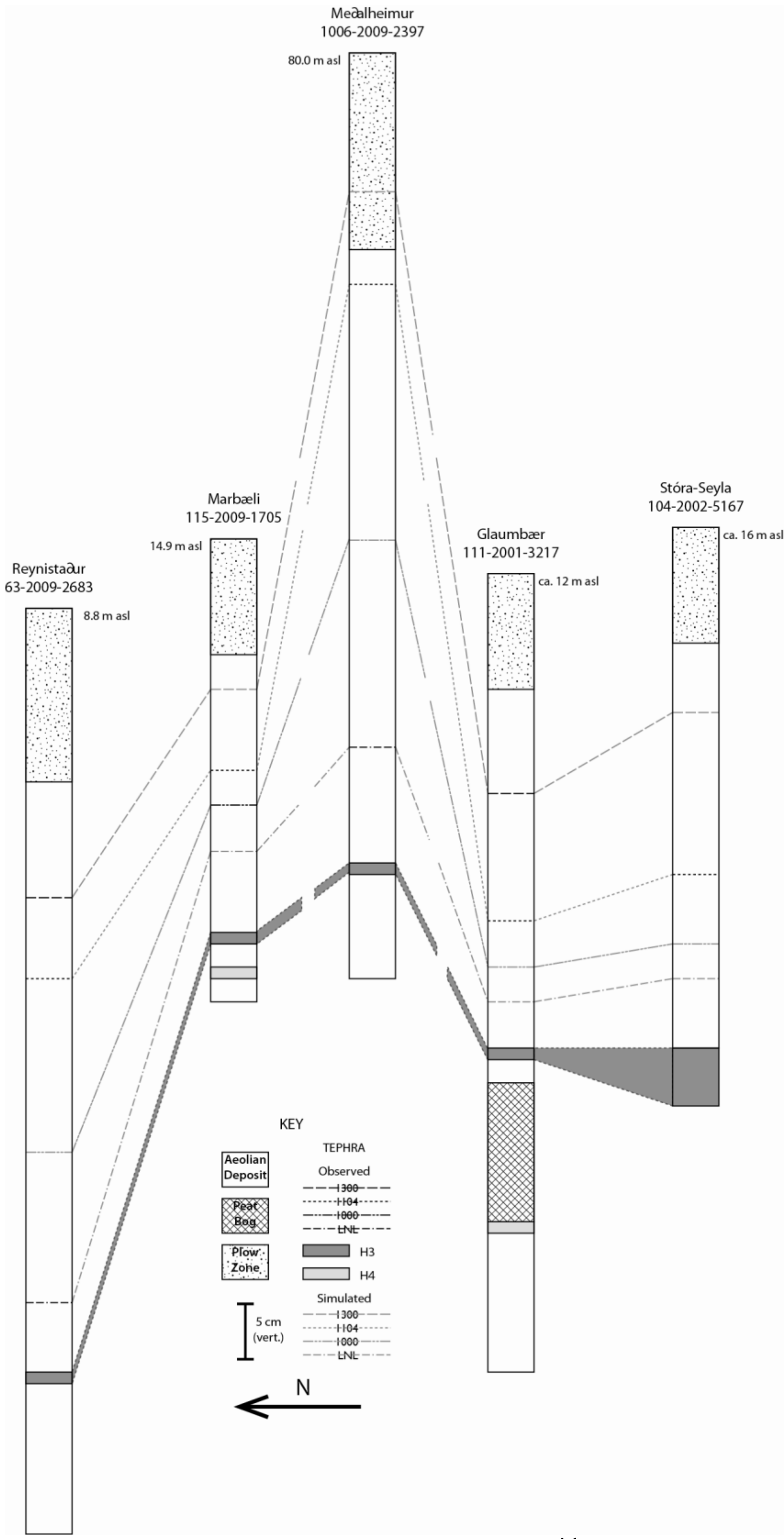


Figure 8. Core Structure Diagram Cores near the median depths at Reynistaður, Marbæli, Meðalheimur, Glaumbær, and Stóra-Seyla. Simulated tephra isochrons are shown in light grey. Except for Meðalheimur, relative elevations are to scale 0.01x that of the cores. Core depth is measured to H3.

Table 4. Statistics for Observed and Simulated Tephra Isochrons
Heights above base of core are given in centimeters. *Continued on next two pages.*

		Height of 1300		Height of 1104		Height of 1000		Height of Landnám layer	
	Core Depth	Observed	Simulated	Observed	Simulated	Observed	Simulated	Observed	Simulated
Geirmunðarstaðir									
N	43	7	43	15	43	3	43	-	43
Minimum	7	10	3.715	2	2	13	1.236	-	0.806
Median	48	35	28.553	19	19	19	13.601	-	9.245
Maximum	93	51	53.568	39	39	32	32	-	21.279
Std. Dev.	21.217	12.526	12.165	10.224	9.791	9.713	7.874	-	5.373
Geitagerði									
N	42	6	41	18	41	1	41	-	41
Minimum	0*	17	2.654	12	2.061	20	1.685	-	1.156
Median	45	32	26.461	22	16.491	20	11.796	-	8.089
Maximum	100	34	63.172	55	55	20	34.002	-	23.112
Std. Dev.	25.909	6.380	15.776	12.385	12.964	-	9.144	-	6.154
Geldingaholt									
N	25	8	25	17	25	6	25	6	25
Minimum	20	5	5	9	3.033	6	2.212	5	1.533
Median	55	26	28.725	23	22	15	14.341	8.50	9.245
Maximum	85	45	53.172	45	45	27	38.212	35	35
Std. Dev.	15.670	12.444	13.915	12.408	12.692	8.118	9.391	11.448	7.543
Glaumbær									
N	187	23	187	70	187	11	187	18	187
Minimum	10	0	0	0	0	0	0	1	0
Median	42	20	23.883	17.50	17.316	13	13.481	9.50	9
Maximum	120	45	70.330	65	65	32	40.444	26	27.734
Std. Dev.	16.601	11.415	11.543	12.796	10.062	10.734	7.515	6.488	5.266
Grófargil									
N	50	4	48	7	48	1	48	1	48
Minimum	0	20	2.654	6	2.061	25	1.685	17	1.156
Median	40	44	21.229	18.00	16.491	25	13.313	17	8.866
Maximum	100	60	60	27	41.227	25	33.703	17	23.112
Std. Dev.	21.887	16.990	12.611	7.829	9.264	-	7.205	-	5.074
Hafsteinsstaðir									
N	62	13	62	16	62	-	62	-	62
Minimum	20	8	8	5	4.852	-	3.091	-	2.015
Median	50	33	25.738	19	17	-	13.126	-	8.665
Maximum	90	69	69	53	53	-	32.765	-	21.360
Std. Dev.	13.660	16.586	10.497	11.695	7.702	-	5.301	-	3.609
Halldórsstaðir									
N	19	1	19	1	19	-	19	-	19
Minimum	10	8	5.307	13	4.123	-	3.370	-	2.311
Median	48	8	25.475	13	19.789	-	16.177	-	11.094
Maximum	76	8	40.336	13	31.333	-	25.614	-	17.565
Std. Dev.	19.709	-	11.184	.	8.937	-	7.473	-	5.138

Kjartansstaðir									
N	84	8	83	36	83	3	83	20	83
Minimum	0	14	7.961	7	6.184	15	4.327	5	2.821
Median	42	29.50	24.106	24	17.316	26	13.481	14	9.245
Maximum	180	40	95.532	66	74.209	31	60.665	47	47
Std. Dev.	27.518	9.620	16.151	13.515	13.151	8.185	10.401	10.886	8.410
Litla-Gröf									
N	95	7	94	24	94	2	94	3	94.000
Minimum	0	5	2.654	5	2.061	22	1.685	10	1.156
Median	35	36	19.106	26	14.430	23.50	11.796	20	8.089
Maximum	120	47	79.212	65	65.000	25	50.918	50	50
Std. Dev.	25.167	14.081	16.983	17.429	13.547	2.121	9.360	20.817	6.998
Marbæli									
N	146	14	145	38	145	2	145	21	145
Minimum	0	2	2	3	1.213	7	0.885	4	0.613
Median	35	19	17.593	17.50	13.605	9	10.111	10	6.934
Maximum	100	83	83	60	60	11	41.058	25	25
Std. Dev.	20.026	20.971	12.847	13.139	10.235	2.828	7.355	5.864	5.045
Meðalheimur									
N	153	47	153	60	153	16	153	24	153
Minimum	10	5	3.431	5	2.222	0	0	2	0
Median	70	57	40	25	24.736	30.50	18.537	13.50	11.704
Maximum	170	105	105	91	91	85	85	71	71
Std. Dev.	31.717	27.179	24.024	20.360	17.527	22.349	13.270	16.987	10.222
Páfastaðir									
N	185	23	180	62	180	7	180	56	180
Minimum	0	10	4.777	0	0	5	0	0	0
Median	40	25	23.883	22	16.491	13	12.904	9.50	8.551
Maximum	120	64	100.659	90	90	37	55.639	45	45
Std. Dev.	21.539	17.749	15.295	16.615	12.908	11.611	9.380	10.026	7.269
Reynistaður									
N	406	73	403	174	403	24	403	37	403
Minimum	0	0	0	0	0	0	0	0	0
Median	67	45	39.119	32.50	25.561	29.50	19.783	10	12.270
Maximum	240	143	156.806	133	133	110	110	70	73.146
Std. Dev.	35.689	30.917	25.289	25.825	21.130	25.595	15.513	18.114	11.059
Stóra-Gröf									
N	167	17	160	42	160	5	160	13	160
Minimum	0	6	1.061	0	0	5	0	0	0
Median	40	32	21.229	19.50	15.082	19	11.796	13	8.089
Maximum	160	86	119.384	97	97	28	59.967	32	39.092
Std. Dev.	30.523	22.131	19.564	22.602	15.828	10.644	10.360	8.278	6.931
Stóra-Seyla									
N	112	8	112	17	112	3	112	1	112
Minimum	6	8	3.184	3	2.474	4	1.855	15	1.133
Median	44.50	25	23.087	15	16.491	22	13.481	15	9.245
Maximum	130	63	111.949	102	102	25	38.329	15	24.987
Std. Dev.	21.580	19.272	15.594	25.683	13.002	11.358	7.736	-	5.279

Torfgarður									
N	89	10	89	19	89	1	89	4	89
Minimum	8	3	3	3	1.820	23	1.327	2	0.920
Median	50	19	26.537	15	18.965	23	14.155	9	9.707
Maximum	100	62	65.330	60	60	23	37.093	20	24.181
Std. Dev.	22.887	18.135	13.573	14.753	10.830	.	8.242	8.124	5.692
Total									
N	1865	269	1844	616	1844	85	1844	204	1844
Minimum	0	0	0	0	0	0	0	0	0
Median	48	34	26.537	22	18	22	13	11	9.245
Maximum	240	143	156.806	133	133	110	110	71	73.146
Std. Dev.	29.497	25.956	19.935	20.458	15.886	19.670	11.478	12.753	8.219

*A minimum height of 0 means the tephra layer corresponded to the final depth of the core in at least one core on that farm.

Table 5. Median Core Depth and Soil Accumulation Rate

Farm Name	Jónsbók ID	Cores Studied	Median Core Depth (cm)	Median Accumulation Rate (mm/year)					
				H3 to 872	872 to 1000	872 to 1104	1000 to 1104	1104 to 1300	1300 to 2000
Kjartansstaðir	57	84	42	0.049	0.331	0.326	0.346	0.308	0.258
Páfastaðir	59	185	40	0.044	0.331	0.312	0.326	0.272	0.268
Litla-Gröf	60	95	35	0.043	0.290	0.273	0.253	0.224	0.235
Stóra-Gröf	61	167	40	0.043	0.290	0.312	0.289	0.242	0.235
Reynistaður	**63**	**406**	**67**	**0.066**	**0.496**	**0.523**	**0.579**	**0.477**	**0.355**
Geitagerði	64	42	45	0.042	0.313	0.360	0.477	0.384	0.232
Hafsteinsstaðir	71	62	50	0.046	0.345	0.363	0.362	0.302	0.280
Geirmunðarstaðir	72	43	48	0.049	0.356	0.414	0.404	0.423	0.302
Grófargil	89	50	40	0.045	0.296	0.308	0.289	0.242	0.253
Geldingaholt	102	25	55	0.049	0.420	0.437	0.481	0.399	0.304
Stóra-Seyla	**104**	**112**	**44.5**	**0.049**	**0.331**	**0.340**	**0.344**	**0.302**	**0.298**
Torfgarður	106	89	50	0.052	0.364	0.390	0.362	0.314	0.335
Halldórsstaðir	109	19	48	0.059	0.397	0.375	0.405	0.338	0.375
Glaumbær	**111**	**187**	**42**	**0.048**	**0.331**	**0.351**	**0.362**	**0.308**	**0.268**
Marbæli	**115**	**146**	**35**	**0.037**	**0.248**	**0.250**	**0.253**	**0.212**	**0.221**
Meðalheimur	**1006**	**153**	**70**	**0.063**	**0.455**	**0.515**	**0.551**	**0.544**	**0.429**

CHAPTER 3

RESULTS

Median soil accumulation rates exhibit several distinct trends over time. The first is an initial fluctuation in soil accumulation rates, followed by a slight but generally stable decline during the 11th century (Figure 9). The second clear trend in the data is an exaggeration of preexisting landscape differences (Figure 10). The dramatic increase followed by stabilization of absolute soil accumulation rates is thus mirrored by an equally dramatic increase and stabilization of the *difference* in soil accumulation rates between farms. Taking soil accumulation rate as a proxy for land quality, this means that the most productive farm at *landnám* becomes even more productive through the Viking Age, and the least productive farm, while it may experience an absolute increase, appears poorer in comparison. As soil accumulation rates stabilize, these differences become fixed, and may be mobilized in the form of rent. Inherent local soil properties are therefore important for the long-term productivity of the farm and the wealth and status of its inhabitants in the social hierarchy of the region. Dynamic soil properties – i.e., land management – are not explicitly detectable, but if present, they do not appear to alter the overall inherent spatial order of the region.

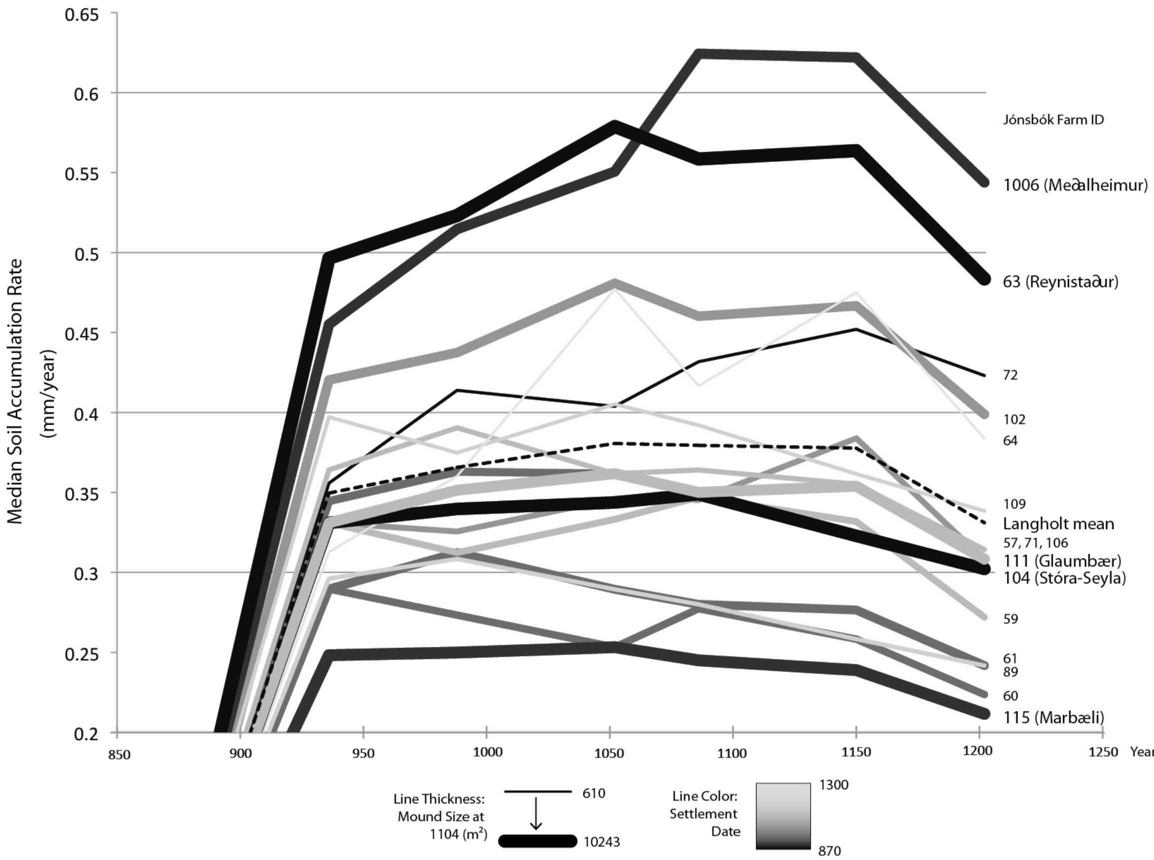


Figure 9. Median Soil Accumulation Rates

Rates are shown at the midpoint of their calculated date range; i.e., the data points at 1150 reflect the median rate for each farm between 1000-1300, and the points at 936 reflect median rates between 872-1000. The dotted line shows the average of all median rates. Accumulation rates are variable and rising until the mid-11th century, after which rates are more stable and declining. The major farms addressed in the text are labeled; for farm ID number correspondences, see Table 1.

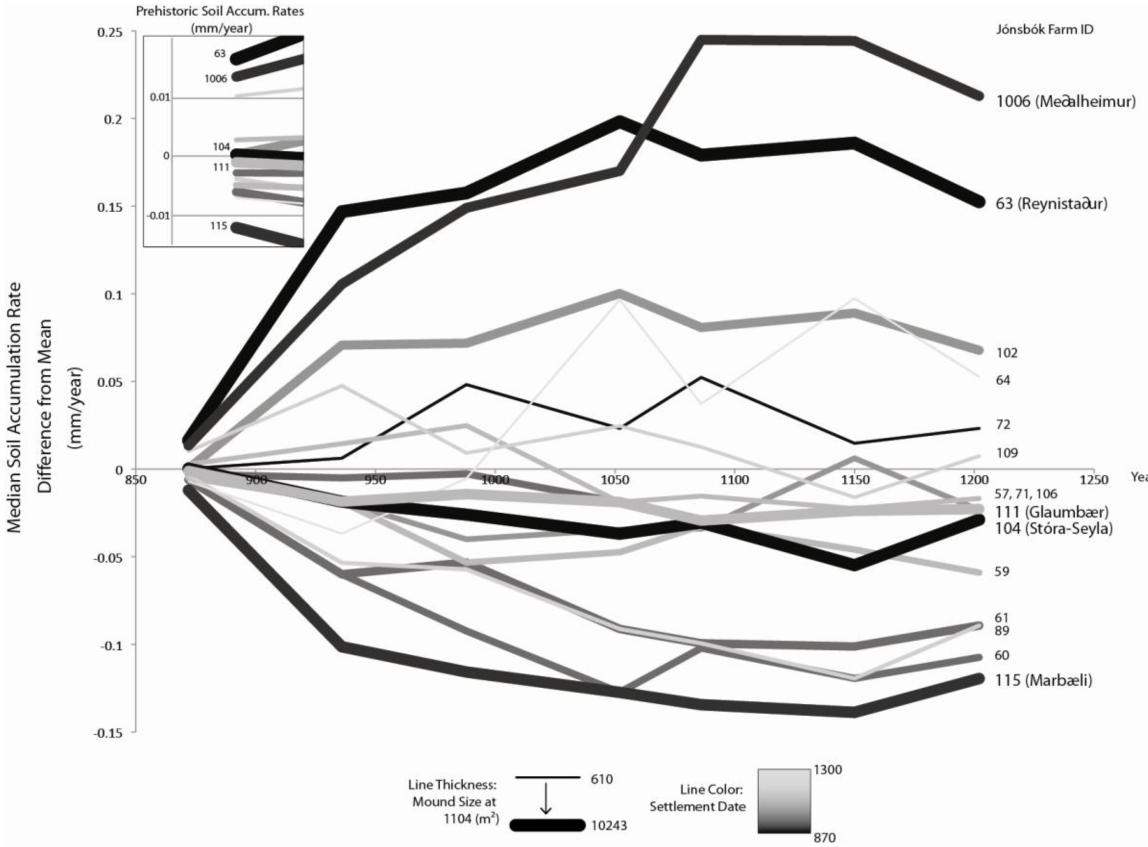


Figure 10. Relative Median Soil Accumulation Rates

Rates are shown relative to the average (dotted line in Figure 9). Differences in accumulation rate, interpreted as proxies for relative productivity (rent), are unstable and rising until the mid-11th century, at which point they become relatively stable. Stabilization of rents sets the stage for institutionalization of tenancies and social stratification based in rent-seeking. The inset plot is a large-scale view of relative soil accumulation rates at *landnám*: rate-ranks are persistent through time.

Before *landnám*, the landscape of Langholt accumulated soil at a rate of about half a millimeter every decade. Accumulation rates increased after settlement by an order of magnitude, a response to skyrocketing erosion rates from the highlands as deforestation, cultivation, and grazing played havoc with environmental conditions. The increase in accumulation rates was not uniform throughout the region but responded proportionally to small variations in the prehistoric accumulation rate, such that the landscape at 1300 had become an exaggeration of the conditions at *landnám* (R^2=0.74, p=0.0; Figure 9, Figure 10, Figure 11, Figure 12). Differences in median accumulation rate between neighboring farmsteads increased from millimeters to tens of centimeters every century, escalating pre-existing, long-term differential trends.

Settlement order and mound size are not well correlated with soil accumulation rate (R^2=0.075, p=0.315 for mound area vs. rate from 872 to 1104; Figure 9, Figure 10, Figure 13). Higher soil accumulation rates occur on farms clustered in the north and at the center of the region (Figure 12, Figure 13), and there is furthermore no consistent correlation within the northern, middle, and southern subregions or within *hreppar* between soil accumulation rate and establishment date or mound size (R^2<0.5 in the north, <0.1 in the middle and south, p>0.1 in all cases). This implies that the spatial order of land quality, whether or not it was apparent during the settlement, was not as important as other factors in selecting or allocating farmstead locations.

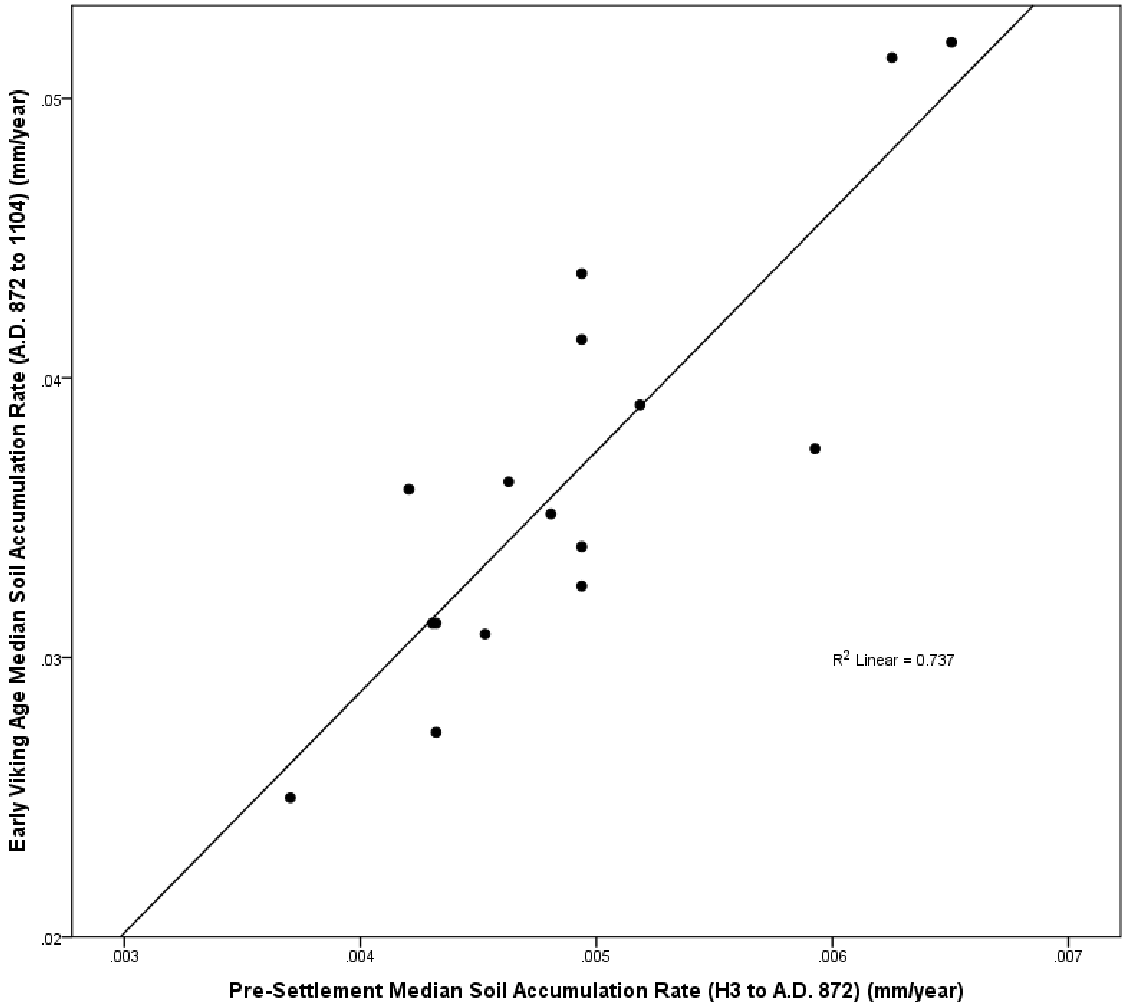


Figure 11. Pre-Settlement vs. Early Viking Age Soil Accumulation Rates

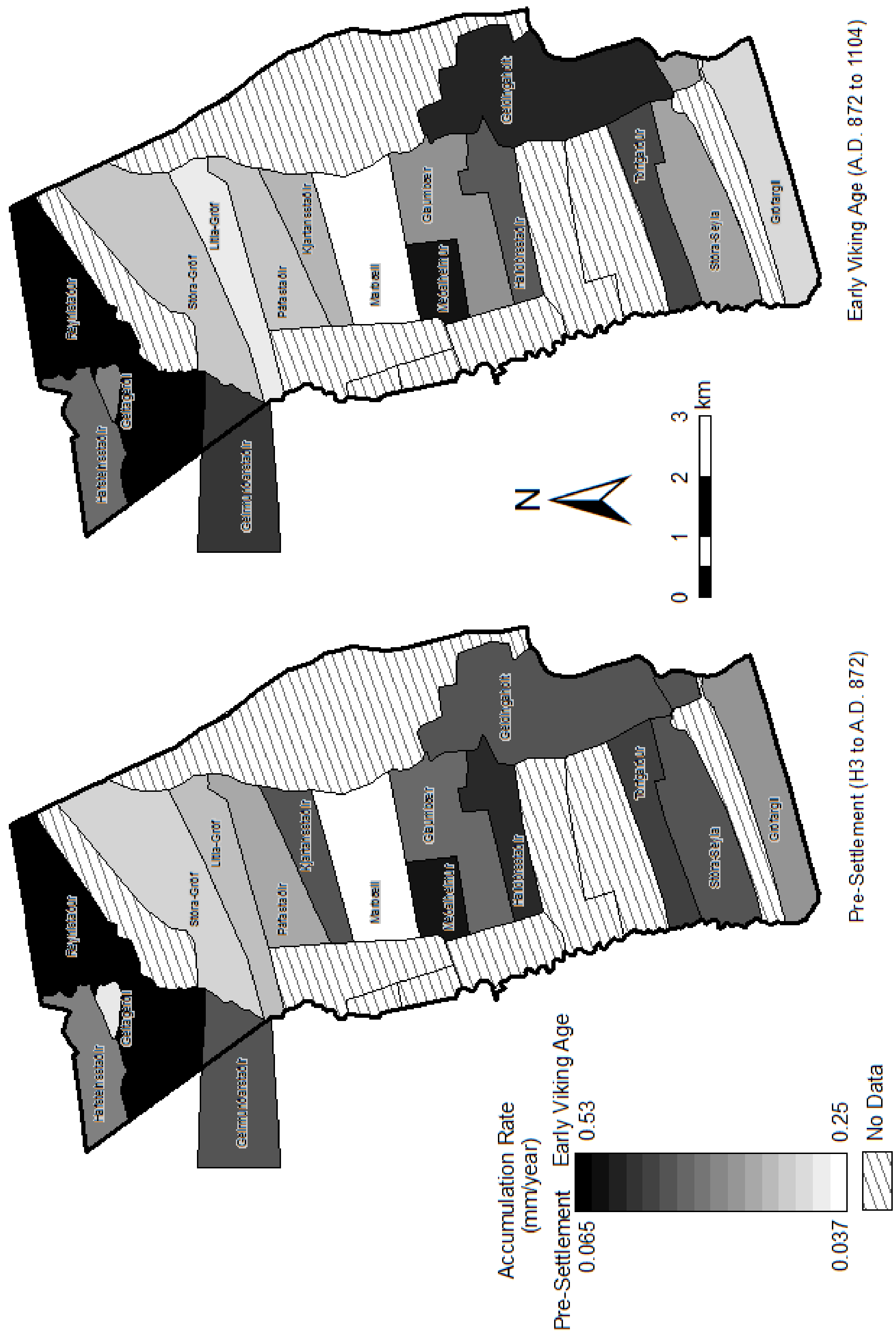


Figure 12. Spatial Distribution of Pre-Settlement and Early Viking Age Soil Accumulation Rates
Subregional spatial clustering of high and low accumulation rates is temporally persistent.

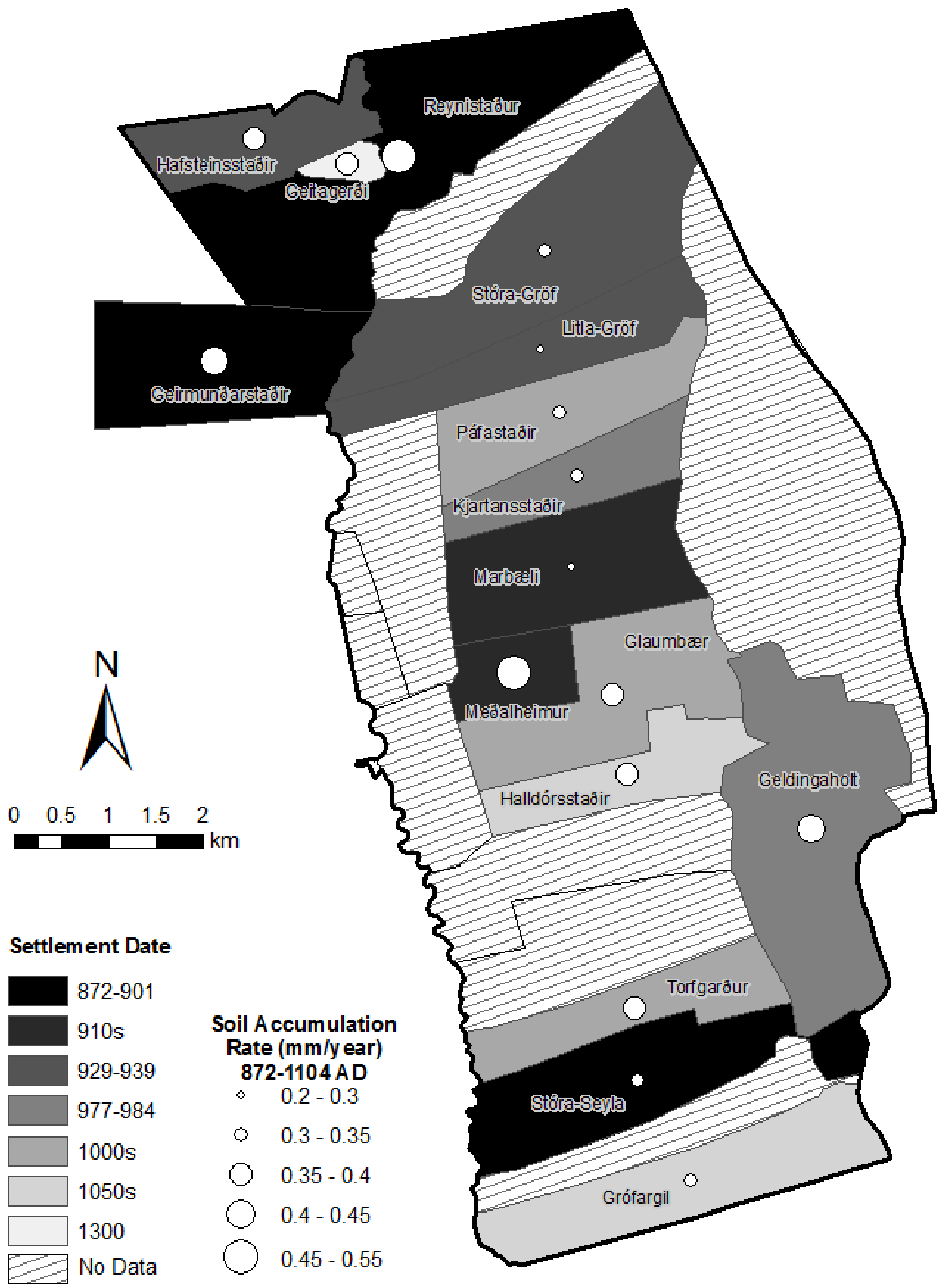


Figure 13. Map of Soil Accumulation Rate and Settlement Date

The ends and the middle of the region were settled first, then smaller farms filled the rest of the region. High accumulation rates cluster near the north and center.

A comparison between the slopes of the lines in Figure 9 and Figure 10 reveals changing environmental trends that begin to stabilize ca. 1000 and are set in place by 1100. After the massive *landnám* increase, absolute soil accumulation rates experience initial stability or slight increases on individual farms, followed by a universal downward trend in accumulation that begins in the 11th century and continues with some fluctuations to the end of the Viking Age, especially on the five largest farms (labeled) (Figure 9). Relative accumulation rates display an initial fluctuating increase followed by relatively level stability after the mid-11th century (Figure 10).

The upsurge in absolute soil accumulation rates accompanied by fluctuations in relative rates over the first century and a half of settlement suggests that early environmental changes were turbulent and localized, as the landscape of each farm responded individually to the unfamiliar stresses of agricultural production. During these years, fluctuations in both charts represent local environmental volatility, masking any regional trends. As the environment of the inhabited landscape slowly stabilized, settling into the cycles of agricultural production, local changes are no longer so evident, and the consequences of comprehensive and systematic environmental degradation become increasingly apparent. When these large-scale regional trends became the dominant source of landscape change, median farm accumulation rates ceased to vary much with respect to the regional mean, and the difference in accumulation rates between farms remained relatively stable. At the same time, the mean accumulation rate across the region was slightly decreasing: the accelerated process of deforestation and overgrazing had largely ceased, such that the erosion from the highlands was reaching a stable maximum of aeolian-andic deposition across the lowlands of Skagafjörður as existing erosion fronts moved steadily downslope. It is furthermore worth noting that these trends, both the initial post-*landnám* fluctuating increase and the beginnings of stabilization in the 11th century, predate the onset of the Little Ice Age (ca. 1425) by nearly half a millennium (Dugmore, Borthwick et al. 2007).

These findings are consistent with results from other studies around Iceland that have used soil accumulation rates and palaeoethnobotanical analyses to show that the *landnám* accelerated environmental changes that were already in motion during the 9th century and earlier, and that erosion rates and soil properties are highly sensitive to variations in local and microenvironmental landscape conditions (Dugmore, Newton et al. 2000; Simpson, Adderley et al. 2002; Dugmore, Church et al. 2005; McGovern et al. 2007; Dugmore, Gísladóttir et al. 2009; Trigg, Bolender, Catlin et al. 2009; Arnalds 2010). Trends of initial variable, localized impacts followed by widespread regional change have been observed at Mývatnssveit (McGovern et al. 2007; Adderley et al. 2008). Dugmore, Church et al. (2005) argue convincingly that *landnám* changed the process of sediment accumulation, the dominant source becoming aeolian redistribution and reworking of extant soils rather than glacial erosion and primary tephra fall. On Langholt, a change in accumulation processes does not appear to have altered accumulation pathways. Subtle patterns of soil accumulation are inherent, persistent, and increasingly apparent over time.

CHAPTER 4

DISCUSSION

The inhabited landscape has been described as a "social map, or physical contract" (Earle 1998:95) that manifests and inscribes property rights and social hierarchies. Soil accumulation rates, as a proxy for land quality and productivity (Thompson et al. 1990; Pennock 1997; Sigfusson, Gislason et al. 2008; Arnalds 2010), can make visible these buried social landscapes of the past. Inferred changes in relative productivity across the landscape of Langholt through the Viking Age imply that the basis of the emerging political economy and inter-household social stratification ultimately lies in differential access to scarce resources (Ricardo 1817; Gilman 1995; Hunt 1998). Multiple strategies are available for negotiating access to these resources, and by correlating differences in productivity with differences in farm size, establishment date, specific histories, and known or inferred relationships between farms, we can propose whether the origin of differential wealth and social stratification lies in obtaining control over productive land through primacy, intensified production, or exploitative rent-seeking. In fact, this approach suggests that all of these mechanisms were at play, and that each of them may have been dominant at successive phases of the settlement sequence.

Reynistaður

Reynistaður ("farm on the rowan tree headland", Jónsbók ID 63 (Johnsen 1847)) was settled by the late ninth century, making it the oldest farm on Langholt, and its mound size at 1104 is by far the largest at over ten thousand square meters, larger than Seyla by more than a third (Figure 2, Figure 4, Figure 5, Figure 13, Table 1). Its location at the northern end of the region, with low-lying, level fields between the Reynistaðará river (the northern section of the Sæmundará) and the small hills that bound this end of Langholt, may make it a natural catchment for riverine sediments and aeolian deposits (Figure 14a). Coring in the large bog just over the river from the farm mound made it clear that there was repeated turf cutting over centuries of habitation.

According to the *Landnámabók*, "Sæmund the Hebridean … took possession of the whole of Sæmundarhlið between Vatnsskard and Sæmundar Brook and lived at Sæmundarstead" (Pálsson and Edwards 1972:88). Reynistaður's prime location and early settlement date make it a contender for this original farm, but the situation is ambiguous. The homefield is just to the west of the river, which would place it within Sæmundr's claim if the saga boundaries are accurate. It is unclear to what degree the river may have meandered over the intervening centuries. In any case, historical accounts give Reynistaður unquestionable social and economic prominence through the medieval period. Few records describe Reynistaður prior to the 11th century (Bolender 2006:105). The *Saga of Eirik the Red* relates that the family of Þorfinnr Þordarsson Karlsefni, one of the first Europeans to travel to America, lived at Reynistaður (then called Reynines) in the early 11th century, and that his father came from the farm at Hof on the other side of the fjörd (Kunz 2009). The *Saga of Grettir the Strong* refers to the farm by the early name as well (Scudder 2005: 159). By the late 11th century, Reynistaður was one of the primary estates owned by the Ásbirningar, one of the five chiefly families (*ætt*) who would come to dominate Iceland over the next 150 years (Karlsson 2000, Pálsson 2001). As a large church farm, Reynistaður would have been eligible to collect tithes from the surrounding farmsteads after 1097, and the farm was home to a convent that collected rent from every farm in the northern half of Langholt by the end of the 13th century. Though the cloister was eventually closed, these northern farms continued to owe rent to the proprietors of Reynistaður through the early modern period. Official tax and census records from the 18th to the 20th centuries consistently show Reynistaður as the highest valued farm in the Langholt region, with the greatest number of animals and the most productive land (Magnússon and Vídalín 1930; Bolender 2006). Today the church at Reynistaður is one of two in the region that are still active.

Reynistaður is both the earliest and the wealthiest farm in the study region, and its soil accumulation rates are consistently the highest, as much as twice that of most other farms. Its 19th century value is very high compared to its 1104 mound size (Figure 7), making it clear that Reynistaður's wealth continued to grow well after the end of the Commonwealth. Reynistaður therefore appears to vindicate the suggestion that the first settler, given the opportunity to select the best land, becomes the wealthiest farmer over time. Since the results of this study show no direct correlation between settlement order and soil accumulation rate, and given that the landscape of Langholt probably appeared quite homogeneous at *landnám*, is it reasonable to suggest that the founders of Reynistaður consciously selected the best land for themselves?

"Best" is a socially contingent term. In selecting the "best" land, the first settler would have been influenced by the choices of earlier settlers in other regions of Iceland as well as the landscape of his home in Norway (or the Hebrides, if the saga is correct in this case). In addition, any land that stood out from its surroundings in a positive way would have seemed advantageous. Reynistaður's location, on a headland above the river near small glacial hills with flat, level fields, is unique in the region. I argue that the eventual success of Reynistaður owes, at least in part, to positive, conscious landscape choices made by the first settler in favor of high productivity.

The settlers who arrived later were greeted with a smaller range of options. While there are some few hills and other minor variations in topography, most of Langholt's other farms are positioned along the slope that stretches north to south above the rivers Héraðsvötn and Húseyjarvistl, situated between wet, boggy lowlands and higher pastures. In appearance and prospect they are largely similar to one another. The settlement choices made by the second, third, and fourth settlers seem to have been predicated at least as much on social factors as on environmental considerations.


a.


b.

Figure 14. Photos of Reynistaður and Stóra-Seyla

14a: Reynistaður. Small glacial hills near Reynistaður's level fields. Sæmundará river is in the middle ground. The farm mound is at center, with trees growing on it between the church and the farmhouse (white with red roof). Photo taken facing northwest.

14b: Stóra-Seyla. The gentle slope in the middle ground can be followed north-south through most of the farms of Langholt. The two small structures at center are near the post-1100 farm mound; the earlier mound is downslope and to the left. Photo taken facing southwest. Both ©Pálsson 2001.

Stóra-Seyla

Stóra-Seyla (ID 104), the second oldest farm on Langholt, was settled around the turn of the tenth century, probably not long after Reynistaður and ten kilometers to the south, at the opposite end of the survey region and along the slope that characterizes most of the farms in the region (Figure 2, Figure 13, Figure 14b, Table 1). Reynistaður and Seyla form part of an evenly distributed settlement pattern at this early date, if the region is extended to include their historically identified neighbors to the north and south (Bolender and Steinberg 2010). Seyla, which means "ox-bow," may take its name from the nearby bend in the Húseyjarvistl river, and it is not far from the mountain pass that connects Langholt with Vatnsdál and lands to the west. The prefix *stóra*, "large," was added much later when a portion of the farm was split off to create Litla-Seyla, now called Brautarholt (ID 105) (Pálsson 2001). At 1104, Seyla had the second largest farm mound in the region (over 7100 square meters). Seyla's soil accumulation rate through the Viking Age was consistently near the average rate for Langholt.

The *Landnámabók* states that "a man called Ulfljot … took possession of the whole of Langaholt [sic] below Sæmundar Brook" (Pálsson and Edwards 1972:89); it seems probable that he made his home at Seyla, a good location with access to bogs and uplands, and quite a distance from its nearest neighbor. It was the central farm of Seyluhhreppur (which takes its name), and its importance continued into the medieval period. At ca. 1100, archaeology reveals that both the longhouse and church were shifted up to the top of the slope (Steinberg 2009); the reason is unknown, but there may have been interest in obtaining better sightlines over distant properties and tenant farms.

Seyla's status declined over time. By the 1700s it was no longer consistently owner-occupied, it had only two tenant farms (having possibly lost at least one tenancy to the bishopric at Hólar), and its early church had been abandoned in favor of those at Reynistaður, Glaumbær, and Víðimyrí (to the south, which incidentally is historically associated with Reynistaður). A mention of the farm in the *Sturlunga Saga* suggests that Seyla's churchyard may have been out of regular use for burials by the middle of the 13th century (Zoëga 2011, elec. comm.). However, Stóra-Seyla is remarkable for its persistence as one of few independent farms in Skagafjörður; all other major properties on Langholt were owned by the church during the late medieval period, whether the bishopric at Hólar, the cloister at Reynistaður, or the parish church at Glaumbær (Bolender 2006; Steinberg, Damiata et al. 2008). In more recent times, Stóra-Seyla has taken advantage of its access to windswept pastures by relying on winter grazing as a supplement to stored hay, renting its pastureland to other farmers after cultivation ceased in the late 20th century (Bolender 2006; Steinberg, Damiata et al. 2008).

Seyla's establishment date and mound size fit well within regional trends (Figure 4, Figure 5, Figure 13). Its 19th century value is somewhat lower than its 11th century size would suggest (Figure 7), reflecting a decline in fortunes over the intervening 800 years. Together with its consistently average soil accumulation rate, these factors seem to suggest that Seyla may owe its original prominence more to its early settlement date or the productivity of outfields within its original large land claim than to inherent land quality in the immediate vicinity of the homestead and the *tún*. Furthermore, if soil quality was apparent at *landnám*, the original settler at Seyla may have considered its physical location (near the river bend and equally spaced between its closest neighbors) to be a more important criterion. However, despite Seyla's early success and possible first-settler advantage, its tenant farms were limited both in quantity and quality, and its inhabitants were ultimately unable to leverage sufficient social and economic power to surpass the inherent mediocrity of its land.

Marbæli and Meðalheimur

Much like its neighboring farms, Marbæli ("sea farm", ID 115) is situated on the sloping hillside above the soggy valley bottom, about 15 meters above sea level. Its prospect is typical; it is not set in a hilly catchment or at the confluence of streams. Meðalheimur ("middle home", ID 1006), in contrast, is one of the highest farms in the study area at about 85 meters above sea level. It is located about 1.5 km to the southwest of Marbæli on a gradual slope just at the dividing line between fertile grassland and scrubby pasture, with access to bogs but not to a nearby river. Both farms were established in the early tenth century and are located just south of the dividing line between Staða- and Seyluhhreppurs, approximately equidistant from Reynistaður and Stóra-Seyla (Figure 2, Figure 13, Figure 15, Table 1). Placement equidistant from their nearest preexisting neighbors (Figure 2, Figure 5, Figure 13) continues the evenly distributed settlement pattern of the first phase of farmstead establishment. The sagas tell us nothing about the early settlement of either farm, but as Bolender and Steinberg (2010) have suggested, it is easy to envision them as the last independently settled farms on Langholt (later farms being subdivided from these initial land claims).

Meðalheimur's accumulation rate is strikingly high – like Reynistaður's, as much as twice that of most other farms. Marbæli's, on the other hand, is the lowest in the region. At 1104, Marbæli's farm mound is close in size to Seyla's, about 7000 m^2. Meðalheimur's mound size, about 4600 m^2, is similar to that of farms established during the next phase of subdivision. Both of these sizes are reasonable for the establishment date (Figure 5).

Marbæli began paying rent to the bishopric at Hólar on the other side of Skagafjörður sometime during the medieval period (Bolender 2006). Like Seyla, it was not valued as high as predicted in the 19th century for a farm of its size (Figure 7), indicating a decline in prosperity since the Viking Age. Very few records exist for Meðalheimur. In the early 16th century, it is listed as a tenant of Glaumbær (Bolender 2006), while in the 1701-1714 census, it is mentioned as having been abandoned about 12 years earlier (Magnússon and Vídalín 1930). At some point thereafter it became a cow shed (Pálsson 2001). An 1803 map of Langholt does not show the farm at all (Pálsson 2001:226), nor is it listed in the late 19th century tax records. Today the ruins of the Viking Age farm mound are located inside the boundaries of Hatún, one of Glaumbær's modern subdivisions (Pálsson 2001; Steinberg 2007).

Marbæli's decline in status from independent household to tenant farm makes some logical sense, given its consistently low soil accumulation rates. However, if the greatest economic advantages accrue to early farms on good land, Meðalheimur should

a. 

b. 

Figure 15. Photos of Meðalheimur and Glaumbær

15a: Meðalheimur. Coring and remote sensing in 2007. The farm mound is under excavation at rear. Photo taken facing northeast.

15b: Glaumbær. The church, museum, and post-1100 farm mound are at left. The excavation downslope and towards the Vestarhéraðsvötn river marks the location of the earlier longhouse. Marbæli, not pictured, is several hundred meters along the road to the left. Aerial photo taken facing northeast during SASS's 2002 field season.

have rivaled Reynistaður's prominence. Instead, it had become a tenancy by the early 1500s, perhaps earlier, and was no longer inhabited after the 17th century. This issue can be addressed by exploring the relationship between Meðalheimur and its neighboring farm and landlord, Glaumbær.

Glaumbær

Glaumbær ("farm of joyful noise", ID 111) is located just to the south of Marbæli, also on the hreppur line and along the slope above the Vestarhéraðsvötn river, nearly equidistant from Reynistaður and Stóra-Seyla and about 1.5 km east of Meðalheimur (Figure 2, Figure 15b). Glaumbær was not settled until ca. 1000 – 12th out of the 16 farms in the study (Figure 13, Table 1). Other farms established at about this time belong to the class of subtenant farms that were being carved from the initial farmsteads, a class that also includes Páfastaðir (59) and Torfgarður (106) (Steinberg et al [2011]). Glaumbær's distance from its nearest neighbor (Marbæli) is just right for this group of farms, and its 19th century value is also about right for its size at 1104 (Figure 5, Figure 7). Its median soil accumulation rate is consistently average for the region, about the same as Seyla's and, perhaps surprisingly given its proximity, much higher than that of Marbæli (Figure 9, Figure 10, Figure 13).

Glaumbær's size at 1104, however, is strikingly large for its establishment date – at over 6500 m^2, it is almost as large as Seyla and Marbæli at that time. This is also far larger than other farms at a similar distance from their nearest preexisting neighbor (Figure 5, Table 1). Glaumbær's farm mound had grown twice as fast as other farms its size between its establishment date and 1104, and half again as fast as Reynistaður's. This phenomenal growth rate is indicative of a very high population during the 11th century, or at least a high volume of refuse, perhaps the result of regular opportunities to host social events. A closer look at the 19th century tax records (Figure 7, Table 1) reveals that Glaumbær was valued second highest in the region, far behind Reynistaður but well ahead of Stóra-Seyla, and completely outclassing the farms that share a similar establishment date. Glaumbær acquired several tenants of its own as well as a church, and it is one of two known farms (the other being Seyla) to have moved upslope ca. 1100 (Steinberg 2009). This move is particularly interesting in Glaumbær's case, considering the farm had only existed for a century prior. Given its establishment date and distance from Marbæli, Glaumbær should be a small tenant farm. It looks much more like a large, independent farm. A possible answer to the conundrum of Glaumbær and Meðalheimur – one farm wealthier than some indications predict, the other far less prosperous than expected – lies in the relationship between land quality and tenancy.

Hospitality, Rent-Seeking, and the Origins of Wealth in the Viking Age

When the first settlers arrived in Iceland and began to farm the land, they were faced with land abundance and labor scarcity (Durrenberger 1998; Bolender and Steinberg 2010). Under these conditions, because the amount of land that can be put into production is limited by available labor, there is no incentive to create tenancies or collect rent – all available labor is needed simply to ensure that the household can survive to the next season (Steinberg 2006). Viking values of hospitality and reciprocity, as described in the sagas, may have led the first farmers to offer aid and support to the independent settlers who followed in the first few decades of settlement. There would have been little reason to refuse, since any land that these new settlers farmed would otherwise lie fallow for want of labor. In this mutually beneficial arrangement, later independent settlers would benefit from their association with the first settlers, while the "weak debt" of reciprocity owed to the first settler would strengthen his land claim and property rights (Steinberg and Bolender 2010). There are therefore social as well as economic advantages to being first into an unsettled frontier, and these social benefits may be partially responsible for the early large mound size (high status) of Seyla and Marbæli, despite their relatively lower soil accumulation rates (productive capacity).

However, these conditions lasted only as long as productive land remained unclaimed. By ca. 930, the traditional end of the Settlement period, the dynamics of the social and environmental landscape were beginning to change. The population was rising by natural increase even if it was no longer rising by significant immigration, and while the land had not yet reached a maximum density of productive farms, the *Íslendingabók* describes the land as "fully settled" (Þorgilsson 1930). This suggests that new settlers from outside of Iceland were no longer as welcome as they might once have been. In a reversal of the previous conditions, farmsteads now operated under land scarcity and labor abundance (Durrenberger 1998; Bolender and Steinberg 2010). Without economies of scale, larger households could become liabilities as the ratio of consumers to workers rose. If a farmer could obtain a larger return by subdividing his property than by grazing his animals on that part of his land, it was in his interest to remove excess labor from the household by setting up the families of his children or freed slaves on a portion of his property. This new class of dependent farmers could increase the productivity of the parent farm's property by bringing new land into cultivation, while consuming only what they were able to produce in their own household. As environmental decline proceeded and population pressure increased, further subdivision became necessary, but had increasingly high opportunity costs associated with the loss of outfields and pastureland. One way of ensuring maximum returns from dependent properties was to demand rent, in the form of produce or seasonal labor (Bolender 2006). Rent here is distinct from, though related to, Ricardo's (1817) rents that are defined as the difference in productive capacity between the best and worst farms. If Ricardian rents are interpreted as surplus production, the rent owed to a landlord is a portion of this surplus. Rent can therefore increase production by providing an incentive to produce a surplus (Gilman 1981), although in Iceland the harsh climate and decreasing marginal returns to labor meant that large surpluses were not common and that rent collection was a supplement to, not a substitute for, household production (Bolender 2006).

The coring data has shown that relative accumulation rates were unstable and increasing during the first 150 years or so after *landnám*, and the corresponding differences in productivity between farms probably varied greatly from one year to the next, especially for those farms whose average soil accumulation rate falls near the mean (Figure 10). As relative soil accumulation rates began to stabilize through the 11th century, so would the productive divide. When these inherent differences in land quality become obvious, materialized as relatively stable differences in production between farms, rent-seeking behavior may arise as farmers and landowners compete to gain control of the most productive resources. Again, rent-seeking is distinct from (though related to) both Ricardian rent and rents paid in exchange for resource use. Rent collecting as a mechanism to maximize returns from owned property, as suggested above, is a form of profit-seeking in which benefits are maximized by bringing otherwise barren lands into production (Sölvason 1991). Rent-seeking, in contrast, occurs when interested parties expend scarce resources to compete for available rents, often up to or in excess of the potential rent to be gained, and often at the expense of the other party in the transaction (Krueger 1974; Buchanan 1983). Rent-seeking therefore tends to "maximize social waste" (Sölvason 1991).

Rent-seeking has previously been suggested as an important pathway for the development of social stratification in Iceland (Sölvason 1991; Gilman 1995; Bolender and Steinberg 2010). In the Icelandic Commonwealth, after the final phase of land division when the majority of productive land was in use, the sagas describe several ways by which a farmer could nonetheless increase his landholdings (Byock 2001). Land could be inherited on the death of a relative, and could also be obtained through marriage. Land ownership could be disputed in court, and relatedly, land owned by convicted outlaws was remitted to the claimant and his *goði*. In some very few cases, land could be purchased. All of these, with the exception of fully compensated direct sale, are examples of rent-seeking behavior in that they take the form of "noncompensated transfers … to the recipients" (Buchanan 1983:71). Manipulating the legal system to ensure that inheritances and lawsuits are favorably settled, as suggested by the traditional narrative of the origins of the *stórgoðar* (big chieftains) during the 13th century (Byock 2001), is most definitely rent-seeking behavior. The tithe, which funneled additional wealth to the elite class after its institution in 1097, is another manifestation of rent-seeking (Sölvason 1991). I argue that the conditions for rent-seeking were in place much earlier. The reorganization of the political economy during the 10th century, which circumvented diseconomies of scale by establishing dependent farms and non-household labor (Bolender and Steinberg 2010), made rent-seeking feasible by the 11th century by making marginal land profitable just as stabilizing environmental conditions made productive differences evident. The stabilization of Ricardian rents would have made it clear that some farms were inherently more productive than others, as differences in soil accumulation rates exaggerated the inherent spatial order of the landscape. Institutionalization of social inequalities occurred when knowledge of relative farm productivity become consistent and reliable, providing an incentive for aspiring big farmers (*stórböndar*) to ensure that multiple avenues were available to them for acquiring as much highly productive land as possible and collecting large amounts of rent from its tenants.

The Exception that Proves the Rule

Rent-seeking behavior can begin to explain the unusual case of Meðalheimur and Glaumbær. Records from the 16th century show that Meðalheimur was a tenancy of Glaumbær by that time (Pálsson 2001; Bolender 2006). Although we cannot know the details of how and when this relationship began, it may extend back into the Viking Age. Acquisition of Meðalheimur as a dependent or tenant farm by the settlers at Glaumbær soon after their arrival on Langholt, sometime during the 11th century, would fit well with the timeline for stabilization of rents. Upon realizing that their new farm only produced at a middling level, the inhabitants of Glaumbær would have had an incentive to seek rents from a higher-producing farm, gaining not only the wealth of its deep soils but also whatever prestige may have adhered to Meðalheimur as one of the earliest settled farms in the region. If Meðalheimur transitioned from an independent farm to a tenancy or dependency early in the 11th century, this loss of status (or relocation) could be a potential explanation for its smaller mound size at the beginning of the 12th century in comparison to contemporary farms Seyla and Marbæli. There is some evidence that the institution of tenancies resulted in an overall loss in productivity throughout Iceland, as land alienation disincentivized tenant farmers from making improvements and performing basic maintenance (Bolender 2006). Meðalheimur's abandonment before the 18th century fits this pattern, highlighting the inherent inefficiencies of a political economy based on rent-seeking if even such high-quality farmland could not be maintained in production.

Although rent-seeking may explain Meðalheimur's transition to tenant farming, which set the stage for its eventual abandonment, archaeology and economic theory alone are insufficient to address the remaining questions about Glaumbær. Its farm mound at 1104 is far too large for its age, and its inhabitants managed to acquire Meðalheimur – though it would seem more reasonable that if Meðalheimur became a tenant at all, it should have been to an established farm like Marbæli. Furthermore, if Glaumbær did not begin as a dependent farm, how were its founders able to settle on land that had already been claimed? Glaumbær's wealth did not lie exclusively in its own land, nor could its inhabitants claim status based on an early establishment date. What was the source of Glaumbær's wealth?

Several of the sagas mention Glaumbær, but two in particular can shed light on its founding (Kunz 1997; Scudder 2005). *The Saga of the Greenlanders* states that Þorfinnr Karlsefni "purchased the land at Glaumbær and established a farm there" (Kunz 1997:651) with his wife Guðríðr Þorbjarnardóttir and their son Snorri after returning to Iceland from extended sojourns in Greenland and Vínland and trading voyages to Norway. The *Saga of Eirik the Red* furthermore ties Karlsefni's family to Reynistaður (Kunz 1997), suggesting that these two most influential farms on Langholt may have had familial ties. This story corresponds very closely with the archaeological date of ca. 1000 for Glaumbær's earliest occupation (Steinberg 2002; Steinberg 2009). The family who settled at the farm may therefore have had great wealth derived from trade between Scandinavia, Iceland, and Greenland, as well as local prestige and renown from both Karlsefni's connection to Reynistaður and his "extensive reports" (Kunz 1997:652) of thrilling voyages to Vínland. The saga further states that Guðriðr built a church (Kunz 1997), possibly the first on Langholt. The church at Glaumbær was in use prior to 1100, and later became the parish seat (Bolender 2006), which would have increased the status of the farmers who lived there. Such external sources of wealth and status were probably more than sufficient to purchase land in a region that was already full, and to muscle out any other rent-seeking farmers who might have had an interest in Meðalheimur (such as, perhaps, the inhabitants of Seyla, or wealthy farmers from nearby Sæmundarhlið). Glaumbær may therefore be the perturbation in the system, and the exception that proves the rule: early farms on good land ultimately become the wealthiest, *unless* rich Vikings from Greenland move in next door. Inherently productive land is valuable, regardless of when or how it is acquired.

In similar cases from Reykholtsdalur and Mývatnssveit, the ability of a farm to acquire or to create productive land was found to be more important to its ultimate social status and long-term success than the quality of the initial landholding (McGovern et al. 2007:38; Adderley et al. 2008; Sveinbjarnardóttir et al. 2008), implying that in pan-Icelandic context Glaumbær's strategy may not be anomalous. The ability of late-arriving, independently wealthy settlers such as those at Glaumbær to leverage ephemeral wealth by converting it to lasting value in the form of productive real estate clearly suggests that long-term economic success is ultimately inextricable from high-quality land in a marginal agricultural landscape such as Viking Age Iceland. While primacy is also important, it alone is not enough: for long-term success, the first settlers must also choose, or be able to acquire, the highest-quality land.

Other Farms

The other 11 farms in the study were partitioned out of the initial land claims between ca. 930 and 1060 (Figure 2, Figure 13, Table 1) (Bolender and Steinberg 2010). Distances from their nearest neighbors suggest that they began as dependencies or tenants during the later phases of the settlement sequence (Figure 4, Figure 5, Figure 13)

(Steinberg, Bolender et al. [2011]). These farms have median soil accumulation rates that vary by up to about 0.1 mm/year from the average, and they follow the general trend of increasing, then stabilizing differences in soil accumulation rate that magnify conditions at *landnám* (Figure 9, Figure 10, Figure 11, Figure 12). The farm mounds are all of average size at 1104. Farms with similar soil accumulation rates are spatially clustered: those associated with Reynistaður during the late Viking Age (Geirmunðarstaðir (72), Hafsteinsstaðir (71), and Geitagerði (64)) tend to have fairly high rates through time, while Reynistaður's medieval tenants (Stóra-Gröf (61), Litla-Gröf (60), Páfastaðir (59), and Kjartansstaðir (57)) and farms that may have been tenants of Glaumbær and Stóra-Seyla to the south (Torfgarður (106), Grófargil (89), and Halldórsstaðir (109)) have accumulation rates near or below the mean. Dependencies do not always have lower soil accumulation rates than their parent farms, suggesting that they may have been placed in higher-producing outfield locations in a conscious effort to collect higher rents.

The three farms whose median rates fall between Reynistaður's rate and the average value are in some ways exceptional (Figure 9 and Figure 10). The early farm, Geirmunðarstaðir (72), and the later large farm, Geldingaholt (102), are located several kilometers to the west and east of the other farms, respectively. Their high soil accumulation rates may be due to their unique situations, and their historical relationship to other farms in the settlement pattern is not yet fully understood. Geitagerði (64), the very late farm, was not founded until ca. 1300 and should probably be considered a part of Reynistaður's outfields or pastureland during the Viking Age (Bolender 2006). If these three exceptional farms are set aside for the moment, the difference in soil accumulation rates between Reynistaður and Meðalheimur and the rest of the region becomes even more strikingly apparent.

Land Management

Land management practices can alter the dynamic qualities of the soil, and may therefore diminish or accentuate inherent differences in land quality between farms (Warkentin 1995; Carter et al. 1997). The coring data shows that persistent differences in soil accumulation rate are inherent, and correlations between soil accumulation rate and later wealth suggest that homefield intensification (perhaps via manuring) may have been insufficient to overcome these incipient differences in productive capacity. Land management does not appear to significantly *diminish* inherent environmental differences. However, the coring data alone cannot suggest whether land management is effective in *accentuating* differences – manuring may be more effective at increasing the productivity of inherently high-quality land than inherently low-quality land. Phosphorus enrichment data is available that can speak to this possibility.

Bolender (2006) used phosphorus enrichment to describe changing agricultural practices on Langholt at eight of the sixteen farms included in the current study (Grófargil, Stóra-Seyla, Torfgarður, Halldórsstaðir, Glaumbær, Reynistaður, Geitagerði, and Hafsteinsstaðir). High mean enriched phosphorus values are well correlated with high median accumulation rates on a per-farm basis for the prehistoric (pre-872), settlement (872-1104), and medieval periods (1104-1766) (Table 6). Where available, finer periodization of phosphorus sampling after 1000 does not correlate with accumulation rates. Thicker soils, better aerated by a higher input rate of mineral-rich aeolian-andic deposition, may have more available phosphorus than thinner soils, as suggested by the high prehistoric correlation between phosphorus and accumulation. The lack of correlation during the early medieval period corresponds to the mid-11th-century stabilization of differences in soil accumulation rates between farms (Figure 9, Figure 10). Trends in the phosphorous data show that enrichment strategies generally increased in intensity after the 11th century (Bolender 2006), further supporting the suggestion that the 11th century was a period of change and renegotiation in environmental conditions, agricultural practices, and political economy. As rents stabilized, soil enrichment practices became more widespread, perhaps in an attempt to increase the productivity and value of farmsteads that, whether financially or socially, could not afford to obtain control over inherently productive land by other means. These strategies may not have been uniformly effective.

Table 6. Soil Accumulation Rate and Phosphorus Enrichment Statistics
Significant correlations are in bold font.

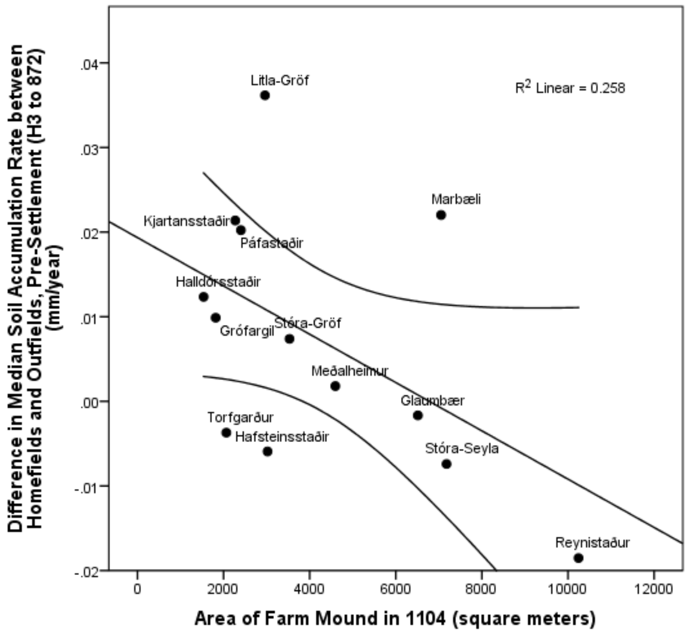
Enriched Phosphorous Period*	Accumulation Rate Period	R^2	p (Sig.)
Prehistoric (H3 to 872)	**H3 to 872**	**0.687**	**0.021**
Settlement (LNL to 1104)	**872 to 1000**	**0.672**	**0.013**
	1000 to 1104	0.196	0.272
	872 to 1104	**0.41**	**0.087**
Medieval (1104 to 1766)	1104 to 1300	0.222	0.238
	1104 to 2000	**0.519**	**0.044**
	1300 to 2000	**0.539**	**0.038**
Early Medieval (1104 to 1300)	1104 to 1300	0.003	0.905
Late Medieval (1300 to 1766)	1300 to 2000	0.026	0.703

* Bolender 2006

Studies from elsewhere in Iceland have suggested that the intensity of homefield management declined in some areas after the first few centuries, but that early, sustained management could mitigate bad years later on (Adderley et al. 2008). Similarly, sustainable winter grazing practices have been shown to have significant long-term positive effects on landscape stability and farm success (Simpson, Guðmundsson et al. 2004). It is possible that while relative rates of soil accumulation in local environments were somewhat stable past 1100, management practices became increasingly idiosyncratic, as farms responded individually to changes in enrichment effectiveness, social relations, loss of pastures, and labor availability (Bolender 2006; Simpson, Adderley et al. 2002). Farms with high accumulation rates that made good management choices during the early years of settlement may therefore have increased their chances for success later on, while those who made poor choices (even on initially good land) undercut their own futures. Simpson et al. (2002) found that initial soil quality is vitally important for achieving high yields, regardless of land management practices, and the relationship between poor management practices and land alienation is well documented (Bolender 2006; McGovern et al. 2007). Manuring and regulated grazing may have been less effective overall at enriching soil nutrients and preventing erosion on farms with inherently lower accumulation rates and shallower soils. If productive land cannot be created by intensifying homefield enrichment, incentives are increased for acquiring control over high-quality land through other means, i.e., rent-seeking.

In general, it has been assumed that fundamental differences exist between the historically cultivated homefields and the surrounding pastures and outfields (Figure 3;

Bolender 2006). Therefore, in the initial stages of research the current study looked for aggregate differences in soil accumulation rate and tephra presence/absence on either side of the historic homefield boundaries, expecting to find the best environmental conditions for agriculture inside *tún* boundaries on large, early farms. Few obvious trends in the data were discernable. Some farms showed significant differences in soil accumulation rate inside and outside of homefields during all or part of the study period (mean differences up to 0.3 mm/year, $t<3.5$, $p<0.05$): Kjartansstaðir, Litla-Gröf, Marbæli, Páfastaðir, Torfgarður, and Reynistaður. Notably, this set of farms is biased in favor of those for which we have broader landscape coverage and more cores collected in the outfield than the homefield (Figure 2, Table 1). The same subset of farms, with the addition of Glaumbær, shows correlations between homefields and presence of the *landnám* and/or 1104 tephra layers ($p<.01$). Differences in the median soil accumulation rate between the inside and outside of the homefield on individual farms suggest that, like overall variability in soil accumulation rate, these differences may have been temporally consistent, and that ultimately wealthier farms may have been located on more homogeneous overall landscapes (Figure 16, Figure 17). There is some suggestion here that later settlers on inherently low quality land may have, first, taken pains to select the best part of the landscape for their homefield, and second, put more effort into intensification. These conclusions must be considered tentative until additional data becomes available, but these preliminary results suggest that the quality of non-intensified landholdings (outfields, pasture) may play a more important role in farm productivity than has been previously understood, and it may be important to consider the value of these lands as opportunity costs or incentives in the process of land division and tenancy.



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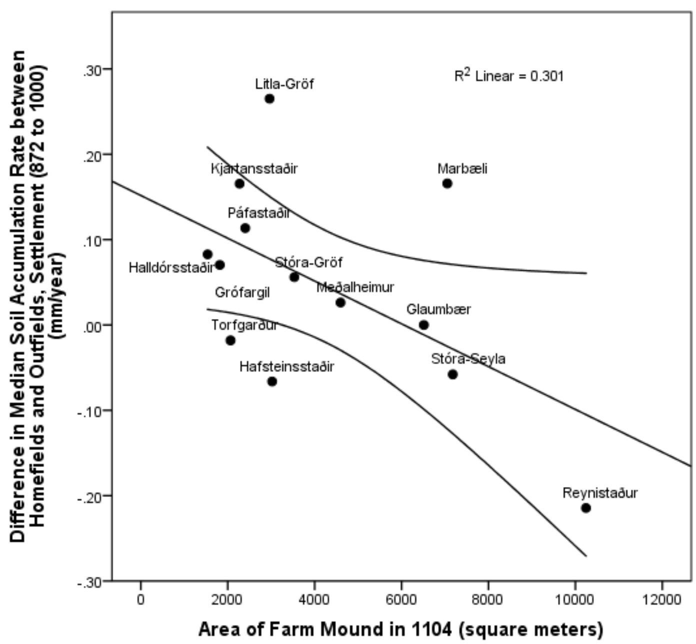

b.

Figure 16. Farm Mound Area vs. Differential Median Soil Accumulation Rate in Homefields.
16a: Pre-Settlement, p=0.076. **16b: Early Viking Age**, p=0.052.
95% mean confidence intervals. Differences between homefields and outfields appear persistent, and greater differences may be apparent on farms established as dependencies. More work is needed.

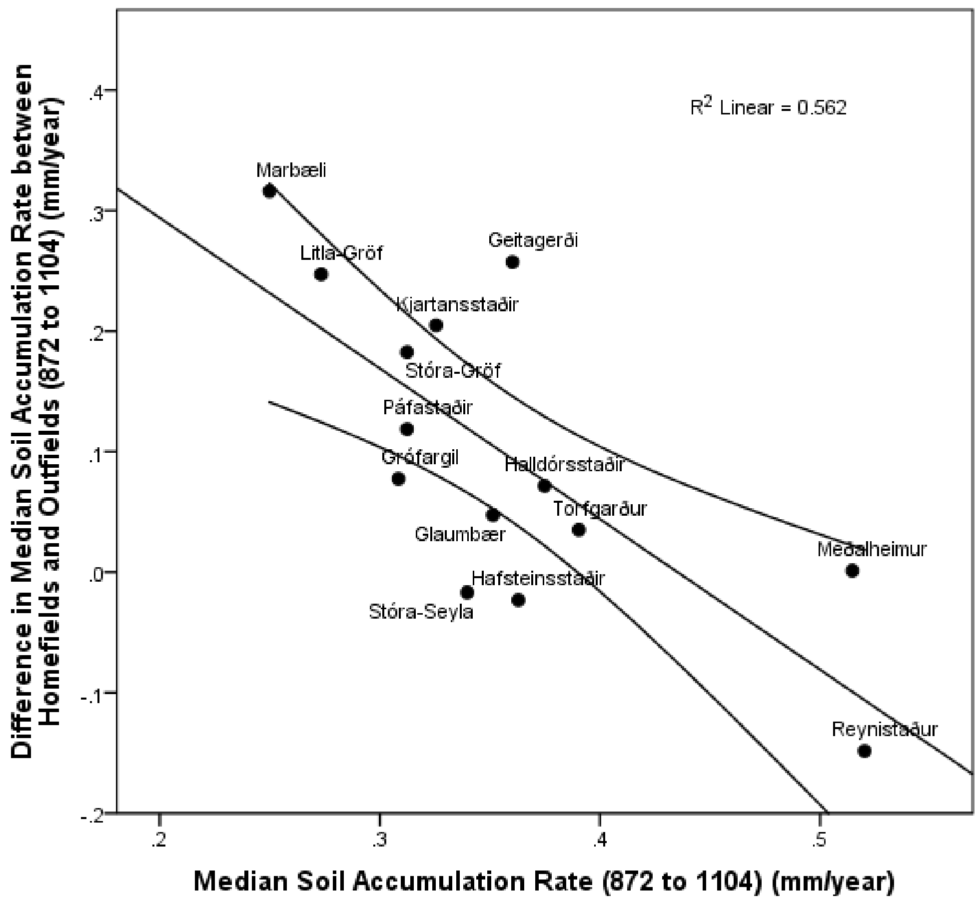

Figure 17. Median Soil Accumulation Rate vs. Differential in Homefields
p=0.001. 95% mean confidence intervals. High median soil accumulation rates for entire farm landscapes may correlate with small differences in rate between homefields and outfields. More work is needed.

CHAPTER 5

CONCLUSIONS

Viking Age Iceland may be the only social context in which we can truly observe the origins and development of a political economy, from unsettled frontier to dispersed egalitarian households to exploitative stratification. Political economies are defined as "the material flows of goods and labor through a society, channeled to create wealth and to finance institutions of rule" (Earle 2002:1). In order to finance an elite class, there must be a source of surplus goods and labor beyond that required for household survival. Iceland's transhumant pastoralism in a marginal agricultural environment was subject to diseconomies of scale and diminishing marginal returns, which had limited capacity for surplus production. What, then, was the source of funds that supported the emergence of an exploitative elite? Subtle differences in soil accumulation rate have suggested that even very limited surpluses are sufficient to create differential wealth and status.

Tracing the patterns of soil accumulation from the prehistoric period through the Viking Age has shown that the ultimate source of wealth lies in differences in the landscape, while the settlement sequence suggests how ways of obtaining this wealth and status changed over the course of the Viking Age. Social stratification emerged in concert with rising population pressure and increasing environmental degradation, and developed out of the initial patterns of land division. In the initial stage, large, independent, well-dispersed farmsteads were established under conditions of labor scarcity and land abundance.   These early settlers enjoyed social advantages of primacy, including the benefits of Viking values such as hospitality and reciprocity – possibly including differential access to scarce labor. Economic advantages also accrued to early settlers who selected the highest quality land, but since productivity was limited by labor availability during these early years, differential rents may have been less important to status than social factors such as reciprocity (and, perhaps, prestige goods and violent reputations obtained on Viking raids or trading expeditions).

The second stage of settlement was rooted in the emergence of land shortages and labor abundance, as environmental degradation accelerated and the population rose. The ability to increase the productivity of the land became vital, and diseconomies of scale with decreasing marginal returns to intensification limited the range of possible strategies and made property subdivision an attractive option. If the new class of dependent farmers could produce at their own subsistence level, the result would be an increase in productivity to the parent farm's property at little cost. This turbulent period was characterized by uncertain differences in soil accumulation rates and productive capacity, and increasing the positive productivity of the land was becoming more important for social and economic success. Early farms on less productive land, including Seyla and Marbæli, may have been at a disadvantage during this period, if the prestige their inhabitants had enjoyed as hospitable pioneers was no longer valued as highly as quality land. Conversely, Reynistaður's access to very high-quality soils ensured continued success.

All of these processes escalated during the 11th century. Advancing population pressure made additional subdivision a necessary measure, and maximizing returns from dependencies required the institution of rent obligations in the form of produce or labor demands owed to the parent farm in compensation for their loss of outfields or pasture. The accelerated process of deforestation and overgrazing had largely stabilized, resulting in relatively stable and evident Ricardian rents, manifested as productive differences between farm properties. As it became apparent that some farmland was of higher quality, aspiring *stórböndar* had an incentive to gain control over these higher producing farms and claim their high rents through any means possible. Inefficiencies inherent in a social structure based in rent-seeking led to exploitation, land alienation, increasing poverty, and eventually, the paradoxical abandonment of even highly productive tenant properties like Meðalheimur.

Inherent, marginal differences in soil deposition rate between farmsteads are, therefore, sufficient foundation for the development of large differences in wealth and the emergence of social stratification during the Viking Age on Langholt in Skagafjörður, Iceland. Institutionalized social inequalities grew out of property institutions of land ownership and farm subdivision that are subject to exploitation when population pressure combines with diseconomies of scale to create a surplus labor market. While early farms with less productive resources may have enjoyed high status for a time, like Marbæli and Seyla, primacy did not automatically translate to long-term wealth without differential access to rents from productive land. Reynistaður, an early farm on very productive land, had no difficulty maintaining high wealth and status through to the early modern period. The example of Glaumbær shows that it was possible to manipulate the existing social order by leveraging external sources of wealth and status in an effort to attain high-quality land – part of a pattern of exploitative rent-seeking which, in this case, compromised Meðalheimur's potential future as a high-status farm and made Glaumbær the second-wealthiest farm in the region.

Differences in land quality are inherent, apparent, and persistent, and while primacy and (perhaps) trade are valid alternate sources of status and wealth in the short term, in the long term these are unsustainable unless they can be converted into good, deep, productive agricultural land. This quality land can be obtained either by choosing the first land wisely or by gaining control over good land via exploitative rent-seeking behavior. Small differences in soil accumulation rate lead to large differences in farmstead wealth and status in the Viking Age on Langholt. Social stratification became fixed as differences in agricultural productivity became apparent in this environmentally marginal, declining landscape. He wins, who controls the best land before the world ends.

AFTERWORD:

Future Work and Implications

As with all archaeological and scientific research, attempting to answer one question has led to several others. This data set in particular is so large and versatile that many avenues of data manipulation and statistical analysis remain untried. Furthermore, exploration of the theoretical possibilities of a data set that speaks to the origins and creation of wealth has only begun. In many ways the most difficult part of this thesis was pausing the analysis in order to write up the results.

The first and most obvious step is to acquire additional cores. Broader landscape coverage on all farms, in particular those where coring was concentrated close to mounds and homefields, should allow for better characterization of the relationship between homefield enrichment strategies, productivity, and the quality of outfields and pastures. Additional coring will also increase the strength of comparison between farms, and geostatistical cluster analysis will be more significant with broader landscape coverage. On farms where data is missing such as Syðra-Skörðugil and Holtsmúli, more cores may provide a better understanding of the relationship between farms. In particular, Syðra-Skörðugil was established ca. 930 during the first round of farm division and is nearly equidistant from Marbæli and Seyla; characterizing its soil accumulation rate could have very important social implications. A Dr. Robert W. Spayne Research Grant, awarded by the University of Massachusetts Boston Graduate Student Assembly, will be put towards this purpose in summer 2011. In addition to new data, subsampling and smoothing protocols could be used to ensure that no farms or environmental zones are oversampled.

Other avenues of research suggested themselves over the course of this study, and may be returned to after the data set is complete. These include fully utilizing the power of ArcGIS's spatial statistics packages to look more closely at local environmental trends in soil accumulation, to consider the effect of topographic variables such as slope and aspect, as well as a closer look at the local impact of erosion events that may remove soil from Langholt. The tephra simulation algorithm should be run individually for the northern, middle, and southern subregions of Langholt. Directional distances to the mound center could reveal patterns of soil accumulation in Viking Age homefields of unknown, non-uniform shape and extent, perhaps making homefield management practices more visible. Preliminary analysis has suggested that erosion may be inferred from soil cores by correlating missing tephra layers with shallow soils, in dry areas not subject to turf cutting, and Voronoi statistics further suggest that temporal continuity in accumulation and encroaching erosion fronts can be modeled within subfarm microenvironments.

The coring data should be more strongly integrated with other archaeological datasets, including faunal, material culture, and botanical analyses as indicators of status, as well as soil chemistry analysis to verify the correspondence between soil accumulation rate and soil quality. Farm mound volume could be incorporated into the study by using the depth of cores taken during the mound survey. Similarly, an attempt could be made to trace mound growth over time by using the less common tephra layers to provide a snapshot of estimated farm population at the time of each isochron, expanding the work that is already complete for the 1104 layer. Cores in bogs could be surveyed for missing tephra layers to quantify the temporal and spatial extent of turf-cutting events. Satellite remote sensing data such as Landsat photography might allow precise correlations between soil accumulation and vegetation cover. Furthermore, the current research should be expanded temporally, to include, where feasible, the 1766 layer, to increase our understanding of the social processes that occurred during the late medieval period amid ever-increasing poverty, stratification, and environmental decline, against a backdrop of neglect on the part of absentee monarchs in Europe. Historical data and homefield fertility measures are more readily available for this period and may provide some interesting correlations.

Archaeological surveys often find that the investigation of adjacent regions provides information about interconnections and interfaces, vital to interpreting the settlement patterns of the initial region (i.e., Feinman and Nicholas 1999). Surveys elsewhere in Skagafjörður (or, in fact, anywhere in Iceland), particularly of regions adjoining Langholt, ideally should include landscape-scale coring protocols that can be compared and appended to the current study. Similarly, if the extent of the rivers that feed into Langholt could be mapped over time, Viking Age topography could be correlated with wealth and soil accumulation.

Settlement pattern studies have relevance to the distribution of land claims and subsequent subdivision in other archaeological contexts, including the European colonization of America (e.g., Johnson 2009). Although Iceland is certainly not an ideal analogue for the Atlantic seaboard – the active presence of Native Americans and the lack of tephra layers not least – an investigation of relative land quality with respect to trajectories of wealth formation and property division has the potential to be a fascinating study into the social relations and political economy of colonial America.

Finally, the study of past anthropogenic environmental change and its social consequences has important implications for the modern world, as we struggle with the effects of population pressure, environmental decline, and poverty on a global scale. Our collective natural resources are no more plentiful than good land in Iceland, and a rent-seeking attitude of "he who claims the best land, wins," at the expense of all others, continues to increase the divide between a wealthy elite and the impoverished majority. Iceland provides no easy answers, but its bounded and simplified example may offer a blueprint for exploring, and potentially altering, social dynamics that create and perpetuate institutions of poverty and exploitation.

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