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DEEP CORING, VIKING AGE ACCUMULATION RATES AND HOUSEHOLD WEALTH IN SKAGAFJÖRÐUR, NORTHERN ICELAND

A Thesis Presented

by

ERIC D. JOHNSON

Submitted to the Office of Graduate Studies,
University of Massachusetts Boston,
in partial fulfillment of the requirements for the degree of

MASTER OF ARTS

June 2015

Historical Archaeology Program

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DEEP CORING, VIKING AGE ACCUMULATION RATES AND HOUSEHOLD

WEALTH IN SKAGAFJÖRÐUR, NORTHERN ICELAND

A Thesis Presented

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ERIC D. JOHNSON

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ABSTRACT

DEEP CORING, VIKING AGE ACCUMULATION RATES AND HOUSEHOLD WEALTH IN SKAGAFJÖRÐUR, NORTHERN ICELAND

June 2015

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Directed by Dr. John M. Steinberg

Discerning and explaining social and economic differences is a fundamental task of archaeology, but a fine-tuned measure of household wealth is often obfuscated by the inability to account for time or demographics in the archaeological record. This project tests the ways that Iceland, settled by Norse populations between A.D. 870 and 930, provides a temporally-sensitive mode of measuring household income through average rates of deposition of architectural material and fuel refuse while also providing a context for studying the emergence of inequality in a previously uninhabited landscape. In 2014, a deep-coring survey of 11 occupational sites was conducted in the region of Langholt in Skagafjörður, Northern Iceland to supplement shallow-coring data previously collected by the Skagafjörður Archaeologcial Settlement Survey. Volumetric estimates of sites were generated in ArcGIS. Site occupation duration before A.D. 1104 was used to calculate average accumulation rates. I argue that average accumulation rates can be used as a proxy for household income and thus wealth over time. There is a strong logarithmic relationship between the average accumulation rates and occupation duration of sites, suggesting that the settlement order impacted wealth advantages. I argue that the concept of precedence, or the correlation of settlement order and wealth advantages over time, can be used to help understand the long-term dynamics of inequality in Langholt as both an economic and social process.

ACKNOWLEDGMENTS

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CHAPTER 1

INTRODUCTION

A central problem in anthropology is to understand how social and economic inequalities emerge, develop, transform and reproduce themselves over time. In the absence of historical records, the political economy of a region must be reconstructed through the archaeological record itself, through the palimpsest of human and natural action that has shaped its present form. Evidence of material differences are ubiquitous in the archaeological record. Archaeologists find evidence of larger or smaller dwellings, greater or fewer ceramics, better or worse cuts of meat from site to site. However, translating these material differences into meaningful economic and social differences is fraught with complex issues. The quantity and character of material remains are the result of a host of variables, both social and environmental, depositional and post-depositional. This project tests the ways that Iceland provides a mode of measuring household consumption rates archaeologically in a context where the anthropogenic landscape has a clear beginning. This beginning allows us to think about how inequality emerges and develops in a previously uninhabited landscape.

Between A.D. 870 and 930, Norse populations primarily from Norway and the Northern British Isles settled along the coastal regions of Iceland, a large island in the North Atlantic (Pálsson and Edwards 1972; Þorgilsson and Hermannsson 1930). As settlers interacted with this new environment, they modified it for various purposes, and the material residues from these activities entered the archaeological record. This project asks two questions: what is the average rate of accumulation of cultural material at farmsteads in Viking Age Iceland? And can this be used as a proxy for household wealth over time? If so, we can assess the degree of unequal distribution of wealth in the region as well as begin to understand what may be causing differences.

This project builds on data collected by the Skagafjörður Archaeological Settlement Survey (SASS) between 2001 and 2014 in the region of Langholt in Skagafjörður, Northern Iceland (Figures 1, 2, and 3). A representative sampling of 11 sites from the total 18 investigated by SASS in the Langholt region were chosen for this project. Coring data and test-pit excavation data were used to estimate the volume of cultural material at each site. The establishment dates of sites were then used to transform volumetric estimates into accumulation rates. Much of the data in this project was drawn from previous SASS field seasons, but key information was missing from the deepest portions of sites before the 2014 field season. A deep-coring survey was conducted in order to investigate the thickness of Viking Age deposits that were buried under meters of later deposits.

In order to argue that differences in household wealth are observable in this project, a definition of this term and its relationship to income and cycles of production and consumption needs to be developed which is translatable to the context of Viking Age Iceland. Chapter One surveys previous research attempting to use “site size” as an assessment of the quantity of material at a site resulting from dynamic variables of population size, occupation duration and material wealth. A summary of site-formation processes at occupational sites in the North Atlantic (farm mounds) shows how the archaeological record in Iceland is well suited to volumetrics-based accumulations research. In summarizing the environmental, social and economic context of the settlement of Iceland, Chapter One establishes an interpretive link between the materials contributing to the volume of a site and how they may relate to consumptive and productive household activities, labor or capital investment on Viking Age farmsteads. This is followed by a summary of the regional context of Skagafjörður and Langholt and a description of tephra layers found in the survey area.

Chapter Two outlines the methodology used for measuring accumulation rates of Viking Age sites in Iceland using a combination of coring, test-pit excavation data and GIS analysis. The aims and methods of the 2014 SASS field season are summarized including the SASS coring protocol. Chapter Two concludes with a description of how areal extent and volume were calculated for each site after exporting data to ArcGIS.

Chapter Three presents relationships between site area, volume, occupation duration and accumulation rate. Analyses are carried out in order to test the conclusions of Steinberg et al. (2016) that earlier households are bigger and wealthier in the Langholt region. Regression analysis suggests an exponential relationship between the geometric variables of area and volume. The volume of sites meanwhile is related logarithmically to their occupation duration, suggesting that occupation duration may be related to the rate of accumulation. In conclusion, regression analysis suggests that sites established earlier tend to have exponentially higher accumulation rates. Chapter Four unpacks various ways that the accumulation rate of farmsteads relates to consumption rates of fuel and architectural material and thus can be used as a proxy for the average wealth of a household over time as well as possible complications to this claim. Inter-household inequality in Langholt is then assessed and the statistical relationships presented in Chapter Three are then interpreted in light of Steinberg et al.’s (2016) data and suggestions are made for future research. The concept of precedence is used to help explain the economic and social dimensions of the relationship between settlement order and wealth advantages over time.

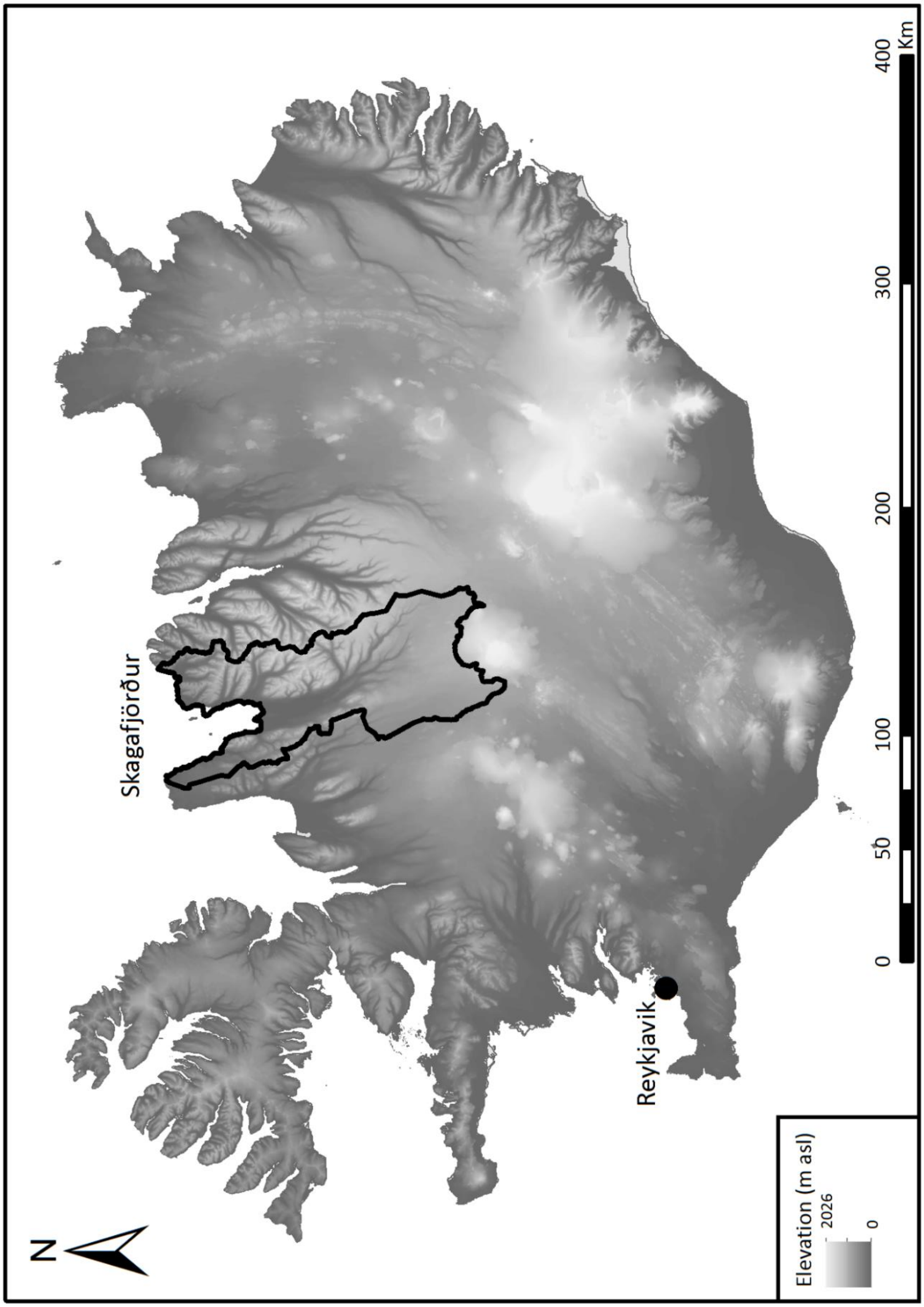


Figure 1. Map of Iceland with Skagafjörður outlined.

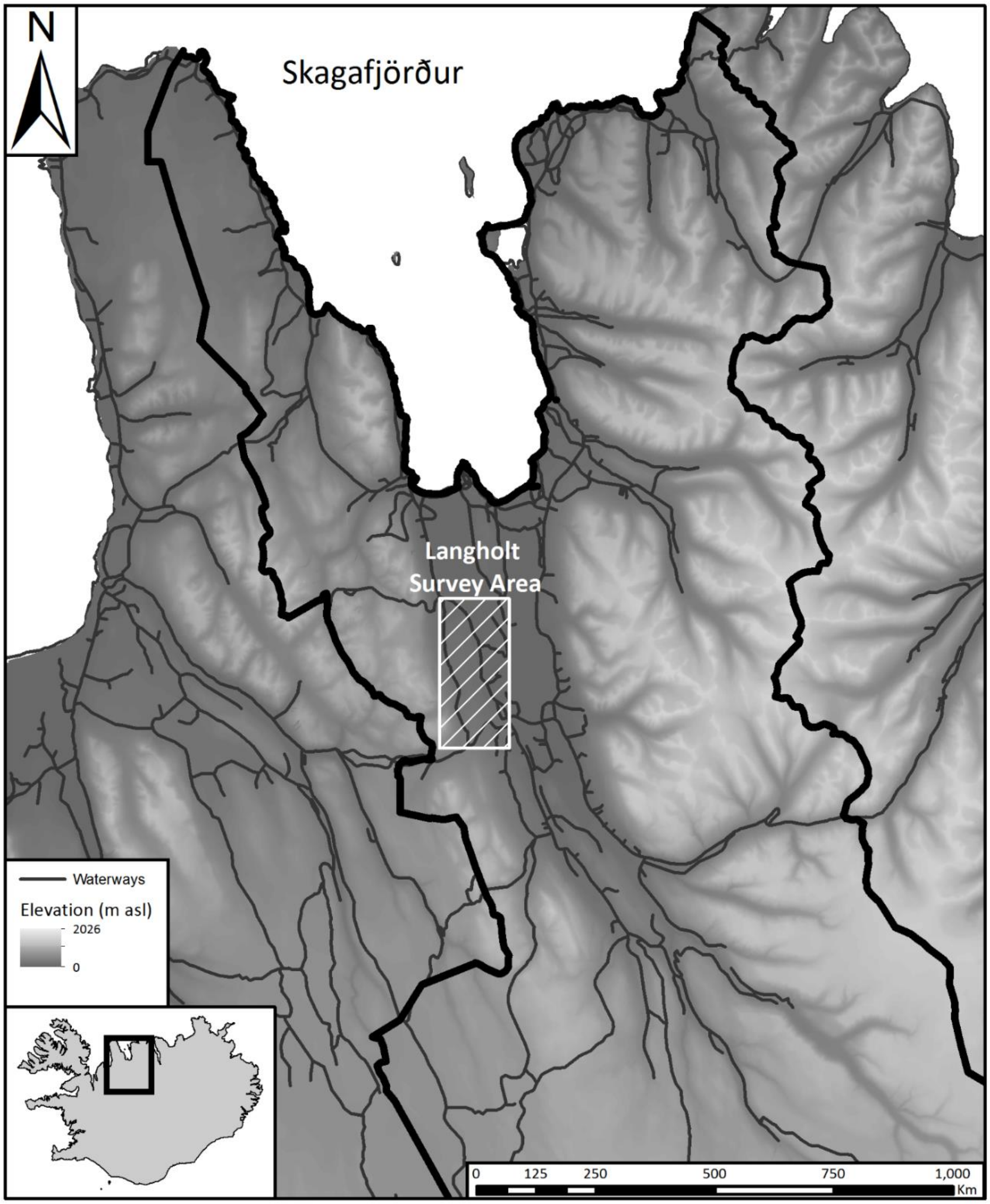


Figure 2. Map of Skagafjörður with the Langholt outlined.

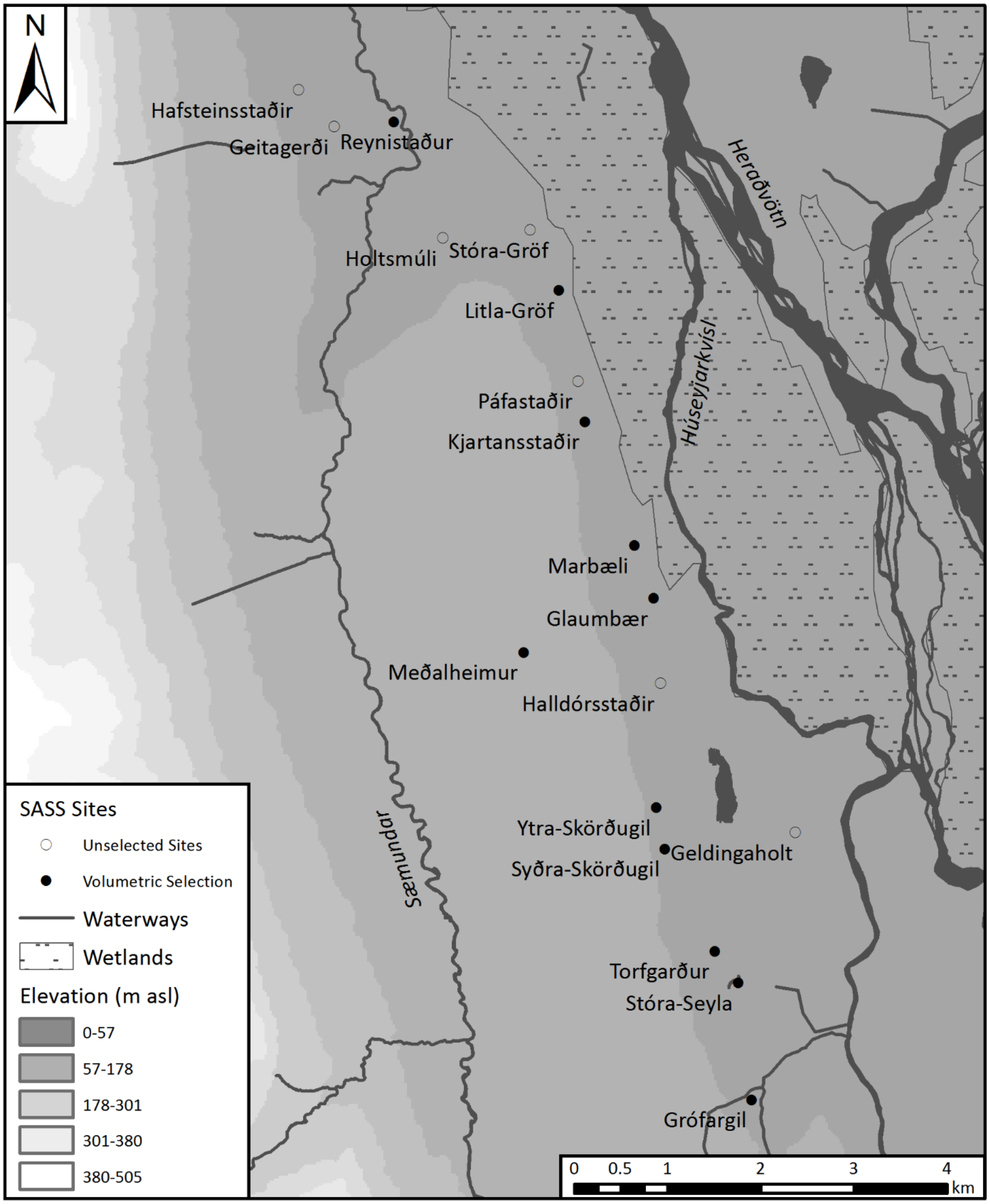


Figure 3. Langholt Survey Area; sites mentioned.

Size, Population, Time and Wealth

There are two theoretical tasks essential to understanding economic stratification using the archaeological record. First, we require an archaeological definition of wealth, a definition with a measurable proxy. Second, we need to account for confounding factors affecting this proxy. With respect to household wealth in agrarian contexts, Michael Smith (1987) notes that wealth is commonly defined in the field of economics as the total value of assets of a household. When it comes to measuring value, Smith argues that the Marxist tradition of measuring value through labor input is the most useful for archaeologists, given that labor-time can be measured through ethnographic or experimental analogy. Hence, the quantity of material at a site resulting from human labor may be used as a proxy for wealth. Extrapolating into pre-capitalist archaeological contexts, Smith breaks down this aggregate definition of wealth into basic categories of labor (both in the form of slaves and servants), portable wealth (both produced and consumed goods) and non-portable wealth (land and buildings).

A major complication of this definition, for both economics and archaeology, is that wealth is generally measured at one moment in time. It does not fully account for the actual process of how wealth is accrued or spent over time through productive and consumptive cycles. Take, for example, Household A and Household B. Household A has a smaller income than Household B but spends less and saves more per year. Household B has a higher income but disproportionally higher rate of consumption. At one moment in time, Household A may technically be wealthier than Household B by Smith's definition. However, this higher consumption rate of Household B should not necessarily be considered "waste"; in some cases what looks like consumption archaeologically may be an investment in social or material capital. Over time, therefore, Household B may be wealthier than A given a rate of return on previous consumptive investments which increases its average income. Therefore, measuring the durability of wealth over time through average income may be a better way of assessing inequality. That being said, increasing this time-scale too broadly may mask significant economic changes that can occur over shorter periods of time, as in the case of economic crises.

The methods of archaeology could theoretically be deployed for the purpose of measuring income of households, but this requires control over the variables of occupation duration and household population. As early as the turn of the twentieth century (Nelson 1909), archaeological interpretations have been based on the assumption that there is a relationship between the number of people at a site, the duration of occupation, and the accumulation of cultural material at a site (see Varien and Mills 1997). Put another way, the total amount of material modified by humans and brought to a site is a product of x number of people contributing at a rate of y over a period of time t.

Site size is a common way of estimating the amount of material at a site. Of course, definitions of "site" and definitions of "size" vary. Contributions to size that result from consumptive activities are generally secondary depositional contexts such as middens. Other studies measure size as mainly architectural material, be it monumental, residential or both. Areal extent and volume are the primary means of empirically assessing size in the archaeological record. Interpretation of these different measurements depends on the research question at hand as well as the context of the site. Areal extent, for instance, is generally used to understand demographic variables, whether at the scale of multi-household units or single households. Volumetric assessments of a site fall under two main categories: accumulations research of middens or labor-input estimates for monumental architecture. These various types of research are summarized below. Not all of these studies are concerned directly with economic differences between sites, but each wrestles with at least two of the variables at the complex intersection of site size, population, time and wealth and are therefore relevant to the current project.

In measures of consumption, accumulations research uses the total quantity of certain artifact types such as ceramics or shells to determine the occupation durations or accumulation rates of sites. This then provides inferences about ancient demography, site-formation processes, seasonality and abandonment cycles or sociopolitical dynamics (Pauketat 1989; Stein, et al. 2003; Varien and Ortman 2005). Where secondary depositional contexts create mounded deposits over time, volumetric estimates of middens have been used to assess the total amount of material constituting middens. Studies of shell middens are the most common kind of accumulations-based volumetric research (Cannon 2000; Cook 1946; Gifford 1916; Heizer and Cook 1956:231-232; Nelson 1909; Stein, et al. 2003). Ethnoarchaeological studies of midden accumulation, meanwhile, help to clarify the sometimes complex relationship between the volume of middens, the number of households contributing to middens and their associated kin-based or spatial networks (Beck and Hill 2004).

In measures of production—broadly defined here as human energy expended to contribute to the size of a site—wealth can be understood through a Marxist framework of economic value through labor, hence the branch of “energetics research” in archaeology that emerged in the 1980s (Smith 2004:92). Implications for social stratification will vary, of course, depending on whether labor is assumed to be coerced or independent. In contexts where the size of a site refers to the volume of earth moved for the purpose of monumental architecture, size is often interpreted as a degree of social power through control over labor (Abrams 1994; Arnold and Ford 1980; Blitz and Livingood 2004; Cheek 1986; Payne 1994; Turner, et al. 1981). This, in turn, also has implications for estimating population (Webster and Kirker 1995). However, all of these cases must account for the variable of time in order to make conclusions about power or demography. In the context of Mississippian mounds for example, Blitz and Livingood (2004) found that only 10 to 40 percent of the variation in the size of mounds could be explained by occupation duration alone; they conclude the rest of the variation might be explained—among other possibilities—by different degrees of control over a labor force.

When site size is understood as a household-based independent architectural construction, the areal extent of a site is most commonly used as an index of population size. In multi-household geographical units such as villages or communities, site area represents the extent of a settlement, and this can be used as a proxy for population (Brumfiel 1976; Healy, et al. 2007; Kvamme 1997; Schreiber and Kintigh 1996). At the scale of household archaeology, the floor space of a site and/or the number of rooms within the house is often assumed to relate to the number of household members (Cook and Heizer 1968; Naroll 1962). That being said, ethnoarchaeological studies have shown stronger correlations between house size and wealth or status rather than the number of household members, even if the house size is not the primary *cause* of wealth (Wilk 1983). Therefore, measuring the areal extent of a dwelling is not a measure of wealth per se, but it may be a measure of the effect of wealth differences. To confound things further, the number of household members and the wealth of a household have been found to correlate cross-culturally (Netting 1982:660; also Smith 1987:323). Therefore, household size, duration of occupation and overall wealth of a household may all co-vary with a single archaeological variable: areal extent.

These studies of site size, ranging from volumetrics-based accumulations research to studies of site area and population, are key to understanding the archaeology of Viking Age Iceland, both for methodological and interpretive insight. In the case of the Skagafjörður Archaeological Settlement Survey (SASS), a site, often the deepest component of a farm mound (see below), typically represents an individual household unit. After determining the location of sites using prospective coring and geophysical surveys, SASS then conducted a more targeted coring survey to determine the presence and absence of cultural material accumulated in the Viking Age with the help of terphrochronology. As defined by Steinberg et al. (2016), areal extent "denotes the maximum site expanse possibly reached before A.D. 1104." The size of a dwelling and the spatial extent of refuse disposal are subsumed within the variable of site area. For these reasons, Steinberg et al. (2016) have argued that site area is a variable that can be used as a proxy for both the number of household members and overall household wealth (following Netting 1982). Hence, "big" acquires a triple meaning, implying the size of a site, a household's population and its ability to loom large in the political landscape by being situated on the more productive land or through control over resources. But is this the case? Is a more "spread out" farmstead wealthier? Is areal extent indicative of the total quantity of material at a site per year of occupation? As summarized above, areal extent (a two-dimensional measure) and volume (a three-dimensional measure) can each be understood as their own proxy for wealth using different lines of argument. However, it is possible that population, occupation duration and wealth might each might affect area and volume differently. Understanding these differences is key to understanding the utility and limitations of each measurement as a proxy.

This project transforms a measure of the total quantity of cultural material at a site, which is inherently a sum of depositional events over time, into a synchronic variable that can be used to compare sites across a region during one time period (Smith 1992). In many other areas of the world, the limitations of the archaeological record make this an extremely difficult, if not impossible, task. But as will be shown by the end of this chapter, the specific environmental, social and economic context of Iceland makes this type of research possible. An index of the average accumulation rate of a Viking Age farmstead may be a more sensitive measure of household wealth than areal extent given that it takes both the depth of deposits and the duration of occupation into account. What is needed is to combine the rich archaeological and anthropological literature on site size, population, time and wealth—mostly produced within the Americanist archaeological tradition—with the study of site formation in the North Atlantic (studies of farm mounds) in order to better understand how social stratification can develop in the process of settling a previously uninhabited landscape.

Farm Mounds

Farm mounds are archaeological features found throughout Iceland, Greenland, northern Norway, the Faroe Islands and the Orkney Islands (Bertelsen and Lamb 1993). They result from continued occupation at a single location over a period of time. The build-up of architectural and refuse material over time creates a mounded deposit which is typically visible on the surface (Figure 4). In comparison to other types of mounded archaeological features such as monumental Mississippian mounds, Mayan house mounds or burial mounds of various types, farm mounds have more in common with Near Eastern tells given their mode of accumulation. The primary difference between them being that farm mounds are generally inhabited only by a single household (see Vésteinsson 2010 for a recent overview). Social and economic explanations of farm mounds vary, but a common denominator is that they result in specific arctic and subarctic environments in the North Atlantic with a stable, relatively dispersed household-based settlement pattern (Urbańczyk 1992:105-120). Depending on the region, farm mounds generally date from as early as the late Iron Age into the early modern period. In Iceland the earliest possible date for a farm mound would be consonant with the settlement ca. A.D. 870. When it comes to accumulations-based volumetric research, farm mounds in the North Atlantic are double-edged swords. The environmental and social conditions that produce farm mounds provide archaeologists with a means of quantitatively measuring the material remains of household practices as a tangible volumetric accumulation – i.e. mounding from peat ash, architectural debris, etc. Additionally, tephra layers in Iceland allow this accumulation to be tracked with a great degree of temporal precision. However, the process of mounding itself also produces the greatest challenge to studying the earliest phases of a farm mound: access. Many archaeological sites in Iceland are continuously occupied from the Viking Age to today. This primarily post-Viking Age duration creates the farm mound as we recognize it today, burying the Viking Age components of a site beneath meters of accumulation. Thus, in reviewing this literature, it must be remembered that a "Viking Age farmstead" and a "farm mound" are not entirely synonymous. Even though they are made of similar

Figure 4. Sydra-Skorðugil farm mound.

types of deposits, their spatial extent may be very different. Viking Age cultural deposits in Langholt for example that are buried under later farm mound deposits often spread out beyond the edge of the farm mound itself (Steinberg, et al. 2016). This project develops a deep-coring methodology to contend with "the farm mound problem" and take advantage of the unique opportunities farm mounds pose to the study of the settlement of Iceland.

Research on farm mounds has operated at two levels of explanation: 1) an understanding of what constitutes a farm mound and its formation processes and 2) the social and economic causes or implications of their emergence in the North Atlantic landscape. This project focuses less on the reasons for their emergence and more on the reasons behind their variation in size, but a general understanding of previous farm mound debates is necessary in order to understand how variations in size may relate to wealth differences.

While there is a general consensus on how farm mounds form among scholars working in different regions across the North Atlantic, key differences in presumed formation-processes lead to very different social and economic explanations depending on the region. For example, most agree that the bulk of the material constituting a farm mound is turf used for architecture followed by household refuse including ash as well as natural accumulation (Bertelsen 1984; Hallgrímsdóttir 1991:115-116; Snæsdóttir 1990:18; Urbańczyk 1999:132; Vésteinsson 2010), but in Northern Norway and the island of Sanday in Orkney, animal dung has been cited as a primary farm mound constituent. Following this line of evidence, farm mounds are believed to emerge along with changes in fertilization practices, whether due to the inherent fertility of the soil (Davidson, et al. 1986) or increased participation in the fishing trade with mainland

Europe (Bertelsen 1984:7-8; Brox and Munch 1965; Holm-Olsen 1981; Munch 1966, 1973; see Urbańczyk 1992:105-116 for an overview in English; Urbańczyk 1999). Buckland et al. (1994:16-18) follow this hypothesis into Iceland, suggesting that as labor was diverted to fishing in the medieval period, the labor of spreading manure over the infield was neglected and therefore contributed to the increased accumulation rates of farm mounds. Simpson et al. (2008:523) suggest that in certain local environments in Iceland, regular manuring in the first three centuries after settlement may have reached a "plateau" which necessitated less manure in order to sustain the productivity of home fields in later periods.

Working in Northern Norway, Bertelsen (1979, 1984) has contested this hypothesis on two grounds. First he argues that dung is not a significant enough contributor to the total volume of a farm mound to warrant a change to fishing economy as a full explanation. Second, his study of farm mounds in the Harstad area did not suggest a strong correlation between the size of a farm mound and the proximity of a site to fishing grounds. More recently, Mook and Bertelsen (2007) have offered a functional explanation. Using experimental methods, they claim that farm mounds consist mainly of heat-producing organic material, arguing that farm mounds are an adaption to the marginal environments in which they are located (see also Urbańczyk 1999).

Explanations of the emergence of Icelandic farm mounds have focused on the build-up of architectural material over time resulting from changing architectural forms (Vésteinsson 2010). Therefore it is necessary to first summarize the archaeology of an Icelandic farmstead and changing architectural materials and technologies over time (Byock 2001:358-368; Ólafsson and Ágústsson 2004; Sigurðardóttir 2008; Urbańczyk

1992:79-104; 1999; van Hoof and van Dijken 2008). Buildings in Iceland from the Viking Age to the twentieth century were primarily constructed from three materials: turf, wood and stone. Turf is a complex of root matter formed from a system of bog plants which tangle into a tough, coarse material that can be cut into specific shapes for different uses (Sigurðardóttir 2008:3). Due to the arrangement of cells in the leaves of peat mosses (genus *Sphagnum*), turf is highly absorptive, and it maintains a consistency similar to cork when dried, making it an effective insulator and building material (Mook and Bertelsen 2007:87; Steinberg 2004:62; van Hoof and van Dijken 2008:1028-1029). Archaeological and ethnohistorical data reveal that turf was generally cut into either strips (Icelandic: *stengur*) or blocks (Icelandic: *hnaus*) to build up the walls and roof of a structure (Ólafsson and Ágústsson 2004:6; Sigurðardóttir 2008:3).

Wood provided the frame of a building in the form of rafters, cross beams, roof supports and pillars as well as interior paneling and benches. After rapid deforestation following the settlement of Iceland, the primary source of timber was driftwood, primarily Scots Pine (*Pinus sp.*), spruce (*Picea sp.*) or larch (*Larix sp.*) from Russia and Siberia (Eggertsson 1993; Kristjansdottir, et al. 2001:98). Locally coppiced multi-branched birch could be used for rafters, but by the twelfth century voyages to Norway were made for house timbers (Smith, 1995: 336). Stone's durability and relative impermeability to water makes it an effective buffer between the organic material of a house and forces of erosion and degradation. Walls of barns for livestock, for example, were built with more stone to lessen the deteriorating effect of animals rubbing against the walls (Ólafsson and Ágústsson 2004:20). Floors were sometimes paved with stone, most commonly at the entrances of houses. Stone could also protect timber pillars from rot when placed beneath the pillar foundation, either in a posthole or directly on the earthen floor.

The architectural narrative in Iceland begins during the settlement period in the late-ninth century with the Viking Age hall, a building type with direct parallels in Scandinavia (Lucas 2009; Price 1995). A hall (termed *skáli*, pl. *skálar* in the medieval period and later) is generally comprised of one oblong structure, usually with the longer sides bowing outwards, built of turf walls and an internal timber frame with possible wooden partitions on one or both ends (Figure 5) (Ólafsson and Ágústsson 2004). This is generally thought of as a multi-purpose dwelling area, though not without localized activity areas (see Lucas 2009:373-376; Milek, et al. 2014). Recent large open-area excavations have revealed that outbuildings are a major component of Viking Age farmsteads (Lucas 2009; Milek 2011). Outbuildings may have served as smithies, cattle byres, hay barns, storage buildings, places of textile production, lavatories, corn-drying kilns or specialized cooking buildings (Berson 2002; Milek 2012:85).

Non-architectural deposits on Icelandic farmsteads include cultural debris consisting primarily of ash, turf and charcoal. Concentrated layers of these deposits can be used to identify and determine the spatial extent of a site (Steinberg, et al. 2016). Household middens form primarily as a locus of fuel refuse deposition (Simpson, et al. 2003; Vésteinsson and Simpson 2004), but they also contain discarded turf as well as zooarchaeological and ethnobotanical material. The nature and shape of middens can vary, sometimes spreading as a thin sheet, other times concentrated in a pile near the dwelling or filling in abandoned semi-subterranean structures (Lucas 2009:380; Vésteinsson and Simpson 2004). It should be noted that the volume of a midden does not account for the total amount of fuel burned at a site. Lucas (2009:382), for example, found at the site of Hofstaðir that the volume of ash accumulated in midden areas was comparable to ash that had accumulated and been compacted in floor spaces inside the structure.

How does this description of a typical Viking Age farmstead relate to explanations of farm mound accumulation in Iceland? First of all, there have been very few complete excavations of farm mounds in Iceland, but where they have taken place—such as at Stóraborg—excavators emphasize turf architecture as the main contributor to farm mound volume followed by fuel refuse such as peat ash (Snæsdóttir 1990:18). This leads Vésteinsson (2010) to suggest that the formation of farm mounds can be attributed to the increased centralization of structures on Icelandic farmsteads combined with the relatively rapid maintenance frequency cycle of turf architecture. At some point during or after the Viking Age, architectural styles change. The farmhouse becomes more differentiated (i.e. consisting of more single-purpose rooms), leading to the development of the "passageway farmhouse" in the medieval period (Figure 6) (Ólafsson and Ágústsson 2004). Regardless of the reasons for this architectural transition, it results in an increase in the number of turf walls in a more localized area, possibly contributing more to the formation of a farm mound.

Turf breaks down quickly compared to most other types of building materials. Maintaining a turf house requires new material to be added to the structure every decade, if not annually, to replace eroded, cracked or crumbling turf (Steinberg 2004:63; Urbańczyk 1999:129; van Hoof and van Dijken 2008:1028). This implies that the entire architecture of a turf house would be completely replaced once or twice every century, depending on environmental conditions. Farm mounds accumulate more rapidly if material is not removed from the site during maintenance or reconstruction (Vésteinsson 2010:19). Vésteinsson (2010:23) also claims that peat ash has a higher mineral content than wood ash, meaning that peat ash as a fuel resource will contribute more to the volume of a mound than wood ash. Therefore changes in fuel resources may also contribute to higher accumulation rates over time (see also Simpson et al. 2003; Vésteinsson and Simpson 2004). However, without more comprehensive data characterizing the relative percentages of wood ash and peat ash and their respective volumetric contributions and degradation rates over time, this should be considered a tentative explanation.

Three relevant points come from previous studies of farm mounds. First, if Vésteinsson's hypothesis is correct, early farmsteads may have a different spatial extent than their later counterparts, and this change in areal extent may not relate to a change in wealth or population over time. Put another way, Viking Age farmsteads may be more "spread out" than later farm mound deposits, but earlier volumetric accumulation rates may be comparable or possibly slower if the number of turf walls increases with later farms. It is still unclear when exactly the process of "centralization" begins due to the current lack of excavated medieval farmsteads (Vésteinsson 2004:74-75). Additionally, where sites are continually occupied from the Viking Age into later periods, a methodology is required to measure deeply-buried Viking Age deposits independently from later (i.e. farm mound proper) deposits.

Second, the primary types of cultural deposits spanning the Viking Age to the nineteenth century are relatively consistent. This continuity can help refine the use of volume as a proxy for wealth using ethnohistorical records from later periods as long as key differences are taken into account. Changing fuel sources (Vésteinsson and Simpson 2004) and changing architectural forms (Ólafsson and Ágústsson 2004) are two such differences.

Third, most studies of farm mounds have focused on the reasons why farm mounds emerge, but few have attempted to draw meaningful conclusions from their variation in size. Bertelsen (1984) is a key exception; he found a correlation between the maximum length of farm mounds in Northern Norway and the number of cattle on a farm in 1723. This may be analogous to Wilk's (1983) ethnoarchaeological study of the Kekchi Maya where house sizes and the number of pigs owned by a household were found to correlate (see above). Bertelsen's correlation perhaps measures the *indirect effects of wealth* as manifested in larger house sizes. If this is the case, farm mounds and their buried Viking Age deposits have untapped potential as a means of measuring social and economic differentiation in Iceland independently of and in conjunction with historical records. But before moving to the method of accessing this data, we must understand the historical and environmental context of the settlement of Iceland and the specific conditions in the study area of Langholt in Skagafjörður, Northern Iceland.

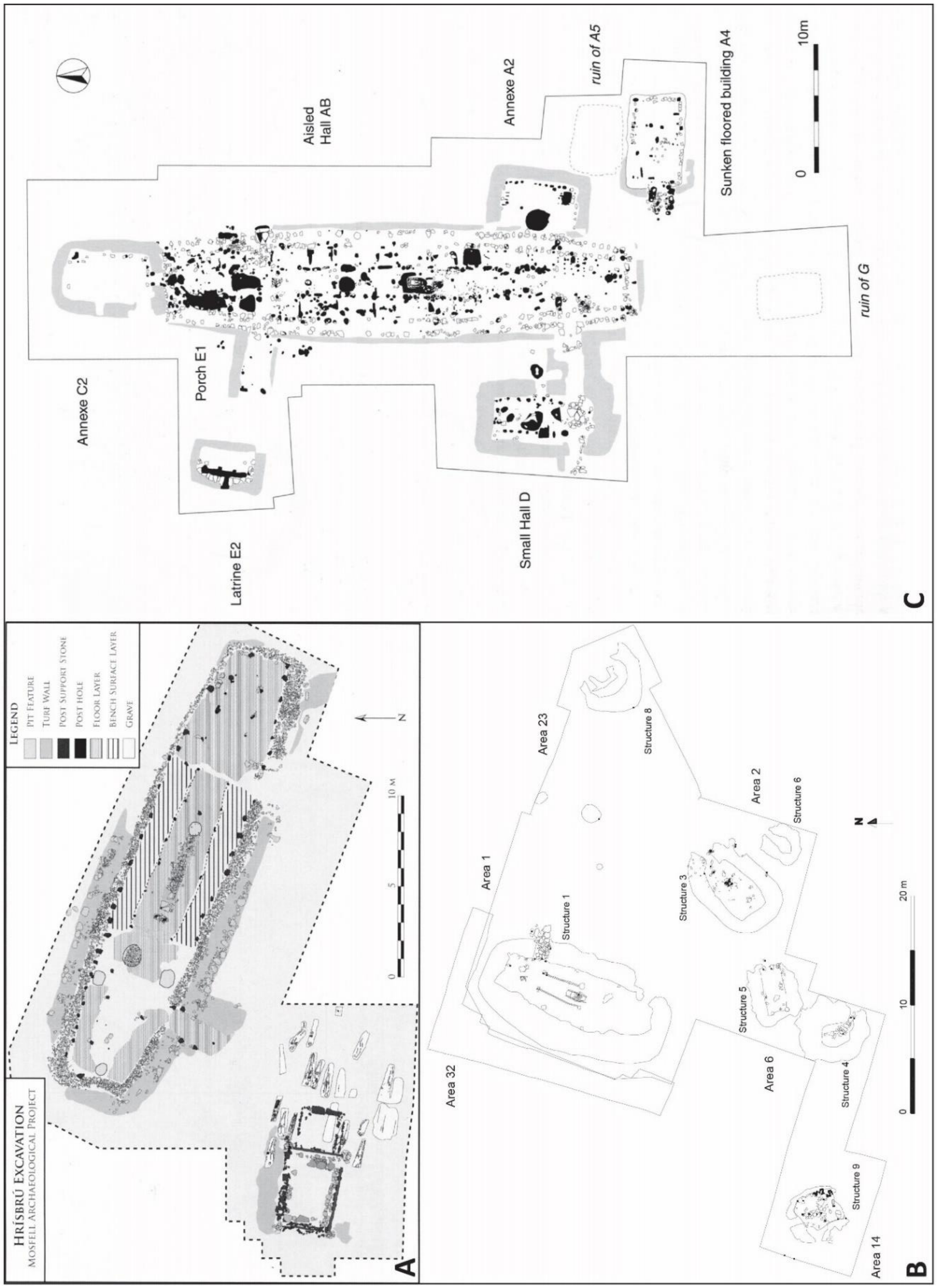


Figure 5. Viking Age farmstead excavations and houseplans. **A**. Hrísbru in Mosfel (Zori and Byock 2014) **B**. Hófstaðir in Mývatnssveit (Lucas 2009) **C**. Vatnsfjörður in the Westfjords (Milek 2011).

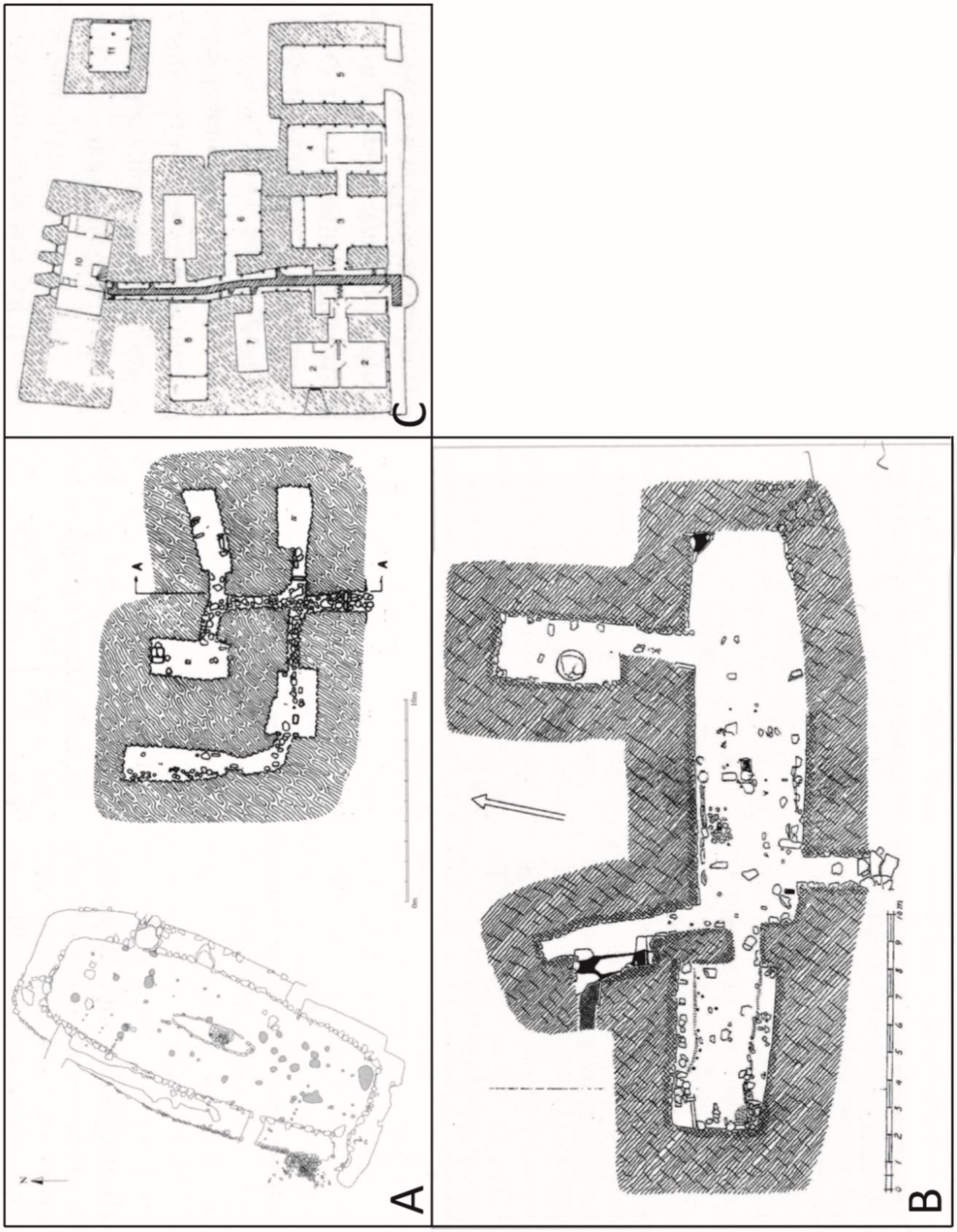


Figure 6. Passageway farmhouse excavations and houseplans (Vésteinsson 2010). **A**. Plans of Aðalstræti, a tenth-century farm to the left, and Sandártunga, abandonded in 1693 to the right, illustrating the differences in wall thickness. **B**. Plan of Gjáskógar, typical of farms in the South of Iceland in the eleventh through the thirteenth centuries. **C**. Plan of the modern turf-farm at Laufás, Northern Iceland.

The Settlement of Iceland

Iceland is a large volcanic island located on the mid-Atlantic ridge between the North Atlantic Ocean and the Arctic Ocean. Frequent volcanic eruptions result in layers of ash that fell on different portions of the island at different points in history. These ash layers, or tephra layers, can be used to date deposits in the archaeological record using tephrachronology (Dugmore, et al. 2004; Dugmore, et al. 2000; Thórarinsson 1981). Despite Iceland's location between latitudes 63° and 67° N, just south of the Arctic Circle, the island is warmed by the Gulf Stream and has a temperate climate. Most of the interior of the island is an uninhabitable highland plateau of sand, mountains, glaciers and lava fields, but the coastline of Iceland traces a series of habitable and in some cases fertile fjords. Settlement took place mostly in lowland coastal regions but also in interior valleys.

The study of the Norse settlement of Iceland (also known as *landnám*) is at present a well-established interdisciplinary topic at the nexus of history, literature, archaeology and paleoenvironmental studies. Icelanders documented the events of *landnám* centuries after they took place. These documents, such as the *Book of the Icelanders* (*Íslendingabók*), the *Book of Settlements* (*Landnámabók*) and the body of prose literature known as the Icelandic family sagas were transcribed in the twelfth and thirteenth centuries. The historical accuracy of these documents, especially with regards to the ninth and tenth centuries, has been debated (see Friðriksson and Vésteinsson 2003). Generally, archaeologists regard these textual sources with healthy skepticism, using archaeology as an independent means of evaluating *landnám* and testing various models of settlement they suggest. Evidence collected over the past two decades broadly correlates with the basic sequence of events depicted in textual sources (McGovern, et al. 2007; Smith 1995; Vésteinsson 1998, 2000a; Vésteinsson and McGovern 2012).

Textual sources and DNA studies confirm that Norse populations migrated to Iceland primarily from Norway and the British Isles beginning around A.D. 870 (Helgason, et al. 2001; Smith 1995:320). A tephra layer resulting from the eruption of Mt. Hekla in A.D. 871±2 coincides with the earliest archaeological sites on the island. The household was the primary unit of production and consumption in Iceland throughout the Viking Age and into the modern period. Settlers brought with them a Scandinavian agropastoral economy. Domestic sites in Iceland throughout most of its history were farmsteads operated by households. Households in this case were made up of a nuclear family in addition to extended relatives, servants and slaves (Byock 2001:84; Christiansen 2002:48; Karras 1988; Smith 1995:320), although slavery appears to decline in the eleventh century after the introduction of Christianity in A.D. 1000. Archaeological evidence largely confirms this single-household model, with the exception of some of the earliest settlements which consist of two or more coincidental dwellings and thus possibly comprising multiple households (Vésteinsson 1998:13-17; Vésteinsson, et al. 2002:120).

The tempo of initial land claims appears to have been relatively rapid. The *Book of Settlements* describes the landscape as “fully settled” by 930 A.D., and archaeological surveys in different regions of the country confirm this timing (Dugmore, et al. 2005; Dugmore, et al. 2000; Einarsson 1995; McGovern, et al. 2007; Sveinbjarnardóttir, et al. 2006; Vésteinsson, et al. 2002; Vésteinsson and McGovern 2012). Sites that are established after 930 are generally thought to result from the splintering of larger households and subdividing of larger landholdings (Bolender, et al. 2008:221; Smith 1995:320).

With the exception of possible early multi-household clustering, settlement in Iceland was dispersed. The initial choice of land was probably determined in part by the economic demands of the settlers and the landscape itself, a landscape which looked very different than it does today. Despite suggestions from the family sagas that the subsistence base of early settlement sites was diverse (Smith 1995), zooarchaeological evidence indicates that raising livestock was the primary aim of settlers, even in locations where fishing and fowling would have been viable (Vésteinsson, et al. 2002:118-119; Vésteinsson and McGovern 2012:209). Vésteinsson et al. (2002:117-125) draw on settlement data from Hjaltastaðaþinghá, Barðaströnd and Rauðasandur to propose that the landscape was filled in first according to readily available, high quality open meadow and then later into previously forested, less productive pasture (see also Erlendsson, et al. 2006). Smaller "planned settlements" were then situated on more marginal land, a mode of site-establishment presumably orchestrated by established landholders. The geographic character of settlement based on this model will depend on the environmental context of any given region.

Studies on the environmental impact of *landnám* have revealed a stark transformation of the Icelandic landscape between A.D. 870 and 1100 (Arnalds 1987; Buckland 2000; Buckland, et al. 1991; Caseldine, et al. 2004; Dugmore, et al. 2000; Erlendsson, et al. 2006; Hallsdóttir 1996; Lawson, et al. 2007; Mairs, et al. 2006; McGovern, et al. 1988; McGovern, et al. 2007; Simpson, et al. 2004; Smith 1995; Vésteinsson, et al. 2002). According to medieval documents and palynological studies, settlers were met with a forested landscape. It is estimated that woodlands, primarily birch (*Betula pubescens*) (Hallsdóttir 1996), covered at least 25 percent of the country at the time of settlement, while today only one percent of Iceland is forested (Arnalds 1987:509). Clearance of trees and the introduction of domesticated animals and plants resulted in rapid deforestation followed by significant erosion. The timing of this process seems to have varied depending on local conditions (Dugmore, et al. 2000; Lawson, et al. 2007). In contrast to previous narratives of *landnám*, McGovern et al. (2007) have argued that this landscape transformation was not simply the result of "cognitive maladies" nor was deforestation and erosion uniformly rapid or unilaterally problematic throughout the country (contra McGovern, et al. 1988).

From the settlement into the modern period, the subsistence economy of Iceland was based primarily on the use of grassland as food for domesticated animals, both as pasture or cultivated for fodder. While horses, pigs, goats, cattle and sheep were raised in Iceland early on, sheep and cattle were the primary source of food. In terms of cattle-to-sheep ratios over time, sheep generally come to dominate the zooarchaeological record in later periods (Amorosi 1996:463-466; Vésteinsson, et al. 2002:109). Horses were not typically eaten, but they were vital to the operation of the farm. Historically, Icelanders subsisted primarily on secondary products from sheep and cow including milk, cheese and whey; milk products were probably important in the Viking Age as well, given the presence of byres in the archaeological record (Vésteinsson 1998:7). Milk products were supplemented by domestic animal meat and to a lesser extent wild animals such as fish, birds or seal. There is evidence of cereal production in the Viking Age, but soil micromorphological and total soil phosphorous studies in the southwest of Iceland indicates that cereal production was primarily low-level subsistence based (Simpson, et al. 2002). Grassland used for pasture or cultivated for hay was thus the lifeblood of an Icelandic farmstead (Adderley, et al. 2008; Amorosi, et al. 1998; Bolender 2006; Eggertsson 1998; Fridriksson 1972).

Livestock management in Viking Age Iceland is generally thought of as a system of transhumant pastoralism (Adderley, et al. 2008; Bolender 2006:25-28; Thomson and Simpson 2007). In the summer, livestock were moved into highland areas to graze so that farmers could grow and store a sufficient amount of fodder in order for overwintering livestock to survive. Culling strategies had to balance the requirements of maintaining a stock and supply of milk products with the requirements of human subsistence. The area immediately surrounding the farmhouse known as the homefield was the primary locus of hay production. In the winter, sheep were brought into the homefield to graze while cattle would have been housed in a byre over the winter (Simpson, et al. 2004) or in some cases cattle were stored in the hall itself (Milek, et al. 2014).

Outside of subsistence economy, there is some evidence of specialized production in Viking Age Iceland. Geoarchaeological evidence from semi-subterranean outbuildings on farmsteads— also known as pit houses—indicates that wool production was an important and probably gendered activity on Viking Age farmsteads (Milek 2012). Burning of fuel took place in pit houses both for warmth, cooking and as part of the textile production process itself. In a geoarchaeological study of a pit-house floor at Hofstaðir, the presence of soluble salts as well as heat-blackened and fire-cracked rocks suggests that water and urine were probably heated in the process of cleaning, fulling and dying wool (Milek 2012:117). Iron products made in Viking Age Iceland included important agricultural instruments, household tools, ships' parts, and weapons (Smith 2005). While trade was certainly important in Viking Age Iceland, it is still difficult to determine what percentage of these products were made for independent household use or exchanged in trade networks within and outside of Iceland.

Langholt, Skagafjörður

Between 2001 and 2014, the Skagafjörður Archaeological Settlement Survey (SASS) has surveyed the region of Langholt in Skagafjörður, north-central Iceland (Figure 1). Like many other fjords of Iceland, Skagafjörður is bounded on the east and west by mountainous peninsulas. The entire region extends roughly 100 km north to south. The central portion of the fjord boasts fertile lowland areas with good access to wetland and grassland areas, both at the time of settlement and today. In the process of settlement and deforestation, rapid erosion from the highlands deposited aeolian material from the central highlands to certain lowland areas including Langholt, much of which was deposited during the Viking Age itself (ca. A.D. 870-1100) (Catlin 2011).

Langholt is a region in Skagafjörður covering roughly 2000 ha of land bordered by the Húseyjarkvísl stream to the east and the Sæmundar river to the west (Figures 2 and 3). While Viking Age political and geographical boundaries cannot be known for certain, documentary and archaeological evidence suggest a certain degree of continuity with the present day landscape. The *Book of Settlements* notes 22 original land claims, and Langholt is one of these claims (Pálsson and Edwards 1972). The SASS survey area includes the entirety of the Langholt land claim as well part of another claim north of Langholt (Steinberg, et al. 2016). In contrast to more marginal regions in Iceland, many farms have been continuously inhabited since the Viking Age in Skagafjörður, creating many farm mound sites on top of Viking Age deposits (see above). However, between 12 percent and 20 percent of farmsteads in the survey—those that were abandoned or relocated—showed no surface sign and required coring and geophysical survey to locate (Steinberg, et al. 2016).

SASS has investigated roughly 18 Viking Age farmsteads in the SASS survey area (Steinberg, et al. 2016). Most of these lie in a more or less linearly constrained and homogenous environmental context between 15 and 40 m asl. Sites are bounded by wetlands at lower elevations to the east and to the west by higher elevations before the Sæmundar river. Sites are aligned roughly north-northwest, somewhat parallel to the Húseyjarkvísl stream that feeds into the larger Hérðsvötn river further north. The site of Meðalheimur is one exception to this pattern. It is situated further west and at a significantly higher elevation (90 m asl). The results of SASS indicate that farmsteads were established relatively quickly after A.D. 870. On average, a new farm was established in the survey region every 11 years, fluctuating between six and 26 years per new farm; the earliest sites were widely dispersed and later sites were established in the interstitial areas between earlier sites (Steinberg, et al. 2016).

Tephrachonology, or the use of volcanic ash layers as chronological markers (Dugmore, et al. 2004; Dugmore, et al. 2000; Larsen, et al. 2002), is a key advantage in Skagafjörður for reconstructing the early settlement history. Not only is the basic tephra sequence relatively consistent throughout the region, but certain eruption events occurred in conjunction with key historical transformations. SASS has detailed the tephra sequence in Skagafjörður, including ambiguities and difficulties of using tephra layers and radiocarbon dating to date sites (Steinberg, et al. 2016). Prehistoric tephra include Hekla

4 (H4), ca. 2300 B.C., and Hekla 3 (H3), ca. 950 B.C. The "*landnám* sequence" of tephra includes a dark layer probably from Katla ca. A.D. 860 ± 20, the well-known *landnám* layer (LNL) from ca. A.D. 871 ± 2, and a poorly understood blue-green layer tentatively dating to A.D 950. These layers bracket the settlement of Iceland, traditionally ca. A.D. 870-930 (Smith 1995; Vésteinsson, et al. 2002). Sometime around A.D. 1000, about the same time as the conversion to Christianity in Iceland (Vésteinsson 2000b), the tephra layer from Veiðivötn-Dyngjuháls fell in various portions of Skagafjörður. The easily identifiable white tephra known as Hekla 1104 (H1) layer largely corresponds with the end of new farm establishment in Langholt as well as the introduction of the tithe in Iceland in 1097 (Bolender, et al. 2008; Steinberg, et al. 2016). Two other dark tephra layers from eruptions of Hekla date to A.D. 1300 and A.D. 1766.

Of the entire tephra sequence in Skagafjörður, the H1 layer is relied on most heavily for this project. It is the thickest and most visually distinctive of the historic tephra layer. It can be identified relatively easily in both excavation and coring contexts, particularly in undisturbed midden areas of farm mounds. Unless it is identified in a block of turf that had been relocated for architecture sometime after A.D. 1104, the presence of H1 provides a quick and confident method of determining a *terminus ante quem* (TAQ) for deposits. Based on the sequence of site establishment, the vast majority of the sites identified in the survey area were established between A.D. 870 and 1104, and with a few key exceptions, many sites in the region remained in their basic location up until the present. The H1 tephra layer thus provides a temporal marker of the end of the farmstead-establishment period in Langholt.

CHAPTER 2

METHODS

Modelling the volume of Viking Age cultural deposits requires control over three main subsurface variables: areal extent of cultural deposits, depth of cultural deposits (including the deepest cultural deposit) and the depth of the Hekla 1104 tephra layer (H1). While large-scale excavation methods would provide a detailed and precise account of these variables, the costs would be largely prohibitive. Instead, this project sampled these variables across space using a combination of coring and test-pit excavation data.

In using coring surveys to determine the depth of subsurface deposits, the methods used in this project are similar to those using coring to map subsurface features (Canti and Meddens 1998; Cloutman 1988; Scarborough 1983:736). This project expands on these studies by determining a vertical measure of accumulated cultural material between two subsurface features: the deepest cultural deposit (DCD) and H1. In some core samples, the distance between these features and the sum of the total thickness of cultural material between these features were different values.[1] For this reason, subsurface contours were not mapped, but rather, the summed thickness of cultural

[1] For example, if a core consisted of an aeolian accumulation bounded above and below by cultural deposits, all of this below the Hekla 1104 tephra layer, this would result in an error if volume was calculated by mapping the subsurface contours of H1 and DCD and subtracting the difference in their depths.

material between the DCD and H1 was used to calculate a “Viking Age thickness” value per sample. This value was then interpolated across space using the areal extent of the cultural deposits as a boundary where the thickness diminishes to zero. This interpolated surface provided the Viking Age volumetric estimate that could be compared to areal extent.

Sites were selected based on their representivity and on the nature of previously collected data. Variation in areal extent was the primary variable to determine a representative sample. Eleven sites of areal extents ranging from 602 to 7,573 m^2 were chosen from the total 18 sites analyzed by SASS ($n = 10$; $\bar{x} = 4,943$; $s = 2,188$) (Table 1). From here on, this subset of the Langholt dataset will be referred to as the volumetric dataset. The number of sites included in the volumetric dataset was limited by the quality of previous data and the logistical and time constraints of sufficiently supplementing previous data during the 2014 field season. Three sites—Lower Stóra-Seyla, Lower Glaumbær and Ytra-Skörðugil—were included in the final analysis but were not cored in the 2014 field season because previous coring data was deemed sufficient to calculate a volumetric estimate for each site.

SASS has developed two “rules” for defining independent sites through prospection:

> The modern farm rule simply combined all areas on a given historically identified farm and used the earliest establishment date for that entity. The 100m rule separates areas of cultural material under the A.D. 1104 tephra into different farmsteads if there is at least 100m of interstitial space surrounding a cultural area [Steinberg, et al. 2016].

CORES: ALL FIELD SEASONS					CORES: 2014 FIELD SEASON				
Farm Name	**Site Code**	**Type**	***n***	**%**	**Farm Name**	**Site Code**	**Type**	***n***	**%**
Ytra-Skörðugil	108	T	150	5.8	Ytra-Skörðugil	108	T	0	0.0
		V	5	2.6			V	0	2.6
Grófargil	89	T	103	4.0	Grófargil	89	T	48	1.9
		V	4	2.1			V	4	2.1
Torfgarður	106	T	200	7.7	Torfgarður	106	T	6	0.2
		V	22	11.3			V	3	1.5
Kjartansstaðir	57	T	194	7.5	Kjartansstaðir	57	T	55	2.1
		V	17	8.8			V	11	5.7
Syðra-Skörðagil	107	T	350	13.5	Syðra-Skörðugil	107	T	8	0.3
		V	24	12.4			V	5	2.6
Litla-Gröf (Syðri)	60	T	191	7.4	Litla-Gröf (Syðri)	60	T	54	2.1
		V	19	9.8			V	8	4.1
Meðalheimur	1006	T	259	10.0	Meðalheimur	1006	T	21	0.8
		V	27	13.9			V	7	3.6
Glaumbær	111	T	257	9.9	Glaumbær	111	T	66	2.5
		V	23	11.9			V	7	3.6
Stóra-Seyla	104	T	229	8.8	Stóra-Seyla	104	T	50	1.9
		V	29	14.9			V	5	2.6
Marbæli	115	T	239	9.2	Marbæli	115	T	51	2.0
		V	11	5.7			V	7	3.6
Reynistaður	63	T	419	16.2	Reynistaður	63	T	71	2.7
		V	13	6.7			V	11	5.7
Total		T	**2591**	**100.0**	**Total**		T	**430**	**100.0**
		V	**194**	**100.0**			V	**73**	**100.0**

Table 1. Coring metadata. T = Total Cores, V = Volumetric Cores.

The 100m rule is used in this project because it produces the most conservative estimates for household areal extent and volume. Reynistaður 1, for example, is treated independently of Reynistaður 2, and Reynistaður 2 was not surveyed for volumetric estimates, although it is possible they represent the same household. For the sake of simplicity, the use of the site name Reynistaður in this paper will refer to the 7,573 m^2 large Reynistaður 1 referenced in Steinberg et al. (2016). The same conditions apply to the sites of Marbæli and Torfgarður. Of the two sites in the survey that were discovered to be abandoned and moved location sometime around 1100 or shortly before (Glaumbær and Stóra-Seyla), the earlier or "lower" sites were chosen for this project so as not to measure the architectural material of a site twice.

Previous SASS Work

Previous fieldwork conducted by SASS served as the foundation for this project (Steinberg 2001, 2002, 2007; Steinberg, Bolender, et al. 2009; Steinberg, et al. 2005, 2008; Steinberg, Damiata, et al. 2009). Coring, along with geophysics and test-pit excavation, is one method of the SASS prospection toolkit (Steinberg, et al. 2016). Between 2001 and 2013, over 4,000 cores were recorded across roughly 18 sites in Langholt. 2,441 of these cores were recorded at the 11 sites chosen for this volumetric analysis.

Coring and augering have been demonstrated as effective means of locating archaeological sites, determining vertical and horizontal extent of sites, determining the relationship between cultural and natural material, or obtaining material for sampling (see Stein 1986 for an overview). Stein (1991) clarifies that augering—cutting sediment or rock in a helical motion—can be more efficient, but it often disturbs stratigraphic sequences. Coring, on the other hand, is a continuous section obtained from a hollow cylinder (Stein 1986:505). SASS primarily uses different types of hollow-cylinder cores depending on the desired depth.

SASS has periodically taken advantage of coring data and tephra conditions in Skagafjörður for purposes other than archaeological prospection alone. Catlin (2011), for example, has estimated soil accumulation rates and land quality in the Viking Age using coring samples. Bolender's (2006) soil phosphate analysis from coring surveys of homefields provided evidence of agricultural investment throughout the medieval period in Langholt.

Before the 2014 field season, previous data were not collected for the purposes of estimating the volume of farm mounds. However, in many instances previous data can be effectively used for this purpose, given the in-field recording protocol standardized by SASS. Of the 189 cores selected for the final analysis, 114 (60 percent) were collected in previous field seasons (Table 1) (Appendix A). Previous test-pit and trench excavation profiles were also converted to samples to increase the sampling coverage.

Previous coring data were limited in two respects; the primary purpose of the 2014 field season was to shore up these limitations with new data. First, at some sites the areal extent boundaries were not well defined. A smaller-spaced shallow coring sampling strategy was required in these areas. Second, most cores from previous surveys were taken with a JMC Backsaver core. The JMC core has a max depth of approximately 1.2 m. Therefore, areas with post-Viking Age cultural deposits deeper than 1.2 m were not represented in datasets from previous field seasons. An Eijelkamp bi-partite gauge auger with a max depth of 5 m was used in the 2014 field season to increase the sample distribution in these areas.

Establishment dates of sites were in previous field seasons using a combination of tephrachronology and AMS radiocarbon dating of material from small-scale excavations of the earliest portions of midden areas. Steinberg et al. describe the SASS dating methodology:

> A farmstead establishment tephra date range was determined by the relationship of the lowest peat ash deposit to the surrounding tephra layers. The bottom tephra is a TPQ, while the tephra above the lowest midden deposit is a *terminus ante quem* (TAQ) establishment date. Point estimates for farmstead establishment dates were derived from the midpoint of the bracketing tephra layers. In many cases flotation or excavation yielded material for AMS dating from that earliest context….If either of the extremes of the 2σ range were narrower than the bracketing tephras, that extreme of the 2σ range was used instead to estimate the midpoint. That is the average of either the bracketing tephra or the extreme 2σ was used to estimate the midpoint, whichever was narrower [Steinberg, et al. 2016].

Possible sources of error for the establishment date include from the imprecision of the calibration curve during this date range or if the radiocarbon material was not collected from the earliest portion of the midden. That being said, Steinberg et al. argue that the basic settlement order is “quite robust and minor alterations to either farmstead size or establishment date estimates would not significantly change the overall pattern” (2016).

Field Methods

Data from previous SASS field seasons guided a judgmental sampling strategy for the 2014 field season. Fieldwork was divided into two concurrent and mutually-informing strategies: deep coring and shallow coring. For the shallow coring, a JMC backsaver core was used primarily around the edges of the farm mound to gather positive and negative evidence for the areal extent of pre-1104 cultural material and its thickness. A hammer-percussion Eijkelkamp bi-partite gauge auger core was used to collect data from the deepest portions of the farm mound. X, Y, and Z coordinates of each core were recorded in the field with a Trimble GeoXH GPS using the ISN Lambert 1993 projected coordinate system.

The JMC backsaver and the Eijkelkamp core operate on the same basic principles. For each sample, a steel cylinder with an exposed section is inserted into the ground and the intact soil column was then removed from the ground. The excess soil is scraped away with a knife to expose a profile. The JMC core (Figure 7) is 40 cm long and 1.5 cm in diameter with a built-in 80 cm extension rod. The cylinder cuts through soil using the weight of the operator placed on foot pedals. Samples were taken in 40 cm segments up to 120 cm. The Eijelkamp core (Figure 8), by contrast, is 1 m long and 6 cm in diameter. The core cuts through the soil by hammering the beating head of the handle with a 2 kg impact-absorbing steel hammer with nylon heads. After each sample segment is extracted, cleaned, and recorded, a gouge auger is used to ream material from sidewall of the borehole. This prevents the core from suctioning to the sidewall during the next sample segment. A 1 m extension is then attached to the core and the process was repeated until natural deposits are confidently reached. Soil from the borehole was kept on a tarp and then re-deposited after each sample.

The start and end depth of deposits from all time periods were recorded on a coring form in the field (Figures 9 and 10). Compaction due to friction between the sides of the cylinder and the core is a possible source of error when measuring the vertical distance of material in a core. Compaction would only affect the relative volumetric relationships between sites if there was differential compaction from site to site; it is possible that deeper deposits or deposits with more organic material were more susceptible to compaction than other deposits. Compaction was approximately accounted for in the field based on the gap between the top of a core and the topmost deposit (see Canti and Meddens 1998), but this approximation may be a source of error. However, according to Canti and Meddens (1998: 104), compaction does not affect measurements for the deepest deposits as much as higher deposits, and the majority of Viking Age deposits were found in the deepest portions of the core.

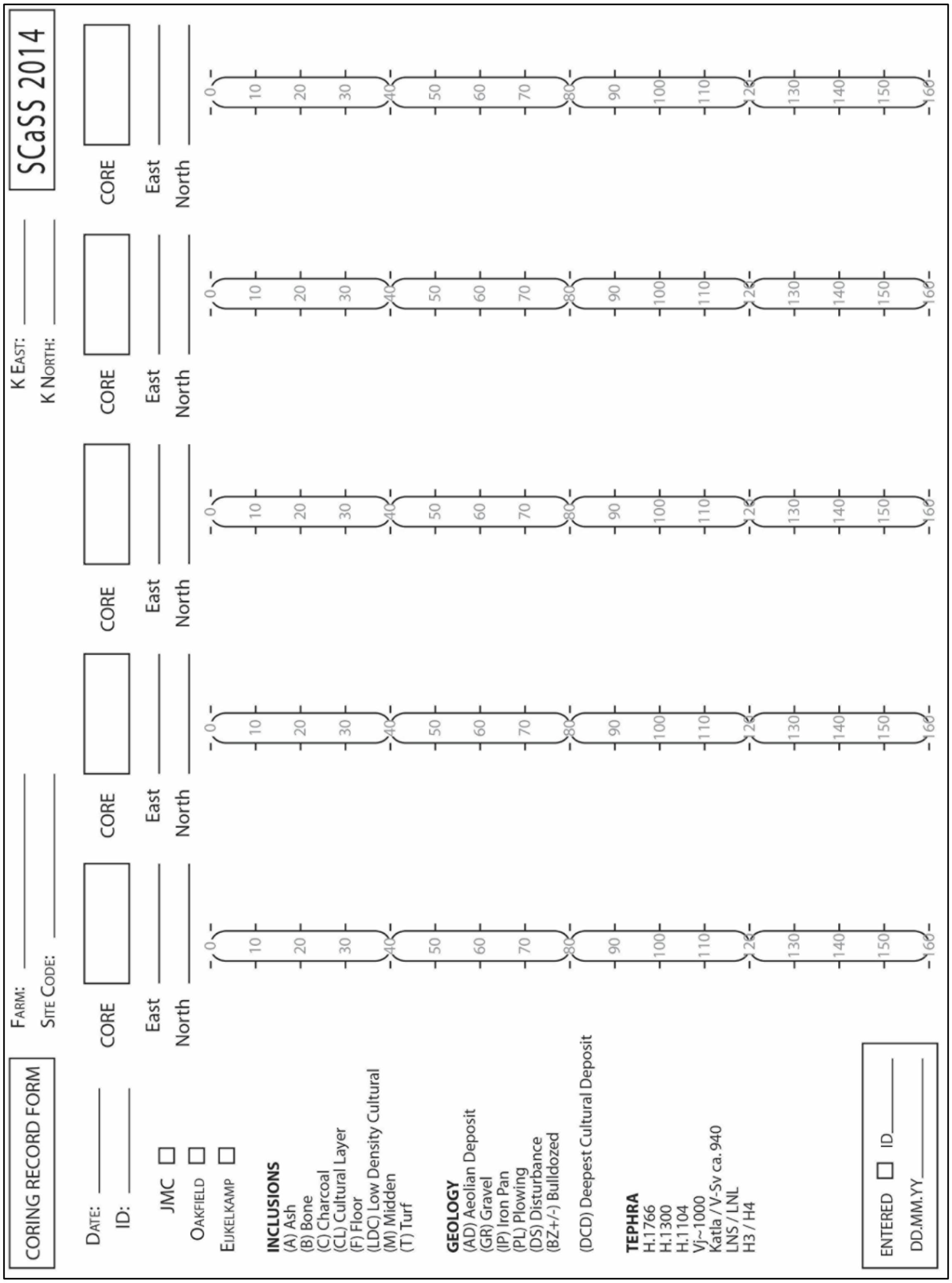
In Iceland, determining different types of deposits in a core is relatively straightforward. Table 2 provides a list of common types of deposits recorded on the form. Cultural deposits constituting a "farm mound" category included midden, turf, floor and low density cultural (LDC). Midden, LDC and aeolian accumulation categories exist on a spectrum ranging in ratios of cultural-to-natural material, and these distinctions were determined by visual in-field inspection. LDC was the minimum benchmark for a significantly anthropogenic contributor to the volume of an occupational site in the survey area. Deposits that were primarily aeolian accumulation with minimal charcoal or ash inclusions, while they are indicative of human activity, were not considered to be a farm mound deposit for the purpose of volumetric calculations. In terms of anthropogenic material, a measurement of the thickness of LDC may be inflated with a greater percentage of natural accumulation than the midden category. However, when comparing the volume of sites this will only skew our interpretation if sites have significantly different ratios of LDC-to-midden. In terms of total sampled material, Stóra-Seyla has a much lower LDC-to-midden ratio (see Table 3), but this is largely due to a clustering of samples in the midden taken in previous field seasons (see Appendix B); spatial interpolation (see below) may account for this error to a certain extent.

Table 2. Types of cultural deposits found in cores.

Deposit		Description
Common	Turf	Cut from bog and brought to site for architecture. Identified by sponge-like texture and interfaces between turf-blocks.
	Midden	Stratified layers of ash, sometimes red (probably peat ash), sometimes grey (probably wood ash). Can contain bone, ash and turf inclusions.
	Low Density Cultural (LDC)	Similar to midden, but with a smaller percentage of anthropogenic material.
Other	Floor	Stratified compacted layers of ash and other anthropogenic material.
	Rock (architectural)	Probably brought to the site for architectural purposes if found within the farm mound areal extent. Typically causes the ending of a core if found.
	Charcoal	Concentrated layer of black residue from fuel refuse, often found with ash.

Figure 7. JMC Backsaver Core. **A**. Core insertion **B.** Core cleaning.

Figure 8. Hammer-percussion Eijkelkamp bi-partite gauge auger **A**. Core hammering. **B**. Core cleaning.



CORING RECORD FORM

DATE: ___

ID: ___

JMC ☐

OAKFIELD ☐

EIJKELKAMP ☐

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

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

(DCD) Deepest Cultural Deposit

TEPHRA
H.1766
H.1300
H.1104
Vj~1000
Katla / V-Sv ca. 940
LNS / LNL
H3 / H4

ENTERED ☐ ID___
DD.MM.YY___

FARM: ___
SITE CODE: ___

K EAST: ___
K NORTH: ___

SCaSS 2014

CORE ☐ East ___ North ___
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160

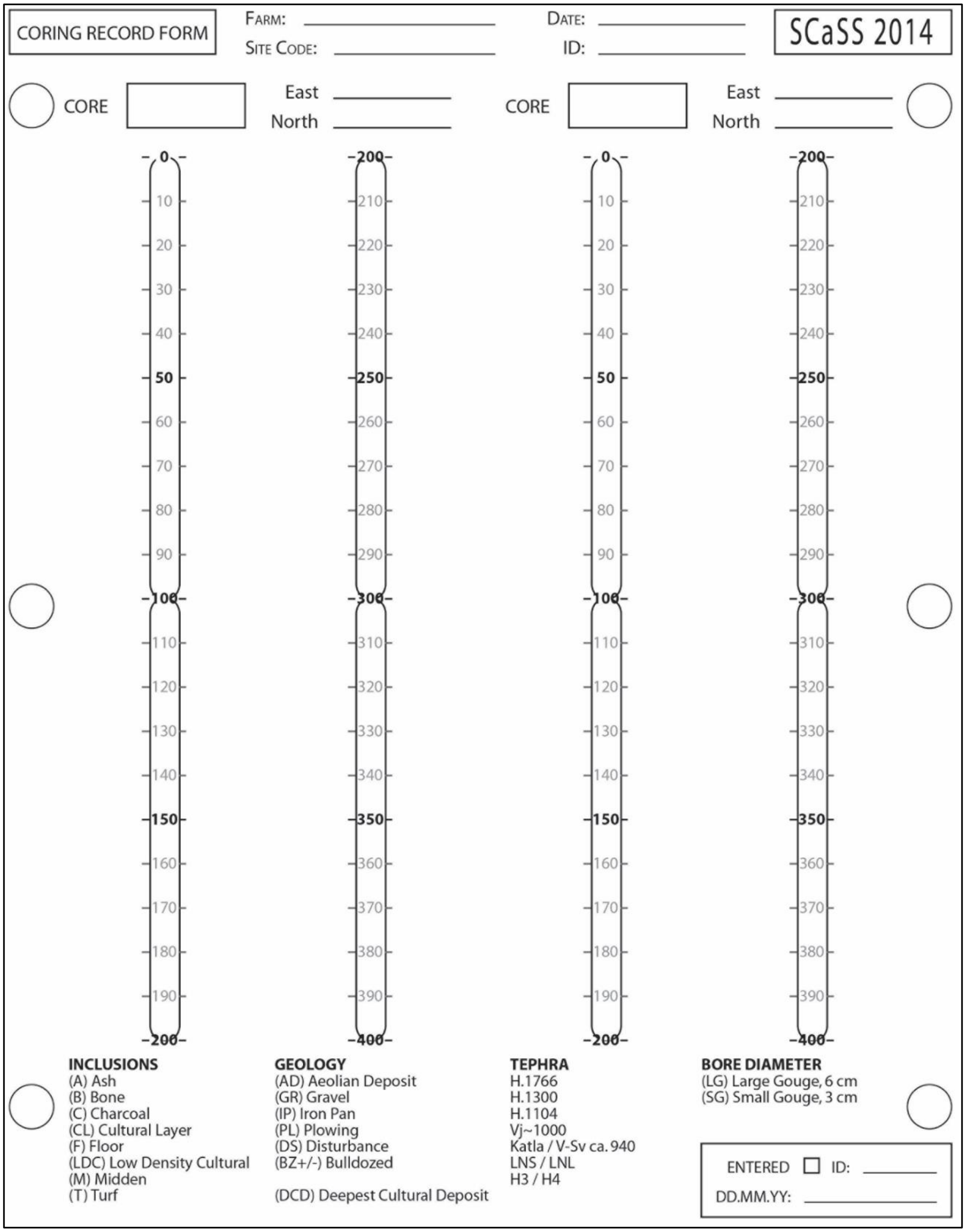
CORE ☐ East ___ North ___
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160

CORE ☐ East ___ North ___
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160

CORE ☐ East ___ North ___
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160

CORE ☐ East ___ North ___
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160

Figure 9. Shallow coring form.


CORING RECORD FORM

FARM: ____________ SITE CODE: ____________

DATE: ____________ ID: ____________

SCaSS 2014

CORE [ ] East ______ North ______

CORE [ ] East ______ North ______

0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200

200 210 220 230 240 250 260 270 280 290 300 310 320 330 340 350 360 370 380 390 400

0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200

200 210 220 230 240 250 260 270 280 290 300 310 320 330 340 350 360 370 380 390 400

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

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

(DCD) Deepest Cultural Deposit

TEPHRA
H.1766
H.1300
H.1104
Vj~1000
Katla / V-Sv ca. 940
LNS / LNL
H3 / H4

BORE DIAMETER
(LG) Large Gouge, 6 cm
(SG) Small Gouge, 3 cm

ENTERED ☐ ID: ________
DD.MM.YY: ____________

Figure 10. Deep coring form.

The volume of cultural material is also affected by taphonomic processes. The volumetric contribution of fuel residues deposited in A.D. 1800, for example, may be greater than fuel residues deposited in A.D. 1000. This would present issues for comparing volumetric rates diachronically, but for comparing sites in the Viking Age period, it is assumed here that the rate of deflation from taphonomic processes are relatively equal for sites within the constrained temporal context of the Viking Age and within the constrained environmental context of Langholt. Future micromorphological studies of midden deposits may be able to confirm this with greater certainty as well as eliminate the possibility of micro-environmental variation in deflation rates.

If a JMC core reached its max depth but did not reach pre-settlement natural deposits, this was also recorded in the field. In cases where a core was stopped by rock before reaching natural deposits (usually in the case of post-Viking Age architectural material), this was recorded and the core was moved to a nearby location. This process was repeated if necessary. Where present, the depth and type of tephra layers were recorded on the coring form in the field. Tephra layers were identified based on visual and textural characteristics. If tephra layers were observed in turf, as opposed to on top of turf, this was also noted. All coring forms were entered into the SASS coring database.

Table 3. Linear meters of sampled cultural material per site.

Farm Name	Site Code	Volumetric Cores	Sampled Material (m)			
		n	*LDC*	*Midden*	*Turf*	*Other*
Ytra-Skörðugil	108	5	0.17	0.18	0.21	0.38
Grófargil	89	4	0.08	0.09	0.42	0
Torfgarður	106	30	0.7	1.24	1.03	0.18
Kjartansstaðir	57	21	0.48	1.52	0.72	0.17
Syðra-Skörðagil	107	28	0.08	1.17	0.95	0.55
Litla-Gröf (Syðri)	60	24	2.59	5.8	0.55	0
Meðalheimur	1006	27	0.66	1.1	0.33	0.18
Glaumbær	111	27	1.76	4.41	1.41	0.27
Stóra-Seyla	104	33	0.26	11.98*	1.77	0.61
Marbæli	115	20	0.63	1.88	0.34	0.95
Reynistaður	63	24	2.47	1.06	3.05	0.32

*This value is significantly larger than the average due to a clustering of samples in the midden area at Stóra-Seyla. Spatial interpolation corrects for the effect of sample-clustering to a degree.

Viking Age Areal Extent and Thickness Calculation

The areal extent of Viking Age farmsteads was derived from the presence or absence of cultural material representing significant occupation (midden, turf, LDC) below H1 in cores. To do this, cores were exported as a point feature class in ArcGIS according to their X and Y coordinates. “Yes,” “no” and “maybe” values were assigned to each core based on presence or absence of cultural material below H1. Perimeters of farmsteads were determined using a judgmental Thiessen polygon rule bounding the areas of contiguous “yes” cores and then half the area of a “no” core, or through a “maybe” core between “yes” and “no” cores. These rules were ignored in instances of “no” results and “maybe” results where the depth of H1 was out of the reach of the core or the samples were close to unambiguous “yes” results, suggesting post-depositional disturbance. This extent was drawn as a polygon feature class in ArcGIS, and the area of each farm was determined from this shape (for a more detailed explanation of this methodology, see Steinberg, et al. 2016).

For the volumetric analysis, there were three reasons why cores were excluded: if cores were not within the areal extent of the farm mound, if they did not include in situ H1 or if they did not confidently extend below the deepest cultural deposit (see Table 1). Cores that contained the H1 tephra layer possibly in turf were also not included. Of the 430 cores taken during the 2014 field season, 68 of them were used for volumetric analysis. The rest of these were either taken outside the areal extent of the farm mound, H1 was not identified in the core or they did not confidently reach natural deposits.

After the Viking Age areal extent was determined for the sites with the addition of the 2014 field season data, the cores within this area were selected for determining the pre-1104 thickness variable. Viking Age thickness was calculated in the SASS database by summing the thickness of cultural material below in situ Hekla 1104 tephra layer and above the deepest cultural deposit (DCD) in each core. Table 3 outlines the basic characteristics of the DCD, depth of H1, and the Viking Age thickness variable per site. It should be clarified that this value is derived from depths-below-surface; it is a measure of thickness, not depth. It represents the accumulation of cultural material at a given point between the establishment date of the farmstead and A.D. 1104. The average Viking Age thickness per sample between sites ranges from 12 cm (Grófargil and Torfgarður) to 45 cm (Stóra-Seyla). Standard deviations range from 11 cm (Syðra-Skörðagil) to 38 cm (Litla-Gröf).

GIS Interpolation and Volumetric Calculation

Some of the earliest attempts at measuring the volume of archaeological sites come from studies of shell middens in California, either through an approximated geometric equation or by first obtaining the weight and density of material constituting the midden (Cook 1946; Gifford 1916; Heizer and Cook 1956; Nelson 1909). Other types of sites with more regular geometry, such as Mississippian Mounds or Maya house mounds and monumental architecture, allow for volumetric calculations using contour maps and basic geometric equations to determine an index of size (Blitz and Livingood 2004; Jeter 1984; Payne 1994; Scarry and Payne 1986; Turner, et al. 1981; Webster and Kirker 1995). Sorant and Shenkel (1984) provide equations and early computer-generated models for determining volumes of sites and strata that were irregularly shaped using contour maps, a method referred to as the contour method. More recently, Lacquement (2010) recalculated mound volumes at Moundville, a Mississippian polity in Alabama, using computer generated three-dimensional models from contour maps and photogrammetry. This method, referred to as the gridding method, is derived from the same principles of the contour method but achieves greater accuracy from the detail provided by photogrammetric maps (Lacquement 2010:345). Lacqument found that older, simplified geometric methods greatly overestimate the volume of mounds. The contour method, however, was relatively accurate when compared to the gridding method.

Previous studies estimating the size of North Atlantic farm mounds are similar to early geometric estimations of Mississippian Mounds and may suffer from the same errors noted by Lacquement (2010). Bertelsen (1984:10) simply used the maximum length as “the data closest related to the size of the activity area” of farm mounds in northern Norway. Vésteinsson (2010:18) estimated an average volume between 2000 and 5000 m^3 for Icelandic farm mounds given basic length, width and heights (note, not depths) of a sampling of 400 farm mounds, but Vésteinsson does not provide a description of his method of calculation. In addition to significant errors in estimating volume, these rough estimates are of limited utility to the study of the earliest portions of farmsteads if the relative percentages of Viking Age, medieval or post-medieval contributions to the volume of mounds are unknown.

This project differs from previous volumetric estimations by targeting the volume of sub-surface deposits rather than a total volume of the mound from topography. The thickness of the Viking Age component of a site was interpolated across space in ArcGIS to calculate the volume of a three-dimensional shape underneath this interpolation and above a plane with a height of zero.

First, cores were exported as a point feature class in ArcGIS based on their X and Y coordinates with Viking Age thickness as an attribute assigned to each point. A raster was generated in ArcGIS from this value using the natural neighbor interpolation method. The farmstead areal extent polygon was used as a boundary where the vertices of the polygon were given a value of zero and included in the interpolation sampling. Natural neighbor interpolation generates two sets of Thiessen polygons, one for the sample points and one for each query point. The proportional overlap in area between the sample point Thiessen polygons and the query point Thiessen polygons determines the weight of its neighboring values (Sibson 1981). This method was chosen as opposed to other interpolation methods because the interpolated values are guaranteed to be within the sample range, thereby avoiding exaggerated peaks or valleys in the output raster. After the Viking Age thickness raster was generated, the Extract by Mask tool in ArcGIS was used to clip the raster to the output extent of the pre-1104 areal extent polygon.

The Surface Volume tool in ArcGIS calculates the area, surface area and volume above and below a raster and a given plane. Given that the Viking Age thickness values were all positive numbers abstracted from relative depths, volume was calculated with a plane height of zero. This methodology was repeated to generate a volumetric estimate for all 11 sites in the survey (Appendix B). The range in volume across the 11 sites is 29 to 1,838 m^3 with a mean of 680 m^3 and standard deviation of 572 m^3 (Table 5).

There are three possible sources of error in these volumetric calculations. It was clear both in the field and in the GIS interpolation process that the central portions of farm mounds had been the most disturbed in later periods and very often did not contain any *in situ* H1 tephra. The midden areas generally had the best preservation. The natural neighbor interpolation method assumes that the depth of Viking Age deposits in the central portions of the mound do not vary from the outer portions even though they may have varied in thickness before disturbance. This trend was relatively uniform from site to site. Lower Stóra-Seyla and Lower Glaumbær are key exceptions to this trend; architectural areas were relatively undisturbed compared to other sites. Therefore, the volumetric estimates from these sites may be inflated relative to the rest of the survey region.

After cores were eliminated from the survey that did not contain H1 or did not reach the deepest cultural deposit, the sampling distribution became less uniform from site to site (Appendix B). In many cases this was an effect of differential preservation rather than an error in the sampling strategy, and an increased sampling coverage would have been of marginal utility. The range of the samples-per-hectare value per site is 1.7 to 7.4 (n = 11; $\bar{x}$ = 4.5; s = 2). In the absence of comparative studies or open-area excavations of farm mounds to test the accuracy of this sampling distribution, it is assumed that this coverage is sufficient to obtain a basic volumetric index of Viking Age sites.

Finally, the thickness of the deepest cultural deposits in the deepest portions of the mound, sometimes underneath up to 4 m of later deposits, was thinner than deposits outside of the farm mound. For example, there was only 1 cm of cultural material below the H1 tephra layer at the bottom of the deepest core at Syðra-Skörðagil (4.6 m deep). There are three possibilities for this unexpectedly small value. The deepest portion of a site may shift location between the Viking Age and later phases of a site. It is also possible that these deposits are affected by compaction from the weight of material above. Or this compaction may also result from the difficulty of using the Eijkelkamp core at these depths. Either way, this possible error would probably not significantly affect the total volume of the site as calculated with natural neighbor interpolation.

Farm Name	Site Code	Volumetric Cores	Deepest Cultural Deposit (m below surface)		Depth of H1 (m below surface)		Pre-1104 Thickness (m)	
		n	$\bar{x}$	***s***	$\bar{x}$	***s***	$\bar{x}$	***s***
Ytra-Skörðugil	108	5	0.68	0.10	0.56	0.13	0.19	0.16
Grófargil	89	4	0.79	0.28	0.95	0.17	0.12	0.19
Torfgarður	106	30	0.93	0.27	0.72	0.26	0.12	0.12
Kjartansstaðir	57	21	1.14	0.90	0.35	0.86	0.29	0.35
Syðra-Skörðagil	107	28	0.90	0.97	0.47	0.98	0.15	0.11
Litla-Gröf (Syðri)	60	24	1.22	0.69	0.38	0.72	0.39	0.38
Meðalheimur	1006	27	0.66	0.34	0.43	0.35	0.16	0.13
Glaumbær	111	27	0.71	0.43	0.37	0.42	0.24	0.21
Stóra-Seyla	104	33	0.96	0.37	0.31	0.41	0.45	0.37
Marbæli	115	20	0.62	0.47	0.24	0.35	0.13	0.13
Reynistaður	63	24	0.94	0.51	0.60	0.44	0.30	0.26

Table 4 Volumetric metadata - Viking Age Thickness, DCD, H1 per site.

Farm Name	Site Code	Est. Date (AD)	Pre-1104 Occupation Duration (Years)	Areal Extent (m^2)	Volume (m^3)	Volume %	Accumulation Rate (m^3/year)
Ytra-Skörðugil	108	1052	52	587	74	1	1.42
Grófargil	89	1052	52	603	29	0.4	0.56
Torfgarður	106	936	168	2,979	209	2.8	1.24
Kjartansstaðir	57	975	129	3,326	395	5.3	3.06
Syðra-Skörðugil	107	933	171	4,161	472	6.3	2.76
Litla-Gröf (Syðri)	60	935	169	4,593	978	13.1	5.79
Meðalheimur	1006	917	187	4,691	534	7.1	2.86
Glaumbær	111	936	168	7,111	777	10.4	4.63
Stóra-Seyla	104	914	190	7,179	1,664	22.2	8.76
Marbæli	115	922	182	7,209	511	6.8	2.81
Reynistaður	63	879	225	7,573	1,838	24.6	8.17
TOTAL					**7,481**	**100.0**	

All Sites	$\bar{x}$	s
Areal Extent (m2)	4,547	2,433
Volume (m3)	680	572
Accumulation Rate (m3/year)	3.82	2.60

Table 5. Farm data - area, volume, and accumulation rate per site.

CHAPTER 3

RESULTS

The volumetric estimation of cultural debris at sites in the Langholt region of Skagafjörður can be used to assess the conclusion of Steinberg et al. (2016) that farmsteads established earlier in Viking Age Iceland were both larger and wealthier. Three primary relationships were analyzed: 1) The total volume of a site is dependent on the areal extent of farmsteads according to an exponential function. However, each variable seems to be affected somewhat independently by other variables. 2) There is a strong logarithmic relationship between volume and occupation duration. This relationship itself is not unexpected, but the fact that a logarithmic model is the best fit for this relationship suggests that the rate of change in volume from site to site (i.e. the accumulation rate) varies depending on the occupation duration. 3) There is a logarithmic relationship between accumulation rate and occupation duration. This confirms the conclusion of Steinberg et al. (2016) that earlier sites tend to be wealthier; however, this relationship is not as strong as the relationship between areal extent and occupation duration would suggest.

Volume vs. Areal Extent Regression Analysis

Given that volume and maximum area are two spatial measurements of the same entity, we would expect the volume of a site to be dependent on the maximum areal extent (much like, for example, the weight of a projectile point is—in part—dependent on its maximum length). Regression analysis thus provides an appropriate test of this relationship (see VanPool and Leonard 2011:178-218). The coefficient of determination (r^2) value in this case is a measure of the percent of the variation in volume which can be explained by the influence of areal extent. Given that these are both measures of the geometry of these deposits, the goodness of fit between the regression line and the observed data is an *assessment of the geometric regularity* of Viking Age cultural deposits in the survey area according to the following function:

$$V = f(A)$$

Here, $V = volume$ and $A = maximum\ areal\ extent$. Given the dimensional difference between areal extent (m^2) and volume (m^3), geometric analogies suggest an exponential relationship between the two. Data should therefore be transformed before linear regression analysis. Take, for example, the following relationships:

Shape	$\boldsymbol{V = f(A)}$
Cube	$V = A^{1.5}$
Sphere	$V = .752A^{1.5}$
Hemisphere	$V = .376A^{1.5}$.
Pyramid	$V = .333A^{1.5}$

With these geometric relationships in mind, the following exponential function was used to assess the relationship between the maximum areal extent and volume of Viking Age cultural deposits:

$$V = f(A^{1.5})$$

This function also has the effect of converting the units of area (m^2) into units of volume (m^3).

Results from regression analysis suggest that the volume and maximum area of Viking Age cultural deposits share a functional relationship and that the exponential model is a better fit for this relationship. With the exponential model, the coefficient of determination increases somewhat ($r^2 = .632$) and the Y-intercept is closer to zero, which is the expected value for an ideal volume-to-area geometric relationship ($a = -7.53$) (Table 6) (Figure 11). This confirms the hypothesis that volume is dependent on area. However, areal extent is not fully predictive of volume. While 59 percent of the total variation in volume can be explained by areal extent, both variables are the result of other processes, some of which affect area and volume disproportionately if not independently. Examining the regression line for this analysis (Figure 11), for example, the sites of Marbæli and Stóra-Seyla have very similar areas (7,179 and 7,209 m^2, respectively) and were occupied for roughly the same duration (ca. 189 vs. 203 years), but Stóra-Seyla has three times the total quantity of cultural debris (511 vs. 1,664 m^3). This corresponds with the fact that the average thickness of Viking Age deposits at Marbæli is 13 cm while at Stóra-Seyla this value is 45 cm (see Table 4). Moving on the X-axis of the graph, the site of Litla-Gröf is 2,518 m^2 smaller than Glaumbær, but its total volume is 201 m^3 larger.

Volume vs. Time Regression Analysis

Older sites have had more time to accumulate material. Therefore time must be accounted for before site-volume can be used to understand the relationship between stratification and settlement order in Langholt. Just as volume is spatially dependent on area, volume is temporally dependent on the duration of human occupation at the site before 1104 A.D. Thus,

$$V\ (m^3) = t\ (years) \times accumulation\ rate\ (\frac{m^3}{year})$$

Expressed in terms of linear regression, if accumulation rates between the 11 sites were equal, we would expect a linear relationship between volume and occupation duration before 1104 A.D. Alternatively, if we expect earlier sites to have higher *accumulation rates*, as the data suggests (See Table 5), we would expect an exponential relationship between volume and duration. By transforming the data to a log-log relationship, the slope of the regression line becomes a measure of the functional rate of change between the x and y variables (Kvamme 1997:720). Or as stated by VanPool and Leonard,

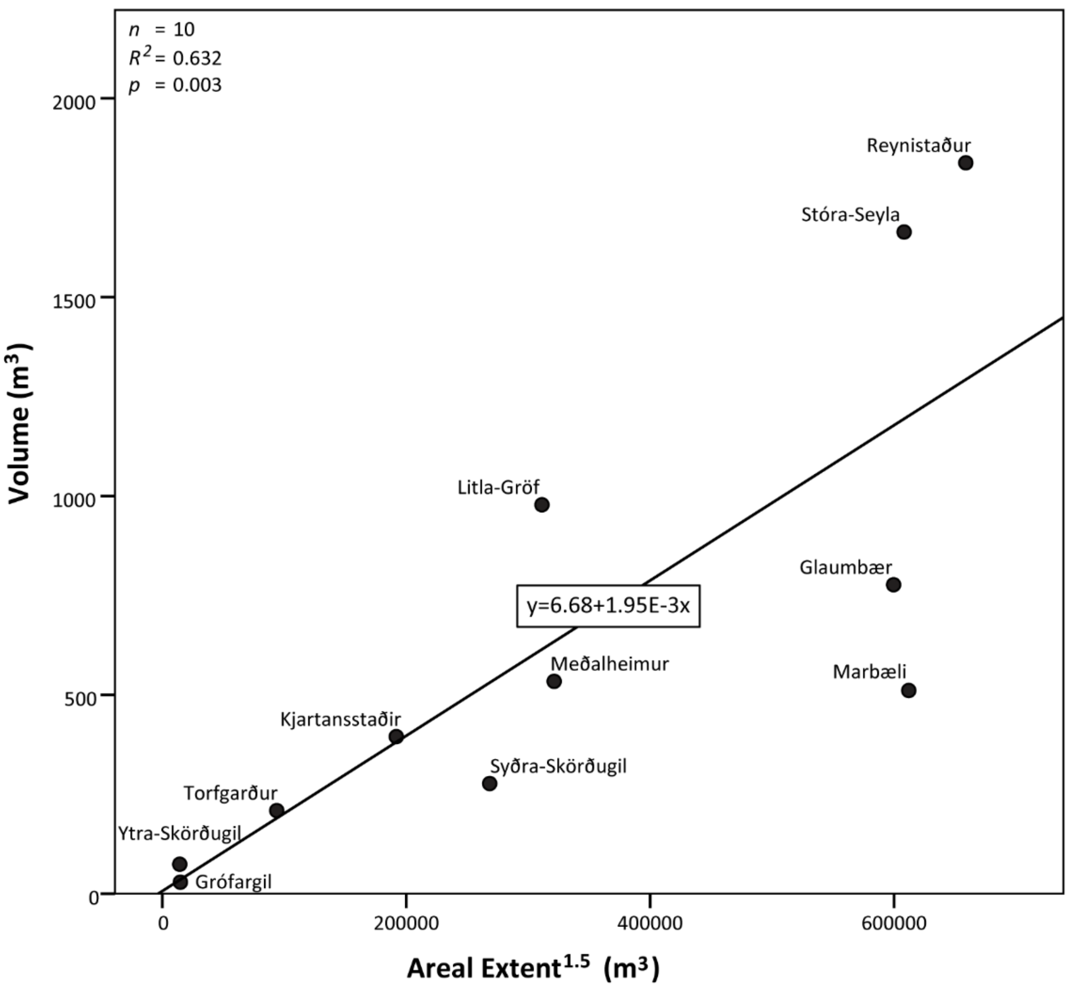


Figure 11. Area and volume regression graph. Area transformed to the 1.5 exponent.

“[logarithmic transformation] is appropriate when percentage changes in the dependent variable vary directly with changes in the independent variable to create an exponential relationship” (VanPool and Leonard 2011:216). This regression model can be expressed as $\log(V) = \log(a) + b\log(t)$, or alternatively as $V = at^b$, where *V* = *volume* and *t* = *occupation duration before 1104 A.D*.

Expressed linearly, there is a relationship between volume and occupation duration (r^2 = .453; *p* = .033). The log-log relationship between volume and occupation duration, however, is much stronger (r^2 = .767; *p* = .001) (Figure 12; Table 6). The goodness of fit with the log-log relationship suggests that accumulation rates themselves are related to the occupation duration of a site. To understand this relationship we must consider accumulation rate independently of volume.

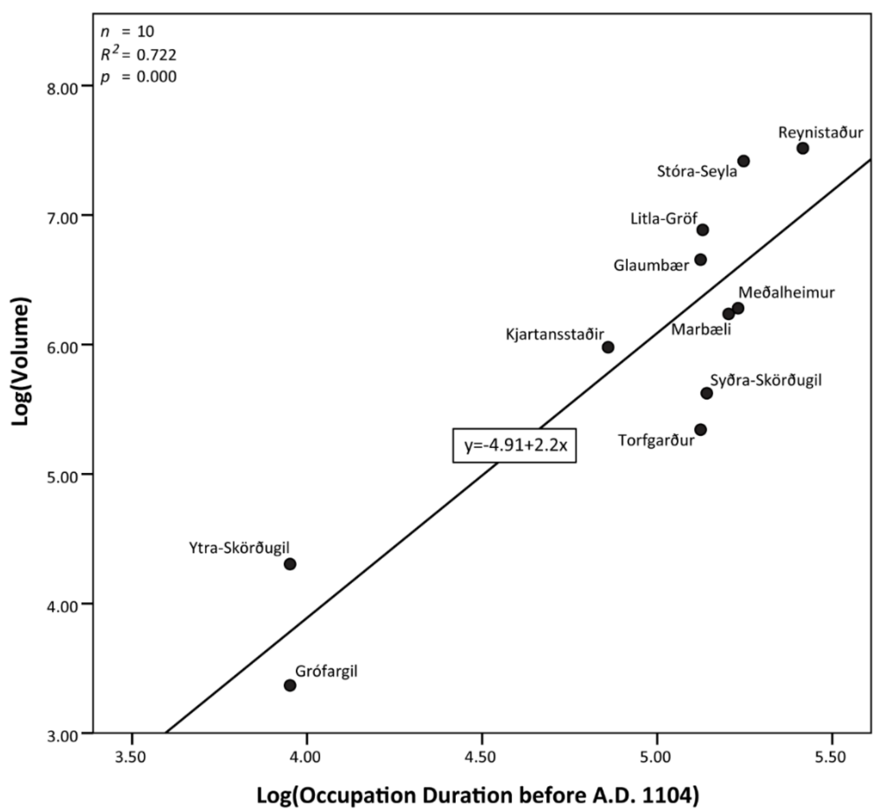


Figure 12. Volume and occupation duration regression graph. Both axes transformed logarithmically.

Accumulation Rate vs. Occupation Duration

Steinberg et al. (2016) use the settlement order to help explain the variation in farmstead sizes. Operating with the hypothesis that early farmsteads were able to claim the most productive land and therefore obtain an economic advantage in the process of settlement, they find a strong relationship between the area of a farmstead and the date of farmstead establishment (n = 18; r = .815; p = .000). Linear regression shows that 66 percent of the variation in areal extent can be explained by how early the farm was settled using a logarithmic relationship.

This implies that earlier farmsteads were bigger in areal extent at an exponential scale. Replicating Steinberg et al.'s (2016) test with the volumetric dataset of farms, there is a strong correlation between the maximum area of a site at A.D. 1104 and the duration it was occupied before A.D. 1104 (n = 10; r = .787; p = .007), and these correlations improve with logarithmic transformation (n = 10; r = .901; p = .000) (Table 7).

Following Steinberg et al.'s (2016) statistics for area and duration, linear regression analysis may be used as a tool to determine the degree to which the accumulation rate of sites is dependent on the settlement order. There are different possibilities for the nature of this relationship, both of which should be taken into account. As with the volume-to-duration relationship (see above), accumulation rates may be related linearly or exponentially with duration of occupation. If the data are related exponentially, data should be logarithmically transformed in order to use a linear regression analysis. An exploratory Pearson's correlation of accumulation rate and occupation duration suggests that a log-log relationship may hold more explanatory value. In fact, the correlation between accumulation rate and duration only becomes significant at the 0.05 level after logarithmic transformation (n = 10; r = .743; p = .014).

The regression model between accumulation rate and occupation duration after logarithmic transformation can be expressed as $\log(\frac{V}{t}) = \log(a) + b\log(t)$, or $\frac{V}{t} = at^b$, where V = *volume* and t = *occupation duration before 1104 A.D*. There is an exponential relationship between the accumulation rate and the duration of occupation (r^2 = .552; p = .014). Fifty-two percent of the variation in accumulation rates can be explained by the change in occupation duration. Put another way, sites that were established earlier tend to have an exponentially faster accumulation rate before A.D. 1104 (Figure 13) (Table 6).

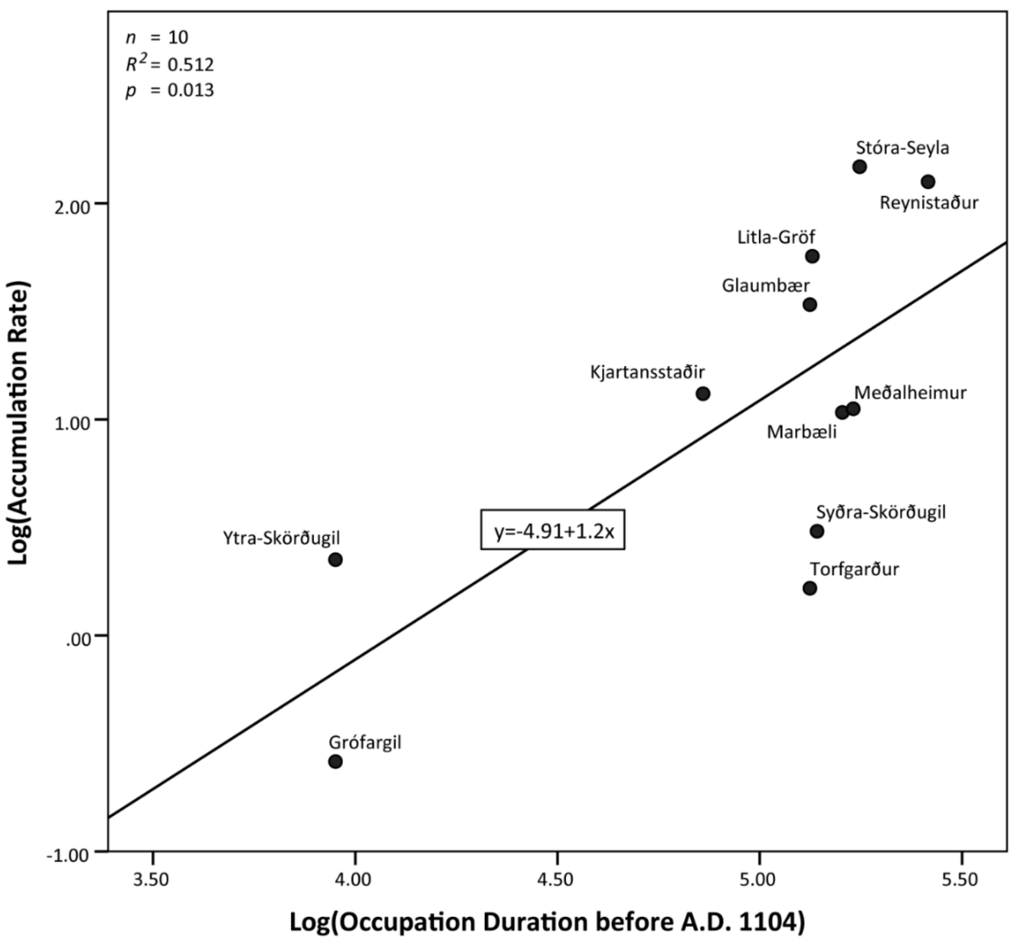


Figure 13. Accumulation rate and occupation duration regression graph. Both axes transformed logarithmically.

Volume vs. Areal Extent					
Model	***n***	***a***	***b***	***r²***	***p***
$V = f(A)$	10	-208.00	.759	.575	.011
$V = f(A^{1.5})$	10	-7.53	.769	.591	.009
Volume vs. Occupation Duration					
Model	***n***	***a***	***b***	***r²***	***p***
$V = a + bt$	10	-736.11	.673	.453	.033
$V = at^b$	10	-6.88	2.58	.767	.001
Accumulation Rate vs. Occupation Duration					
Model	***n***	***a***	***b***	***r²***	***p***
$\frac{V}{t} = at^b$	10	-6.88	1.58	.552	.014

Table 6. Regression analyses

Dataset	Correlation	*n*	*r*	*p*
Steinberg et al. (2016)	A & t	18	.721	.000
	Log(A) & Log(t)	18	.758	.000
Volumetric Dataset	A & t	10	.787	.007
	Log(A) & Log(t)	10	.901	.000
	$\frac{V}{t}$ & t	10	.623	.054
	Log($\frac{V}{t}$) & Log(t)	10	.743	.014

Table 7. Pearson correlations.

CHAPTER 4

INTERPRETATION

Average Accumulation Rates, Consumption, Income and Wealth

Before moving to an explanation of accumulation rate as a proxy for household consumption, it should be clarified that the data in this study can only speak to the scale of inter-household inequality rather than intra-household or inter-regional inequality. Of the variables discussed in Chapter One affecting the total quantity of material at a site, accumulation rate accounts for the total quantity of material and the duration of occupation. It is still very difficult to parse out the number of people residing at a household at any given time. For that reason, “household consumption” is defined here as the aggregate rate of consumption of the household regardless of the number of household members. Even if household size tends to correlate with overall household wealth cross-culturally (Netting 1982; Smith 2004; Steinberg, et al. 2016), without a fine-tuned measure of the footprint of Viking Age house plans, any estimate of accumulation-per-person at a site would be speculative. Nor can we assess the unequal distribution of resources or labor-output within the household which certainly existed. Social stratification of a household was structured by complex intersections of identity and social status ranging on spectrums from chief to slave, men to women, youth to elderly or ethnic differences. These are impossible to detect with the current dataset. This study also does not account for inter-regional inequalities; more marginal areas may have had a more or less unequal distribution of fewer resources.

Understanding the environmental, social and economic context of the settlement of Iceland as well as the specific dynamics of Skagafjörður and Langholt is critical to being able to use an accumulation rate of cultural deposits as a proxy for the consumption rate of a household. To sum up, cultural deposits on Icelandic sites are of two primary types: turf architectural material (*in situ* or as refuse from construction or maintenance) and fuel refuse (primarily peat ash, but also wood and dung ash). Each of these materials implies an array of different kinds of human activities at a farm at different points in its productive cycle associated with labor, capital and exchange in different ways that cannot be fully parsed in the current study. Fuel may have been burned for food processing, light and warmth for sustaining a household or for specialized production (Simpson, et al. 2003). The presence of turf suggests investment in dwellings or ancillary farmstead structures through construction and maintenance. Larger dwellings imply a larger household, suggesting a larger temporary or permanent labor force. Turf for outbuildings—byres, pit houses, smithies—indicate the existence of and contribute to the productivity of subsistence or specialized production by providing infrastructure for livestock, textile production or ironworking.

A volumetric estimate of the total quantity of cultural material reduces a complex web of farmstead activity over a period of time into a single variable. In very broad terms, the more volume of cultural material, the greater aggregate depositional events and thus the greater average consumption of rate of turf and ash at a farm between its establishment and A.D. 1104. Using tephrochronology this study brackets a site by its establishment date and the Hekla 1104 tephra layer and then transforms this accumulation resulting from a series of depositional events into a synchronic variable—*average accumulation rate*—in order compare its proxy across space during a single time period (see Smith 1992). To the extent that the average rate of deposition of turf and fuel residue is a function of the annual income of a household, I argue that average accumulate rates can be used as a proxy for wealth over time.

There are exceptions that complicate the relationship between accumulation rates, consumption rates and wealth in Iceland. First, a large quantity of turf found in a midden suggests the construction and maintenance of larger structures, but it also may relate to a more rapid degradation of turf. The maintenance frequency cycle of turf houses is determined in part by environmental factors (e.g. consistently colder climates requires less maintenance) (Urbańczyk 1999; van Hoof and van Dijken 2008; Vésteinsson 2010). In the constrained environmental context of Langholt, climate would be expected to affect architecture equally. However, maintenance frequency is also affected by the quality of turf (Steinberg 2004). Access to better turf may be a sign of wealth in terms of control over resources, but it would result in a slower accumulation rate of turf refuse in middens from maintenance. More research is required to assess the actual effect of better turf on maintenance-frequency cycles. It is assumed in this paper that this variable does not have a significant enough effect on volume to change the trends observed in the data within the study area.

Second, different types of ash in this study are subsumed into one variable. It is difficult to parse different fuel sources from coring alone. Different quantities of different types of fuel further complicate the relationships between consumption rate and wealth.

Earlier sites probably had greater access to wood as fuel than later farms. This may explain the higher accumulation rates for earlier sites. Whether this is also indicative of greater wealth is a more complex question. Differential post-depositional degradation of different fuel sources may also have a confounding effect on accumulation rates between earlier and later farms (Simpson, et al. 2003; Vésteinsson 2010). Additionally, different types of fuel may be more efficient in terms of energy and resources. Less desirable types of fuel may result in a greater quantity of ash for the same output of heat, suggesting poorer households may produce more ash per person. Without experimental studies of different heat vs. ash output ratios of different fuel sources as well as micromorphological studies of different fuel-type ratios in middens, it is difficult to know the effect of these dynamics on volumetric estimates.

Following Steinberg et al.'s (2016) assessment of stratification in Langholt using areal extent, the Gini coefficient for measuring the unequal distribution of accumulation rates for the volumetric dataset of farms in the Langholt area is .35 (n = 10). This suggests relative inter-household equality, aligning with Steinberg et al.'s (2016) Gini coefficient of .30 (n = 18). This is also comparable to material measures of wealth inequality for agro-pastoral societies cross-culturally (Mulder, et al. 2009). Granted, the Gini coefficient for this study is calculated with a subset of the total universe of farms, but the subset is largely representative. This measure of inequality should still be taken with caution, however. It only measures the unequal distribution of accumulation rates at the scale of households in the survey area and does not account for intra-household and inter-regional inequalities (see above).

To interpret the significance of the relationship between accumulation rate and settlement order, it is necessary to first compare the theoretical stance of this paper to Steinberg et al.'s (2016) assessment of wealth inequalities and the advantages of arriving first in a previously uninhabited landscape. In general, sites with a larger maximum areal extent before A.D. 1104 are established earlier. These sites also tend to have higher accumulation rates, confirming the conclusion of Steinberg et al. that earlier sites are wealthier. However, certain individual sites have "faster" and "slower" accumulation rates than their areal extent suggests. This implies that each variable may be affected somewhat differently by different processes from site to site. Therefore, while area may correlate with wealth, it should not be thought of as a direct proxy for the total amount of material at a site. This then begs the question, if area is affected somewhat independently of volume, what drives these differences?

A key argument that Steinberg et al. make is that the maximum areal extent of farmsteads before A.D. 1104 can be used as a "sum of a series." They admit that farmsteads relocated at the end of the Viking Age such as Glaumbær and Stóra-Seyla "expand" at a rate of up to 2,766 m^2 in just four years, a rate which at least by most archaeological standards is essentially instantaneous. If sites are able to expand at such a rate (i.e. if at least *some* cultural material can be spatially distributed as such almost instantaneously) it may be inappropriate to conceive of sites as "growing" in areal extent at all, and areal extent should only be considered as a synchronic variable for the Viking Age period. Contraction of sites may have occurred any time after reaching their maximum extent before A.D. 1104, and the SASS methodology is unable to account for this.

There are simple alternative explanations for Steinberg et al.'s robust correlation between areal extent and settlement order if we suppose that the two-dimensional spread of a farmstead is a synchronic measure of its maximum areal extent *at some point before* A.D. 1104 and not necessarily *at* A.D. 1104. If Vésteinsson's (2010) "centralization" hypothesis is correct and this was a gradual process beginning in the Viking Age, it may be that Steinberg et al. are in part measuring the tendency of farmsteads to contract over time. The earlier a farmstead is settled, the more likely it is to "spread out" at a given time. This correlates with the farm consuming more in A.D. 1104 as measured by the accumulation rates in this study, but it may not be a direct measure of wealth. Depositional practices may have changed as later households began to concentrate the deposition of cultural debris closer to the farmhouse and outbuildings began to become consolidated into the main farmhouse structure (Ólafsson and Ágústsson 2004). Future research on post-Viking Age areal extent and accumulation rates may help elucidate this process (see below).

Alternatively or concurrently, a "spread out" mode of refuse and architectural deposition may be a factor of the number of household members occupying a site; many studies of site area have confirmed this relationship in other areas of the world (Brumfiel 1976; Healy, et al. 2007; Kvamme 1997; Schreiber and Kintigh 1996). In this case, the maximum extent of a farm mound may have been reached at the time when the household had the most members. This also may have been when the household was first established. If we consider area as being potentially variable over time, area may contract at sites after establishment but before A.D. 1104 as households splinter into smaller groups. The process of dividing large households and large properties into smaller households and smaller properties over time (Bolender, et al. 2008) may also explain the smaller areal footprint of later sites. The variation in the accumulation rates would then suggest some earlier households, such as Marbæli or Syðra-Skörðagil, tend to have more members but they are producing significantly less annual volume per person than other households between their establishment and A.D. 1104. Without direct comparative ethnohistorical evidence, however, we can at present only speculate on annual volumetric contributions per person.

The Impact of Precedence

As noted above, in the case of Langholt a Gini coefficient of .35 suggests that inter-household stratification was certainly unequal, but not particularly extreme. This stands in contrast to the seventeenth century when 95 percent of Icelandic households lived on tenant properties (Bolender 2006; Lárusson 1967). In Langholt, of the four earliest-established sites in this survey, three of them are listed as landowners in the early eighteenth century while the rest are listed as tenant farms (Magnússon and Vídalín 1930). I argue that the endurance and heightening of stratification in the landscape after the Viking Age is in part due to the impact of precedence.

Precedence, as an anthropological concept used to understand and explain human behavior, proposes that people can organize and understand the asymmetrical distribution of social status through a real or constructed “chain-like temporal sequence of status-defining ‘historical’ events, connecting the past with the present through dualistic, recursive, asymmetric and (to some extent) transitive linkages” (Reuter 2002:22). Precedence in this case has two different but related meanings, both the fact of coming before someone or something in time and as having superiority over something through order or rank. Various studies have located precedence as a primary organizational concept in the context of Austronesian societies (McWilliam 2002; Reuter 1992, 2002; Vischner 2009), but it is clear that as a basic mode of constructing status through time-based relationships, precedence is a fundamental principle in many different contexts in more or less nuanced ways. Precedence can operate on multiple scales, including the household or the village, but for the purpose of interpreting data from Skagafjörður, I want to focus on how the "valency" of status distribution can be organized at the scale of regional inequalities. Among the central highland people of Bali, for example, "various relationships of member villages to the central temple, and to the origin village in which it is located, are defined by the historical order of their foundation" (Reuter 2009:21).

Most of the anthropological research on precedence has focused on the emic constructions of status through historical/textual, linguistic and ethnographic evidence. What is missing from this approach is an examination of the durability of material and economic wealth-structures alongside more subjective status-distinctions. In short, there are often concrete and long-lasting economic advantages to "being first" (Glazer 1985; Steinberg, et al. 2016). The question remains, do these align with the ideological dimensions of "being first"? I suggest that in Langholt, precedence—the correlation of wealth advantages and the order of settlement—was simultaneously an economic and social process. This argument follows similar attempts to unite material practices with experiential dimensions of landscape (Kosiba and Bauer 2012; Smith 2003).

Economically, as summarized above, the faster accumulation rates of sites that were established earlier suggests these households had secured more productive land, had more access to resources and labor, or both. Hence, faster accumulation rates may be a proxy for greater accumulation of capital which endured over time. If we consider precedence as a social and political process, individuals may have appropriated the historical events of *landnám* through the production of history to justify their place in the present. For evidence of this in the medieval period, we can turn to the fact that texts were generated documenting the process of settlement, such as the *Book of the Icelanders* (*Íslendingabók*) (Þorgilsson and Hermannsson 1930), *The Book of Settlements (Landnámabók)* (Pálsson and Edwards 1972) and the family sagas. As Margaret Clunies Ross notes regarding the ideological dimensions of the settlement of Iceland,

> Not only did the long genealogies that appear in several indigenous genres have an important relationship to actual or potential land claims…but accounts of how ancestors laid claim to territory with divine backing must have had an important legitimating function for those who claimed descent from them [Clunies Ross 1998:161].

I suggest that once inequality was established, the order of settlement itself, as codified in medieval texts, may have functioned as its own ideology in later periods. Just as the physical process of farm mound accumulation created more visually prominent and entrenched features on the landscape, the ideology of precedence may have helped keep property rights in place for certain individuals and certain linages, thus helping to keep rates of accumulation higher at sites that were established earlier.

This is at present a tentative hypothesis. More research on farm mound accumulation rates in later periods is needed in order to fully understand this process. A major question for future research is, do sites with faster accumulation rates in the Viking Age continue to have faster accumulation rates in later periods? It should also be noted however, that despite its grounding in "historical" events, precedence is a fluid and malleable concept. In the case of Bali, for example, "narrative or ritually enacted status claims can be and frequently are subjected to contestation and refutation" (Reuter 2009:22). Thus, despite the long-term continuity suggested by certain earliest-established sites becoming landlords in later periods, deviations in accumulation-rate trends over time would suggest both the material and experiential instabilities of precedence.

Suggestions for Future Research

This project has confirmed one set of hypotheses while creating a set of important directions for future research. First and foremost, in order to confirm the relationships suggested by these 11 sites, more volumetric surveys of Viking Age sites should be carried out in order to increase the sample size of this study. Future surveys should be planned along a regular grid in order to account for possible errors from uneven sampling distributions (see Chapter Two - Methods). With more comprehensive sampling, it may also be possible to determine percentages of various farm mound constituents. The accumulation rate of turf and the accumulation rate of ash could then be studied separately. Considering that each of these materials suggests different types of household productive activity, this would allow for a more nuanced interpretation of accumulation rate from site to site.

Additionally, micromorphological analysis of sections of middens (Vésteinsson and Simpson 2004; Simpson, et al. 2003) should be conducted in conjunction with macromorphological studies from coring survey. As mentioned above, accumulation rates for later sites may be smaller because fuel in the form of trees is less abundant in later periods. Additionally, wood ash and peat ash may have differential degradation rates

(Simpson, et al. 2003; Vésteinsson 2010). Micromorphological studies may be able to assess both the effect of differential deflation of volumetric contribution and the percentages of wood and peat ash at earlier and later sites. Micromorphological studies of deeper portions of the mound may also be able to assess the degree of compaction of Viking Age deposits under later deposits, another possible source of error for volumetric estimates.

Finally, this study should be repeated for post-Viking Age material. Later historic tephra layers in Skagafjörður are more difficult to identify and are usually not as well preserved as H1, but if a careful sampling protocol was put in place, it may be possible to periodize areal extents and accumulation rates of farm mounds based on the other tephra layers (870-1104, 1104-1300, 1300-1766). Differential degradation of material from different time periods would need to be accounted for by examining the relative differences in accumulation rates per period instead of a direct comparison. Variation in relative differences over time may reveal changing dynamics of consumption rates over time in conjunction with other historical and climactic variables such as the introduction of the tithe in Iceland, the gradual decline in temperatures resulting from the Little Ice Age in the late medieval period and Danish rule and independence. Additionally, if areal extent estimates were able to be periodized, a characterization of farm mound "centralization" could be established (Vésteinsson 2010). Finally, if areal extent estimates and accumulation rates are able to be correlated with tax assessor's records and Farmer's Association data in the historic period detailing household size and livestock strategies, the meanings of these spatial measurements of farm mound accumulations could be more confidently unraveled with direct-historical ethnoarchaeological analogy.

The scope of this project is such that only broad characterizations can be made of the nature of inter-household inequalities in the survey region of Langholt. Given the particularly fertile, lowland environmental context of Langholt, even fewer conclusions can be extrapolated to the settlement of Iceland broadly. That being said, this is the first project of its kind attempting to bridge the theoretical implications of volumetric-based accumulations research with site formation conditions in Iceland. While the conclusions in their present state are limited by a small sample size, the development and refinement of this methodological and theoretical bridge alone holds great promise for understanding household wealth not only at the advent of settlement but throughout all time periods in Iceland. In order to understand how inequality can change over time or from place to place, the assessment of inequality arrived at in this study should be placed in comparison to later time periods and other regions. These findings also need to be understood in relation to smaller-scale studies of inequality such as geoarcheological and microrefuse analysis of social spaces of farmsteads that can identify socially-differentiated activity areas (Milek 2012; Milek, et al. 2014) or bioarchaeological research on human remains in Iceland that may be able to assess the concrete effects of inequality on the bodies of individuals (Eng 2014; Lanigan and Bartlett 2013).

APPENDIX A
VOLUMETRIC CORES DATASET

Sample Number	Farm	Site	Profile Context	DCD	Total Thickness	Pre-1104 Thickness	ISNetEast	ISNetNorth
1006-2007-10	Meðalheimur	1006	Core	0.45	0.05	0.05	475475	567670
1006-2007-13	Meðalheimur	1006	Core	0.75	0.15	0.15	475495	567680
1006-2007-23	Meðalheimur	1006	Core	0.72	0.42	0	475485	567680
1006-2007-25	Meðalheimur	1006	Core	0.51	0.31	0.31	475520	567620
1006-2007-26	Meðalheimur	1006	Core	0.78	0.48	0.1	475520	567615
1006-2007-32	Meðalheimur	1006	Core	0.88	0.28	0.28	475512	567615
1006-2007-4	Meðalheimur	1006	Core	0.55	0.33	0.33	475480	567660
1006-2007-44	Meðalheimur	1006	Core	0.7	0.2	0.2	475485	567670
1006-2007-5	Meðalheimur	1006	Core	0.5	0.08	0.08	475485	567660
1006-2007-53	Meðalheimur	1006	Core	0.8	0.35	0	475505	567640
1006-2007-55	Meðalheimur	1006	Core	0.7	0.22	0.22	475510	567695
1006-2007-56	Meðalheimur	1006	Core	0	0	0	475510	567705
1006-2007-653	Meðalheimur	1006	Core	0.75	0.5	0	475530	567665
1006-2007-9	Meðalheimur	1006	Core	0.3	0.2	0.1	475470	567670
1006-2009-2328	Meðalheimur	1006	Core	0.8	0.48	0.48	475524.09463000001	567704.91718900006
1006-2009-2349	Meðalheimur	1006	Core	0.55	0.05	0.05	475485.881161	567684.74297899904
1006-2009-2368	Meðalheimur	1006	Core	0.4	0.05	0.05	475500.86110600003	567630.03341399902
1006-2009-2369	Meðalheimur	1006	Core	0.75	0.22	0.1	475486.57316500001	567675.81414100004
1006-2009-2389	Meðalheimur	1006	Core	0.95	0.2	0.1	475480.92519600003	567687.02906700002
1006-2009-2394	Meðalheimur	1006	Core	0.4	0.07	0.05	475563.71802600002	567637.16642000002
1006-2014-13079	Meðalheimur	1006	Profile	0.56	0.46	0.17	475502.17700000003	567635.02500000002
1006-2014-13080	Meðalheimur	1006	Profile	0.475	0.405	0.05	475532	567664

1006-2014-13081	Meðalheimur	1006	Profile	0.46	0.41	0.04	475528	567665
1006-2014-13082	Meðalheimur	1006	Profile	0.85	0.65	0.44	475540	567660
1006-2014-14914	Meðalheimur	1006	Core (JMC)	0.36	0.19	0.11	475550.304	567618.11199999903
1006-2014-14915	Meðalheimur	1006	Core (JMC)	0.37	0.27	0.04	475555.32500000001	567632.47400000005
104-2002-5112	Stóra-Seyla	104	core	0.48	0.17	0.17	477791.02027400001	564164.90688000002
104-2002-5114	Stóra-Seyla	104	core	0.6	0.25	0.25	477790.89326699899	564160.90778799902
104-2002-5115	Stóra-Seyla	104	core	0.6	0.17	0.17	477790.82976300002	564158.90824300004
104-2002-5124	Stóra-Seyla	104	core	0.58	0.3	0.3	477789.89349400002	564160.93954000005
104-2002-5128	Stóra-Seyla	104	core	0.57	0.23	0.23	477795.892131	564160.74902900006
104-2002-5129	Stóra-Seyla	104	core	0.5	0.09	0.09	477797.89167699899	564160.68552499905
104-2007-716	Stóra-Seyla	104	Core	1.25	0.87	0.87	477747.45	564048.89
104-2007-717	Stóra-Seyla	104	Core	1.3	1.02	1.02	477727	564058
104-2007-719	Stóra-Seyla	104	Core	0.4	0.08	0.08	477720	564058
104-2007-720	Stóra-Seyla	104	Core	1.2	0.8	0.8	477720	564066
104-2007-721	Stóra-Seyla	104	Core	1.2	0.84	0.84	477715	564062
104-2008-706	Stóra-Seyla	104	Core	0.97	0.62	0.52	477835	564140
104-2008-707	Stóra-Seyla	104	Core	0.63	0.43	0.43	477830	564140
104-2008-710	Stóra-Seyla	104	Core	1.1	0.85	0.85	477817	564140
104-2008-713	Stóra-Seyla	104	Core	0.91	0.54	0.54	477825	564130
104-2008-714	Stóra-Seyla	104	Core	1.4	1.02	1.02	477813.94	564147.73999999894
104-2008-715	Stóra-Seyla	104	Core	1	0.62	0.62	477820	564142.5
104-2008-716	Stóra-Seyla	104	Core	1.25	0.86	0.86	477817.5	564145
104-2008-717	Stóra-Seyla	104	Core	1.3	1.01	1.01	477819	564146
104-2008-719	Stóra-Seyla	104	Core	0.4	0.08	0.08	477816	564146
104-2008-720	Stóra-Seyla	104	Core	1.2	0.8	0.8	477816	564145

104-2008-721	Stóra-Seyla	104	Core	1.2	0.83	0.83	477819	564144
104-2008-722	Stóra-Seyla	104	Core	1.3	0.98	0.98	477818	564144
104-2008-723	Stóra-Seyla	104	Core	1.2	0.8	0.8	477820	564144
104-2014-13086	Meðalheimur	1006	Profile	2.2	2	0.3	475529.799999999	567661.69999999902
104-2014-14183	Stóra-Seyla	104	Core (JMC)	0.62	0.62	0.02	477751.402	564111.44499999902
104-2014-14184	Stóra-Seyla	104	Core (JMC)	1.15	1.15	0.01	477750.40600000002	564107.201
104-2014-14186	Stóra-Seyla	104	Profile	1.45	1.45	0.01	477741.50300000003	564120.78700000001
104-2014-14206	Stóra-Seyla	104	Core (Eijkelkamp)	1.46	1.46	0.04	477749.93300000002	564095.41599999904
104-2014-14210	Stóra-Seyla	104	Core (Eijkelkamp)	1.7	1.7	0.02	477744.364999999	564107.44200000004
106-2008-4005	Torfgarður	106	Core	0.8	0.3	0.1	477582	564486
106-2008-4006	Torfgarður	106	Core	0.95	0.4	0.2	477581	564486
106-2008-4007	Torfgarður	106	Core	0.75	0.15	0.03	477581	564487
106-2008-4008	Torfgarður	106	Core	0.85	0.3	0.1	477581	564488
106-2008-4009	Torfgarður	106	Core	0.94	0.49	0.12	477580	564487
106-2008-4010	Torfgarður	106	Core	0.64	0.34	0.04	477580	564489
106-2008-4011	Torfgarður	106	Core	1	0.35	0.05	477579	564487
106-2008-4012	Torfgarður	106	Core	0.95	0.35	0.02	477578	564487
106-2008-4013	Torfgarður	106	Core	0.53	0.23	0.03	477580	564490
106-2008-4014	Torfgarður	106	Core	0.95	0.2	0.02	477578	564490
106-2008-610	Torfgarður	106	Core	0.85	0.1	0.05	477588	564486
106-2008-614	Torfgarður	106	Core	0.9	0.05	0.05	477548	564456
106-2008-619	Torfgarður	106	Core	0.4	0.1	0.1	477598	564486
106-2008-626	Torfgarður	106	Core	1	0.5	0.1	477588	564466

106-2008-628	Torfgarður	106	Core	0.7	0.1	0.05	477578	564496
106-2008-629	Torfgarður	106	Core	0.9	0.4	0.1	477578	564491
106-2008-633	Torfgarður	106	Core	0.85	0.85	0.3	477573	564486
106-2008-656	Torfgarður	106	Core	0.9	0.3	0.18	477580	564489
106-2008-660	Torfgarður	106	Core	0.85	0.35	0.35	477555	564466
106-2014-13069	Torfgarður	106	Profile	1.56	1.22	0.11	477578.5	564482.19999999902
106-2014-13070	Litla-Gröf (Syðri)	60	Profile	1.15	0.75	0.65	475891.75	571560.62
106-2014-14253	Torfgarður	106	Core (Eijkelkamp)	1.51	1.51	0.28	477570.89399999898	564477.31900000002
107-2005-2050	Syðra-Skörðagil	107	Core	0.5	0.3	0.1	477061	565561
107-2005-2051	Syðra-Skörðagil	107	Core	0.55	0.35	0.15	477084	565561
107-2005-2052	Syðra-Skörðagil	107	Core	0.6	0.4	0.25	477092	565560
107-2005-2054	Syðra-Skörðagil	107	Core	0.4	0.1	0.1	477088	565581
107-2005-2060	Syðra-Skörðagil	107	Core	0.65	0.45	0.15	477195	565578
107-2005-3004	Syðra-Skörðagil	107	Core	0.6	0.5	0.08	477056	565553
107-2005-3006	Syðra-Skörðagil	107	Core	0.8	0.7	0.07	477054	565553
107-2011-11301	Syðra-Skörðagil	107	Core (Oakfield)	1.1	0.6	0.13	477041.443638	565531.48707200005
107-2011-11306	Syðra-Skörðagil	107	Core (Oakfield)	0.2	0.05	0	477069.21983900003	565544.01719000004
107-2011-11308	Syðra-Skörðagil	107	Core (Oakfield)	0.39	0.07	0.03	477062.06870100001	565564.71810000006
107-2011-11310	Syðra-Skörðagil	107	Core (Oakfield)	0.48	0.28	0.05	477051.692787999	565574.87275800004

107-2011-11312	Syðra-Skörðagil	107	Core (Oakfield)	0.48	0.43	0.01	477041.39017700002	565582.198554
107-2011-11313	Syðra-Skörðagil	107	Core (Oakfield)	0.35	0.25	0	477030.74566999899	565580.37419200002
107-2011-11336	Syðra-Skörðagil	107	Core (JMC)	0.6	0.1	0.1	477087.41606800002	565565.14855299902
107-2011-11338	Syðra-Skörðagil	107	Core (JMC)	0.5	0.3	0.3	477092.57163700002	565564.72126300004
107-2011-11340	Syðra-Skörðagil	107	Core (JMC)	0.7	0.35	0.35	477119.428240999	565563.66831400001
107-2011-11341	Syðra-Skörðagil	107	Core (JMC)	0.52	0.12	0.12	477116.440670999	565570.43086199905
107-2011-11402	Syðra-Skörðagil	107	Core (Oakfield)	0.4	0.2	0.01	477027.485130999	565602.23879800003
107-2011-11442	Syðra-Skörðagil	107	Core (Oakfield)	0.5	0.38	0.1	476960.81284899899	565529.15409600001
107-2014-13073	Kjartansstaðir	57	Profile	1.45	1.35	0.3	476190.5	570146.5
107-2014-14221	Syðra-Skörðagil	107	Core (Eijkelkamp)	4.635	4.535	0.01	477045.995999999	565559.76500000001
107-2014-14222	Syðra-Skörðagil	107	Profile	0.75	0.75	0.16	477046.41200000001	565534.91200000001
107-2014-14223	Syðra-Skörðagil	107	Core (Eijkelkamp)	1.55	1.45	0.1	477046.81800000003	565543.42000000004
107-2014-14226	Syðra-Skörðagil	107	Core (Eijkelkamp)	2.75	2.65	0.26	477035.81300000002	565567.299
111-2001-10	Glaumbær	111	Auger	0.68	0.45	0.25	476898.90197399899	568216.39985799894
111-2001-27	Glaumbær	111	Auger	0.55	0.31	0.31	476910.145395	568208.03639799904
111-2001-3182	Glaumbær	111	Trench	0.41	0.05	0.05	476889.664001	568199.67987200001
111-2001-3183	Glaumbær	111	Trench	0.58	0.07	0.07	476893.56524800003	568313.04551900004
111-2002-12	Glaumbær	111	Core	0.73	0.58	0.58	476918.834078999	568213.76514499902

111-2002-13	Glaumbær	111	Core	0.79	0.56	0.56	476919.02462400001	568219.76382999902
111-2009-10	Glaumbær	111	Core	0.4	0.05	0.05	476984.47703000001	568203.90934699902
111-2009-20	Glaumbær	111	Core	0.25	0.05	0.05	476948.68199999898	568191.46699999901
111-2009-21	Glaumbær	111	Core	0.25	0.05	0.05	476961.63400000002	568196.50199999905
111-2009-22	Glaumbær	111	Core	0.35	0.15	0.15	476979.33199999901	568202.63399999903
111-2009-23	Glaumbær	111	Core	0.4	0.05	0.05	476984.71999999898	568204.07799999905
111-2009-7	Glaumbær	111	Core	0.25	0.05	0.05	476948.48091500002	568191.27801999904
111-2009-8	Glaumbær	111	Core	0.25	0.05	0.05	476961.40411200002	568196.26534299902
111-2009-9	Glaumbær	111	Core	0.35	0.15	0.15	476979.268695999	568202.34853800002
111-2009-921e209n	Glaumbær	111	Core	0.6	0.4	0.4	476920.61393300002	568209.25495600002
111-2009-928e208n	Glaumbær	111	Core	0.9	0.37	0.37	476927.38079800003	568207.81175300002
111-2014-14508	Glaumbær	111	Core (Eijkelkamp)	1.7	1.6	0.09	476772.641999999	568195.06900000002
111-2014-14509	Glaumbær	111	Core (Eijkelkamp)	1.65	1.15	0.4	476767.00900000002	568219.47100000002
111-2014-14510	Glaumbær	111	Core (Eijkelkamp)	1.45	0.92	0.1	476730.38900000002	568228.70400000003
111-2014-14521	Glaumbær	111	Core (JMC)	0.37	0.15	0.06	476783.33100000001	568207.71200000006
111-2014-14534	Glaumbær	111	Core (JMC)	1	0.62	0.25	476760.15700000001	568185.16200000001
111-2014-14567	Glaumbær	111	Core (JMC)	0.67	0.64	0.24	476775.95500000002	568238.16099999903
111-2014-14569	Glaumbær	111	Core (JMC)	0.43	0.03	0.03	476771.935	568261.97600000002
115-2007-78	Marbæli	115	Core	0.88	0.13	0.13	476690	568820
115-2009-1696	Marbæli	115	Core	0.4	0.08	0.08	476686.14837399899	568851.819181
115-2009-1698	Marbæli	115	Core	0.42	0.12	0.12	476729.82992300001	568854.30912800005

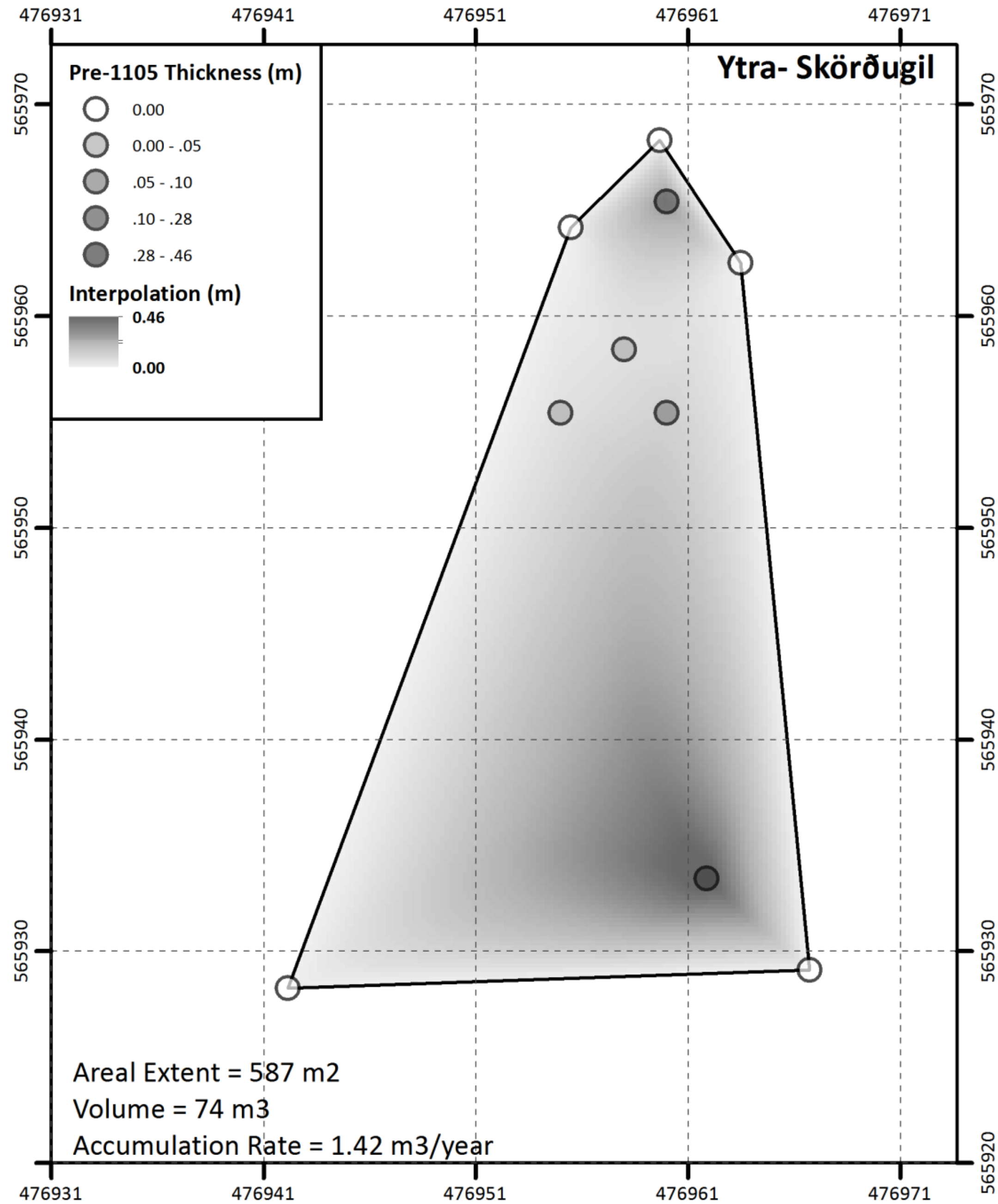
115-2009-1700	Marbæli	115	Core	0.3	0.1	0.03	476775.83147799899	568864.40578599903
115-2014-13072	Syðra-Skörðagil	107	Profile	1.68	1.38	0.12	477040.5	565561.5
115-2014-14803	Marbæli	115	Core (Eijkelkamp)	1.54	1.29	0.31	476676.261	568832.76500000001
115-2014-14831	Marbæli	115	Core (JMC)	0.42	0.42	0.06	476695.07799999899	568792.33200000005
115-2014-14839	Marbæli	115	Core (JMC)	0.25	0.07	0.05	476741.011	568792.96900000004
115-2014-14849	Marbæli	115	Core (JMC)	0.4	0.15	0.02	476685.489	568861.26
115-2014-14852	Marbæli	115	Core (JMC)	0.27	0.02	0.02	476721.01	568853.15500000003
115-2014-14855	Marbæli	115	Core (JMC)	0.25	0.15	0.04	476720.31	568835.84100000001
57-2009-1352	Kjartansstaðir	57	Core	1.52	1.52	0.1	476189.94198800001	570147.349835
57-2009-1357	Kjartansstaðir	57	Core	2.15	2.15	0.79	476184.186206999	570158.00592499902
57-2009-1358	Kjartansstaðir	57	Core	1.9	1.7	0.15	476185.95020800002	570158.55543499906
57-2009-1361	Kjartansstaðir	57	Core	2	1.9	0.24	476184.57065299898	570136.79273600003
57-2009-1375	Kjartansstaðir	57	Core	1.45	0.99	0.22	476191.135577999	570147.61377000005
57-2014-14005	Kjartansstaðir	57	Core (Eijkelkamp)	3.69	3.41	0.08	476179.93199999898	570141.71799999895
57-2014-14007	Kjartansstaðir	57	Core (Eijkelkamp)	1.92	1.91	0.15	476173.940999999	570164.696
57-2014-14023	Kjartansstaðir	57	Core (JMC)	0.62	0.47	0.22	476144.58500000002	570137.73400000005
57-2014-14035	Kjartansstaðir	57	Core (JMC)	0.8	0.51	0.35	476152.10700000002	570150.78099999903
57-2014-14037	Kjartansstaðir	57	Core (JMC)	0.55	0.5	0	476153.98200000002	570172.25899999903
57-2014-14040	Kjartansstaðir	57	Core (JMC)	0.5	0.2	0.11	476166.40600000002	570182.26699999894
57-2014-14041	Kjartansstaðir	57	Core (JMC)	0.44	0.19	0.09	476164.685	570191.49899999902
57-2014-14042	Kjartansstaðir	57	Core (JMC)	0.56	0.04	0.04	476163.72999999899	570200.08999999904

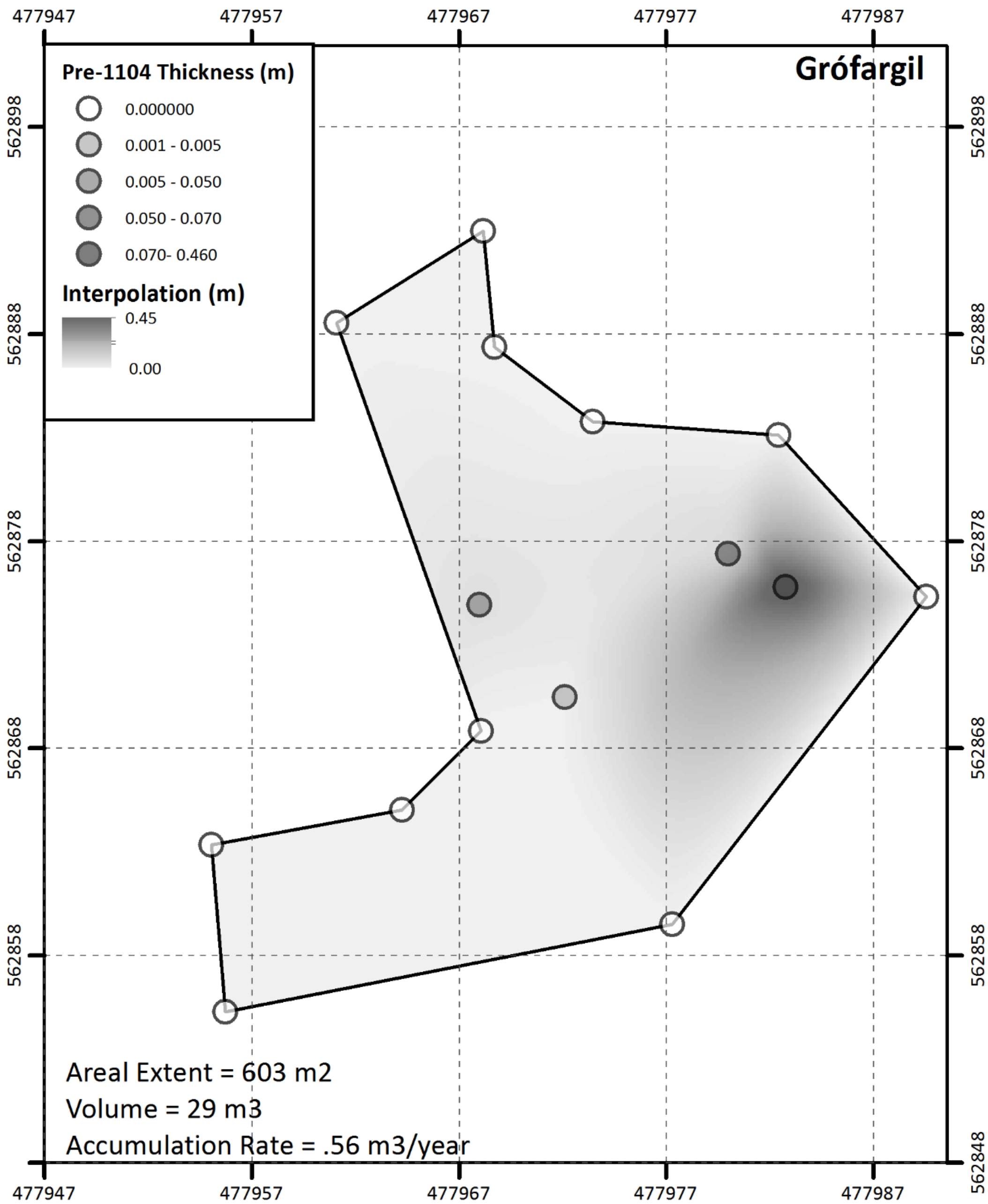
57-2014-14043	Kjartansstaðir	57	Core (JMC)	0.42	0.12	0	476174.272999999	570198.16399999894
57-2014-14044	Kjartansstaðir	57	Core (JMC)	0.65	0.44	0.1	476179.60200000001	570187.35600000003
57-2014-14048	Kjartansstaðir	57	Core (JMC)	0.32	0.02	0.02	476200.755	570160.67299999902
60-2009-2092	Litla-Gröf (Syðri)	60	Core	0.75	0.24	0.24	475909.95499	571544.29466400004
60-2009-2093	Litla-Gröf (Syðri)	60	Core	1.8	1.35	0	475892.017159999	571547.47392799903
60-2009-2094	Litla-Gröf (Syðri)	60	Core	1	0.27	0.17	475893.34362200001	571528.92188699904
60-2009-2095	Litla-Gröf (Syðri)	60	Core	0.85	0.85	0.48	475890.48328300001	571572.02483300003
60-2009-2096	Litla-Gröf (Syðri)	60	Core	1.05	0.65	0.32	475894.21416700003	571538.87279099901
60-2009-2098	Litla-Gröf (Syðri)	60	Core	1.3	1.29	0.54	475893.49990599899	571551.01672199904
60-2009-2099	Litla-Gröf (Syðri)	60	Core	1.53	1.38	1.03	475895.04978200002	571553.51638100005
60-2009-2103	Litla-Gröf (Syðri)	60	Core	1.4	1.39	1.02	475893.756865	571559.02392499906
60-2009-2115	Litla-Gröf (Syðri)	60	Core	1.2	1.1	0.45	475905.19583699899	571569.94658900006
60-2009-2117	Litla-Gröf (Syðri)	60	Core	1.2	1.2	0.5	475900.039373999	571563.02546300006
60-2009-2118	Litla-Gröf (Syðri)	60	Core	1.2	1.1	0.05	475897.688323999	571557.82722600002
60-2014-13071	Marbæli	115	Profile	1.4	1.23	0.4	476686.25	568818.93999999901
60-2014-14607	Litla-Gröf (Syðri)	60	Core (Eijkelkamp)	2.5	2.5	0.35	475877.63199999899	571531.77599999902
60-2014-14626	Litla-Gröf (Syðri)	60	Core (JMC)	0.45	0.23	0.18	475921.74300000002	571538.027
60-2014-14632	Litla-Gröf (Syðri)	60	Core (JMC)	0.7	0.16	0.16	475911.88799999899	571552.38100000005
60-2014-14638	Litla-Gröf (Syðri)	60	Core (JMC)	1.16	0.06	0.06	475852.74900000001	571579.99399999902
60-2014-14645	Litla-Gröf (Syðri)	60	Core (JMC)	0.6	0.35	0.35	475895.84600000002	571587.33999999904
60-2014-14646	Litla-Gröf (Syðri)	60	Core (JMC)	0.65	0.04	0.04	475892.81800000003	571597.91700000002
60-2014-14691	Litla-Gröf (Syðri)	60	Core (Eijkelkamp)	3.35	3.35	0.37	475885.908	571544.27300000004

63-2009-2180	Reynistaður	63	Core	0.85	0.75	0.49	474130.09652000002	573274.94671199901
63-2009-2182	Reynistaður	63	Core	0.4	0.25	0.1	474137.93362600001	573268.10111199901
63-2014-13078	Reynistaður	63	Profile	0.67	0.02	0.02	474133.81	573275.59100000001
63-2014-13083	Reynistaður	63	Profile	1.8	1.42	0.93	474203.12199999898	573370.23100000003
63-2014-14301	Reynistaður	63	Core (Eijkelkamp)	1.72	1.22	0.87	474198.766999999	573373.42000000004
63-2014-14304	Reynistaður	63	Core (Eijkelkamp)	1.15	1.15	0.36	474157.29200000002	573343.38800000004
63-2014-14305	Reynistaður	63	Core (Eijkelkamp)	0.83	0.81	0.04	474157.95299999899	573307.75600000005
63-2014-14311	Reynistaður	63	Core (Eijkelkamp)	1.62	1.22	0.64	474158.51899999898	573358.228
63-2014-14313	Reynistaður	63	Core (Eijkelkamp)	0.86	0.46	0.36	474101.86300000001	573345.00199999905
63-2014-14314	Reynistaður	63	Core (Eijkelkamp)	0.9	0.6	0.4	474100.35700000002	573346.10400000005
63-2014-14315	Reynistaður	63	Core (Eijkelkamp)	1.58	1.48	0.08	474149.38	573293.97499999905
63-2014-14316	Reynistaður	63	Core (Eijkelkamp)	1.88	1.78	0.28	474149.08399999898	573293.99199999904
63-2014-14366	Reynistaður	63	Core (JMC)	0.65	0.5	0.5	474101.47200000001	573345.80299999902
89-2014-13075	Grófargil	89	Profile	1	0.9	0.05	477967.9	562874.80000000005
89-2014-13076	Torfgarður	106	Profile	1.35	0.6	0.15	477577	564486
89-2014-1426	Grófargil	89	Core (JMC)	0.555	0.455	0.005	477972.016999999	562870.33499999903

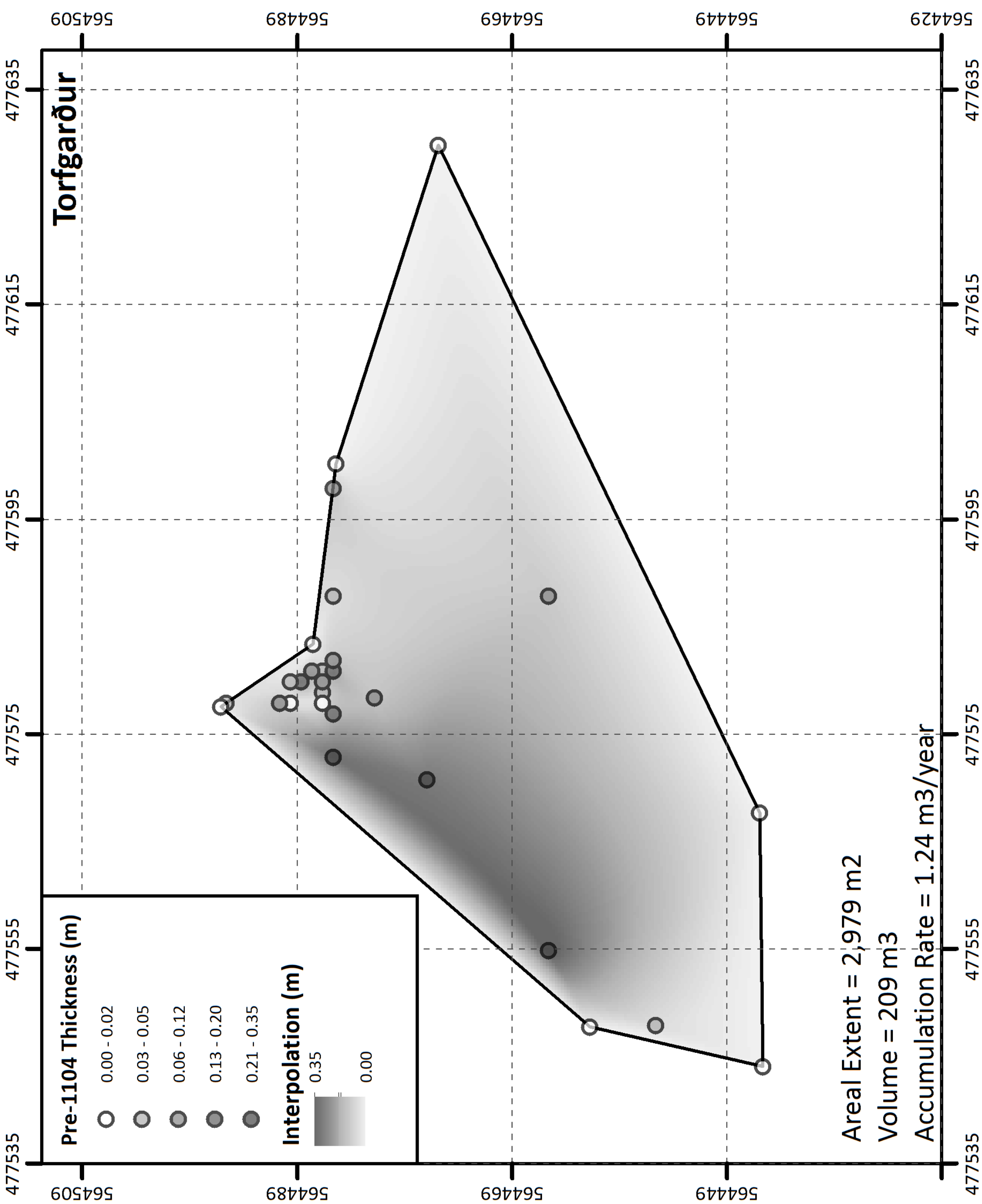
89-2014-1427	Grófargil	89	Core (JMC)	0.77	0.37	0.07	477979.902	562877.27099999902
89-2014-14952	Grófargil	89	Core (Eijkelkamp)	1.2	0.94	0.46	477982.67800000001	562875.67200000002
108-2005-9619	Ytra-Skörðagil	108	Core	0.7	0.6	0.28	476960	565965
108-2005-9621	Ytra-Skörðagil	108	Core	0.7	0.25	0.1	476960	565955
108-2005-9624	Ytra-Skörðagil	108	Core	0.8	0.8	0.05	476955	565955
108-2005-9626	Ytra-Skörðagil	108	Core	0.7	0.7	0.05	476958	565958
108-2011-11547	Ytra-Skörðagil	108	Core (Oakfield)	0.15	0.15		476959.9303	565914.3643
108-2011-11549	Ytra-Skörðagil	108	Core (Oakfield)	0.5	0.5	0.46	476961.8709	565933.0019

APPENDIX B:
SITE MAPS

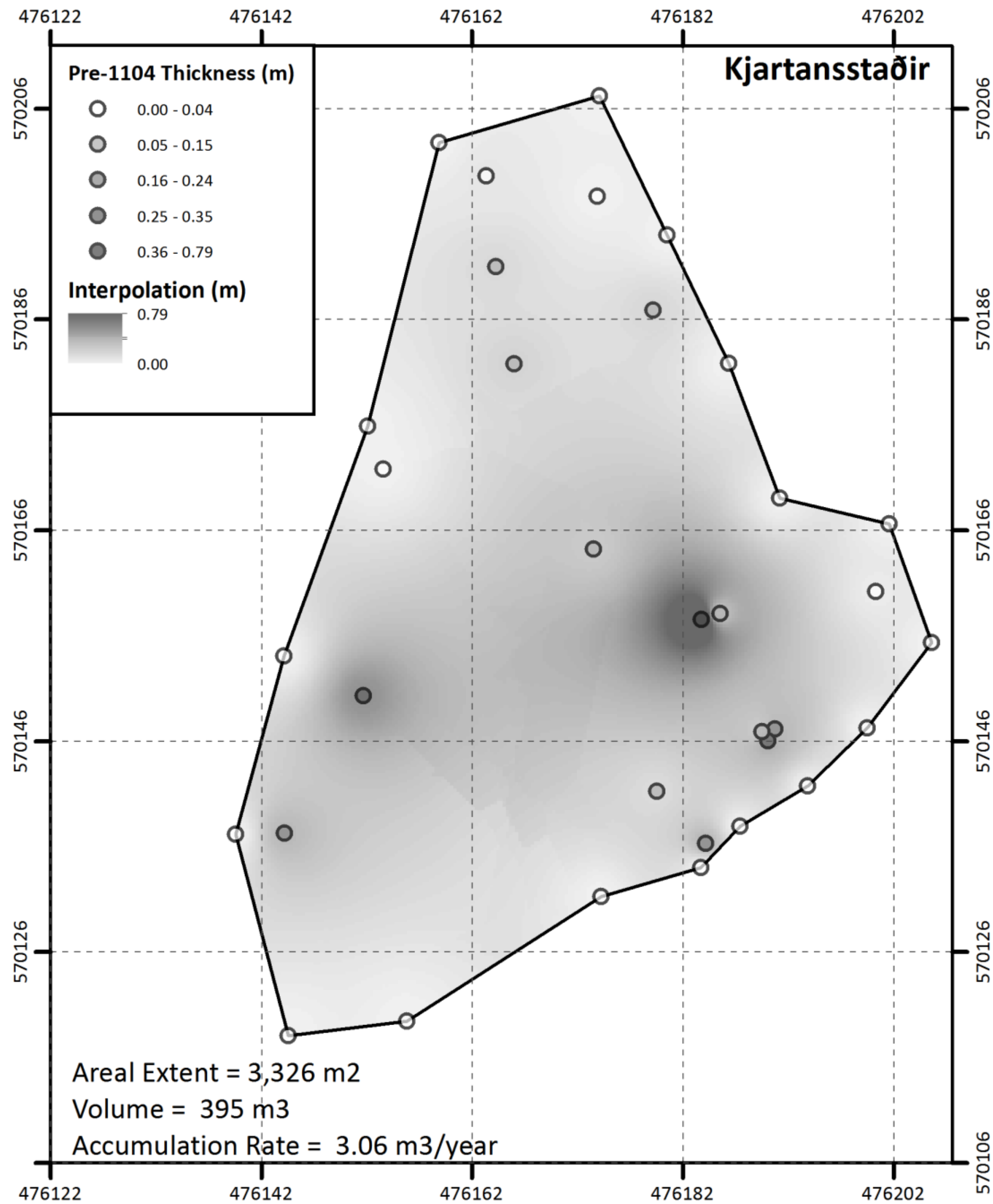


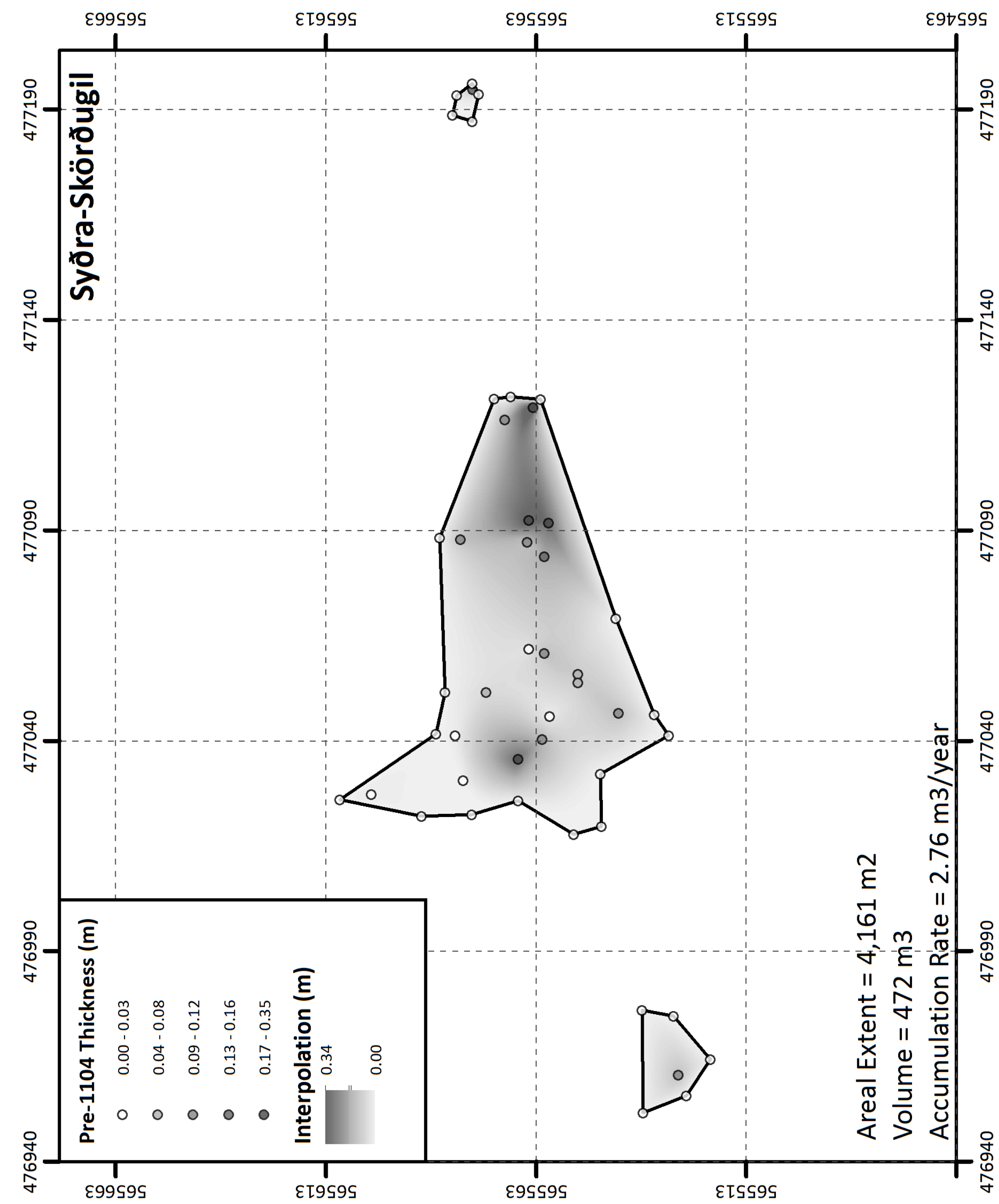


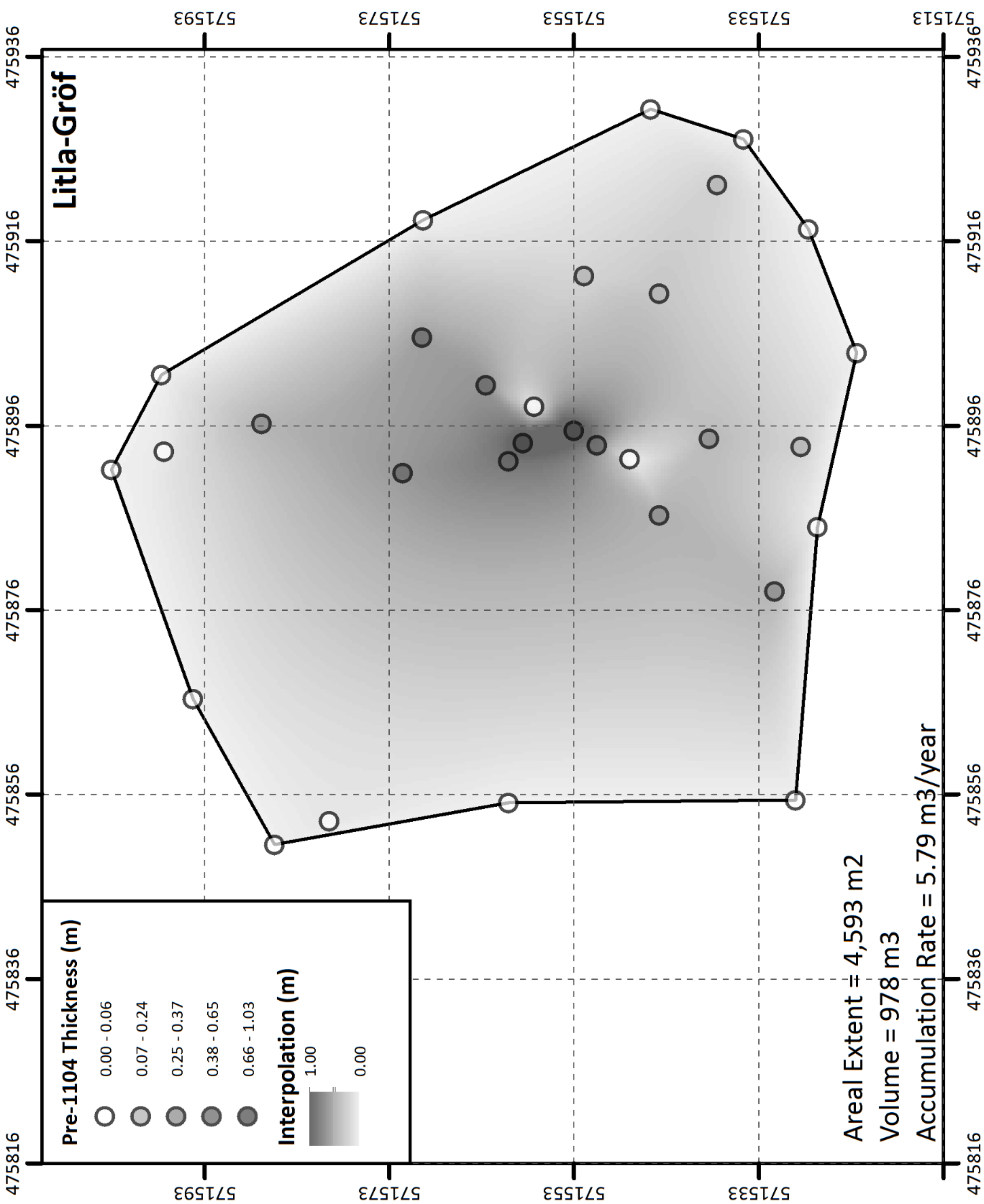
Grófargil
Pre-1104 Thickness (m)
0.000000
0.001 - 0.005
0.005 - 0.050
0.050 - 0.070
0.070- 0.460
Interpolation (m)
0.45
0.00
477947
477957
477967
477977
477987
562898
562888
562878
562868
562858
562848
Areal Extent = 603 m2
Volume = 29 m3
Accumulation Rate = .56 m3/year

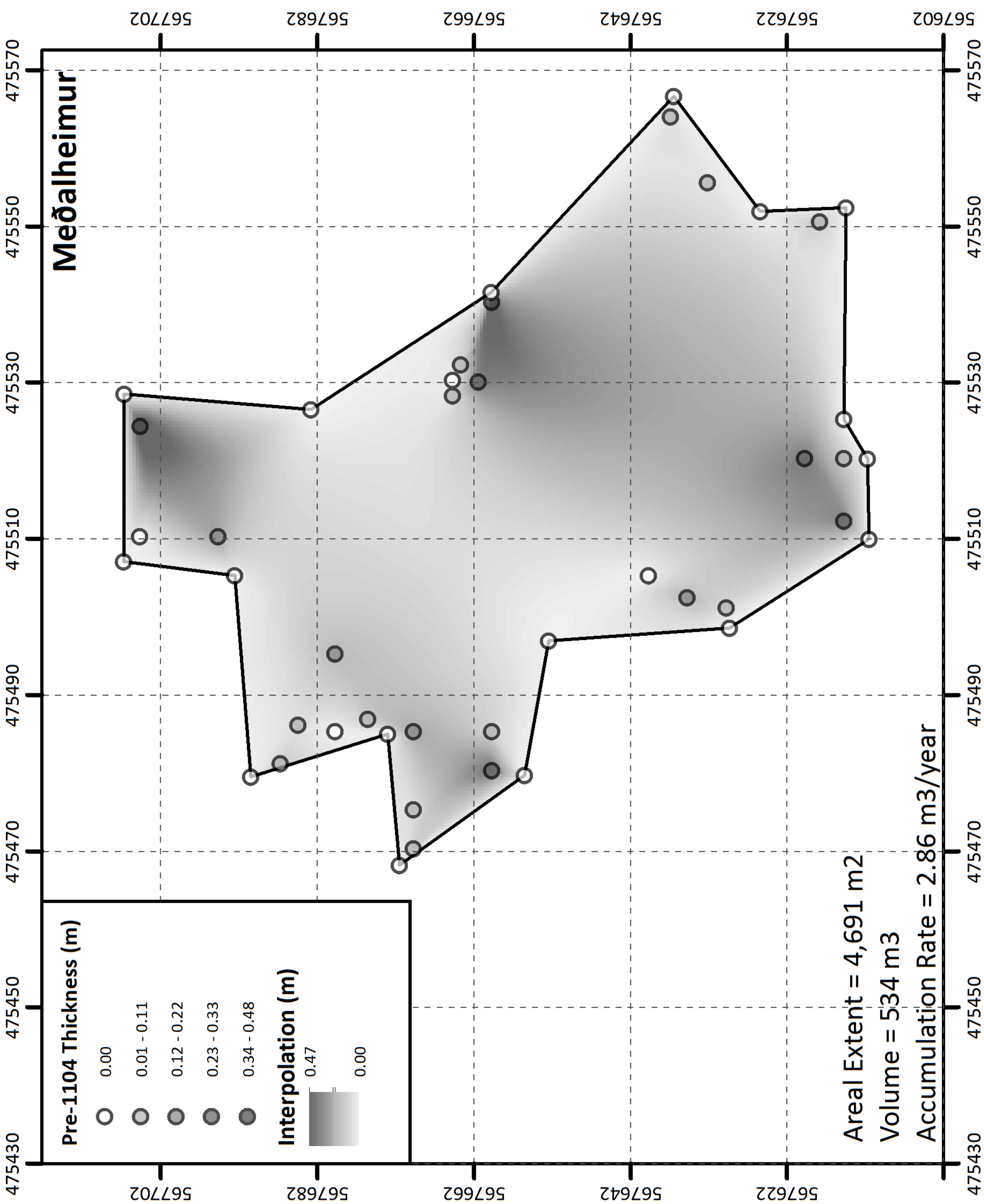


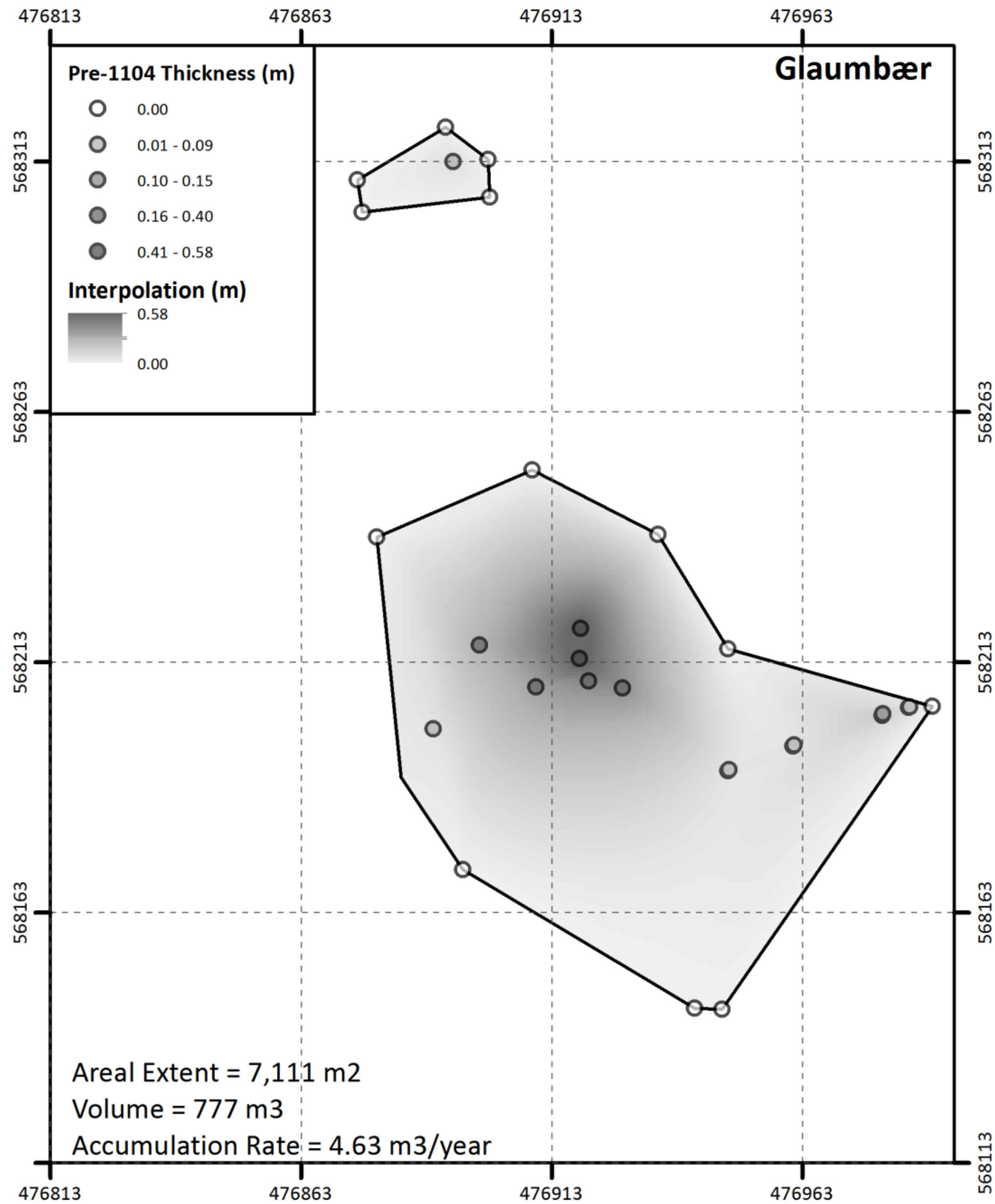
Torfgarður
Pre-1104 Thickness (m)
0.00 - 0.02
0.03 - 0.05
0.06 - 0.12
0.13 - 0.20
0.21 - 0.35
Interpolation (m)
0.35
0.00
Areal Extent = 2,979 m2
Volume = 209 m3
Accumulation Rate = 1.24 m3/year
477535
477555
477575
477595
477615
477635
5645509
5644489
5644469
5644449
5644429

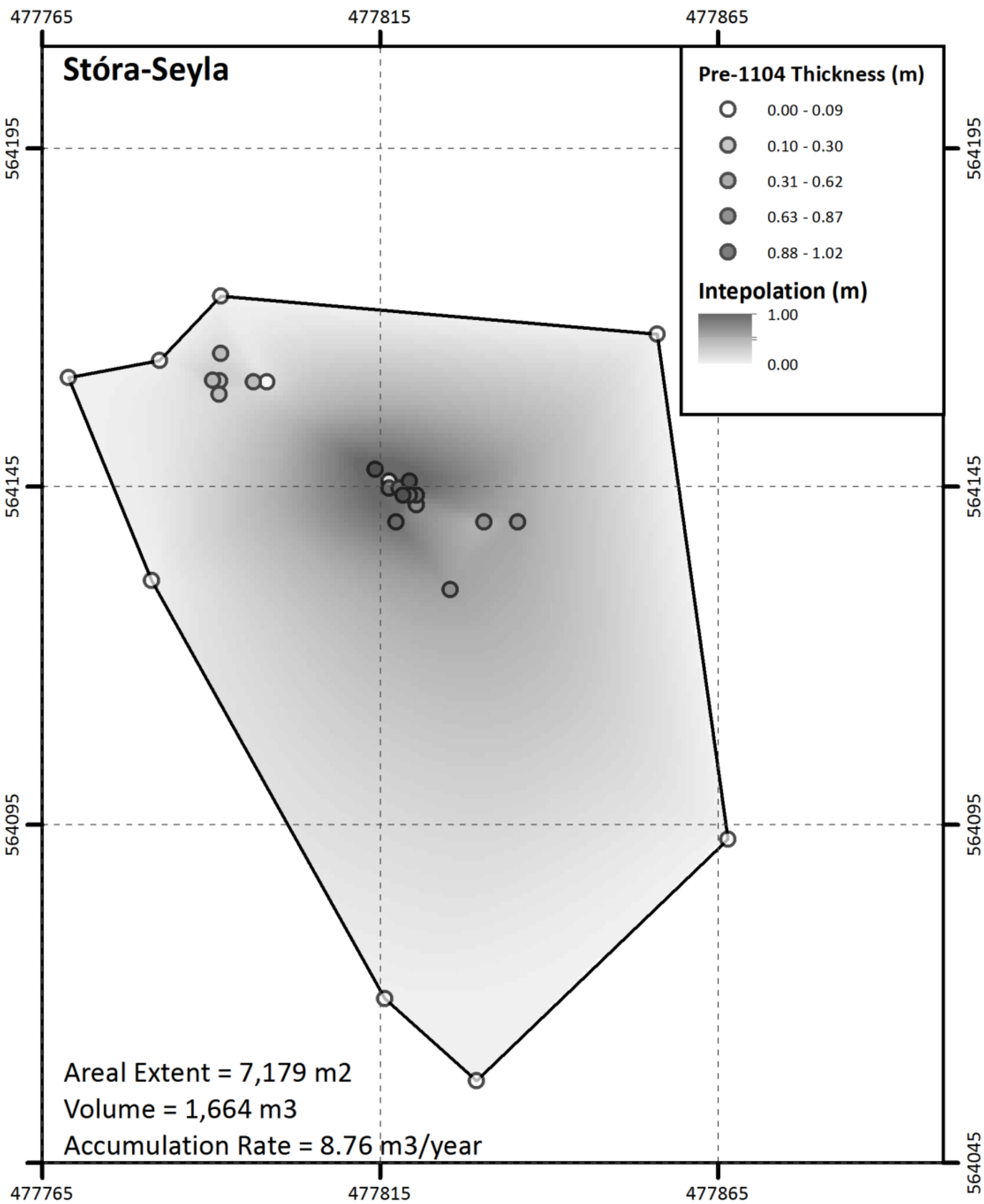

476122
476142
476162
476182
476202
Kjartansstaðir
Pre-1104 Thickness (m)
0.00 - 0.04
0.05 - 0.15
0.16 - 0.24
0.25 - 0.35
0.36 - 0.79
Interpolation (m)
0.79
0.00
570206
570186
570166
570146
570126
570106
Areal Extent = 3,326 m2
Volume = 395 m3
Accumulation Rate = 3.06 m3/year

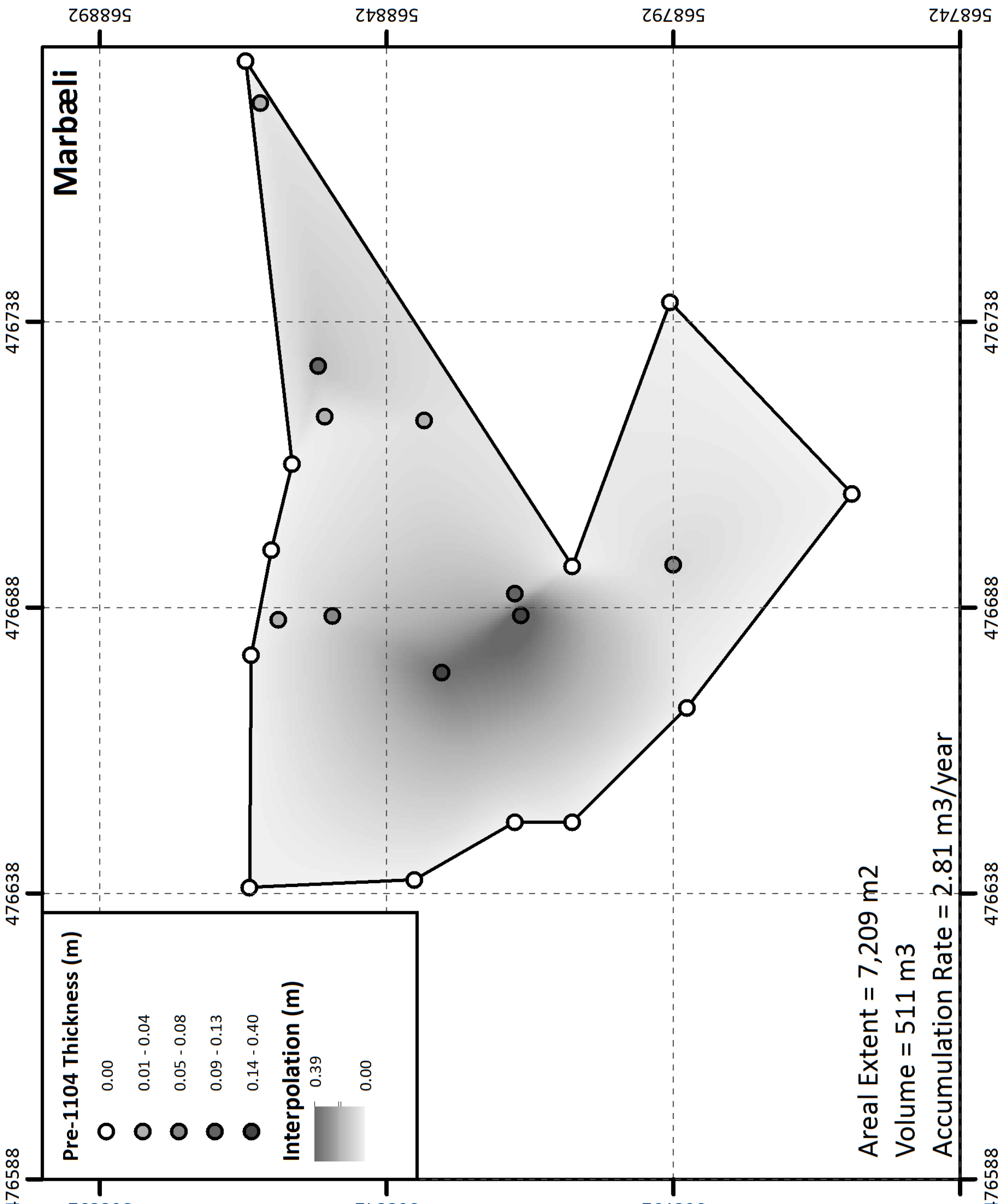

Syðra-Skörðugil
Pre-1104 Thickness (m)
0.00 - 0.03
0.04 - 0.08
0.09 - 0.12
0.13 - 0.16
0.17 - 0.35
Interpolation (m)
0.34
0.00
Areal Extent = 4,161 m2
Volume = 472 m3
Accumulation Rate = 2.76 m3/year
476940
476990
477040
477090
477140
477190
565663
565613
565563
565513
565463

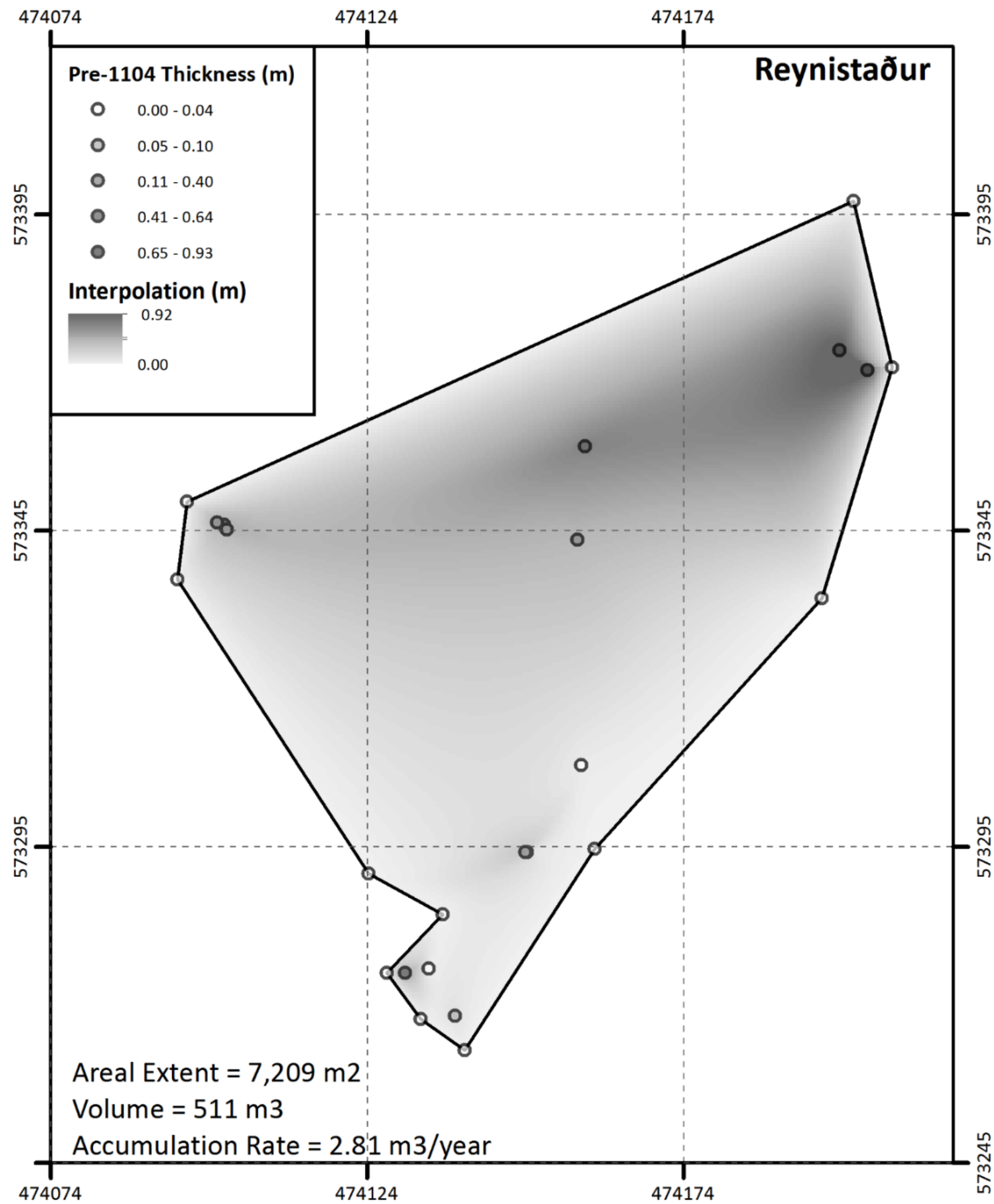

Litla-Gröf
Pre-1104 Thickness (m)
0.00 - 0.06
0.07 - 0.24
0.25 - 0.37
0.38 - 0.65
0.66 - 1.03
Interpolation (m)
1.00
0.00
Areal Extent = 4,593 m2
Volume = 978 m3
Accumulation Rate = 5.79 m3/year
475816
475836
475856
475876
475896
475916
475936
571513
571533
571553
571573
571593


Meðalheimur
Pre-1104 Thickness (m)
0.00
0.01 - 0.11
0.12 - 0.22
0.23 - 0.33
0.34 - 0.48
Interpolation (m)
0.47
0.00
Areal Extent = 4,691 m2
Volume = 534 m3
Accumulation Rate = 2.86 m3/year
475430
475450
475470
475490
475510
475530
475550
475570
567602
567622
567642
567662
567682
567702


476813
476863
476913
476963
Pre-1104 Thickness (m)
0.00
0.01 - 0.09
0.10 - 0.15
0.16 - 0.40
0.41 - 0.58
Interpolation (m)
0.58
0.00
Glaumbær
568313
568263
568213
568163
568113
Areal Extent = 7,111 m2
Volume = 777 m3
Accumulation Rate = 4.63 m3/year


Stóra-Seyla
477765
477815
477865
564195
564145
564095
564045
Pre-1104 Thickness (m)
0.00 - 0.09
0.10 - 0.30
0.31 - 0.62
0.63 - 0.87
0.88 - 1.02
Intepolation (m)
1.00
0.00
Areal Extent = 7,179 m2
Volume = 1,664 m3
Accumulation Rate = 8.76 m3/year


Marbæli
Pre-1104 Thickness (m)
0.00
0.01 - 0.04
0.05 - 0.08
0.09 - 0.13
0.14 - 0.40
Interpolation (m)
0.39
0.00
Areal Extent = 7,209 m2
Volume = 511 m3
Accumulation Rate = 2.81 m3/year
476588
476638
476688
476738
568892
568842
568792
568742


474074
474124
474174
Reynistaður
Pre-1104 Thickness (m)
0.00 - 0.04
0.05 - 0.10
0.11 - 0.40
0.41 - 0.64
0.65 - 0.93
Interpolation (m)
0.92
0.00
573395
573345
573295
573245
Areal Extent = 7,209 m2
Volume = 511 m3
Accumulation Rate = 2.81 m3/year

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