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Tephra isochrons and chronologies of colonisation

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Abstract

This paper demonstrates the use of tephrochronology in dating the earliest archaeological evidence for the settlement of Iceland. This island was one of the last places on Earth settled by people and there are conflicting ideas about the pace and scale of initial colonisation. Three tephra layers, the Landnám ('land-taking') tephra layer (A.D. 877 ± 1), the Eldgjá tephra (A.D. 939) and the recently dated V-Sv tephra (A.D. 938 ± 6) can be found at 58% of 253 securely-dated early settlement sites across the country. The presence of the tephras permits both a countrywide comparison, and a classification of these settlement sites into pre-Landnám, Landnám and post-Landnám. The data summarised here for the first time indicate that it will be possible to reconstruct the tempo and development of the colonisation process in decadal resolution by more systematically utilising the dating potential of tephrochronology.

Keywords: Iceland; tephra isochrons; Landnám tephra; colonisation; periodization; Viking Age

1. Introduction

Understanding the pattern and timing of the peopling of a landscape is a difficult task, because evidence is scattered across sites where the potential for dating may vary from excellent to problematic. Without effective integration, dates of different precisions, accuracy and bias derived from a range of different media may give a misleading sense of either synchronous or time-transgressive change, a problem aptly described by Baillie (1991) as ‘suck in and smear’. The isochrons formed by tephra layers offer a rigorous way to avoid these problems when the volcanic ash (tephra) falls occur around times of colonisation, cover extensive areas, have distinctive properties that are well-characterised, and have good independent dating (Þórarinsson, 1944; Dugmore and Newton, 2012; Lowe and Alloway, 2015). While tephrochronology has been successfully applied to studies of the first human settlement in areas such as Iceland (Vésteinsson and McGovern, 2012) and New Zealand (Lowe et al., 2000), it can be further developed to produce routine high-resolution dating of the pattern and tempo of human occupation. Elsewhere in the world, such as the western parts of the Americas, this approach has great and currently unrealised potential applications to the study of colonisation phases (both human and non-human) across the widespread areas affected by visible or crypto tephra falls.

Iceland was one of the last places on Earth settled by people and yet despite a rich history of academic study, the timing and pattern of the late 9th to early 10th century A.D. Viking settlement of Iceland (the ´Landnám´ or ‘land-taking’) is still debated vigorously (e.g. Vésteinsson and McGovern 2012; Edwards, 2012; Sveinbjarnardóttir, 2012a). Based on later written sources, the onset of Landnám has traditionally been put at A.D. 870 (Benediktsson, 1968); this is broadly supported by the relationship of early archaeological evidence to a tephra from the A.D. 870s named the Landnám tephra layer (LTL). However, controversy over the timing of the settlement has been generated by a dozen or so radiocarbon dates linked to human activity at around A.D. 700 (e.g. Hermanns-Auðardóttir, 1989; Theodórsson 1998; 2009; 2012). The relevance of these 'early' dates to Iceland's settlement history is problematic because either their stratigraphic positions are unsecure or their interpretation is demonstrably incorrect—for example an 'early' date from a secure context above LTL of A.D. 877 ± 1 indicates that the dates are misleading and could, for example, be a result of the use of old timber for fires (Sveinbjörnsdóttir et al., 2004; 2016). Given the widespread occurrence of old dead timber at the time of first human settlement in wooded areas there will always be an element of uncertainty over 'early' charcoal dates in Iceland even if they are from native species and secure stratigraphic locations.

While the overwhelming majority of archaeological evidence occurs above LTL, a small number of archaeological features in the southwest of Iceland are overlain by this tephra horizon (Jóhannesson and Einarsson, 1988; Roberts et al., 2003). In addition paleoenvironmental data in the same region suggest first anthropogenic disturbances (human and livestock) some time between A.D. 830-877 (Erlendsson et al., 2014).

Understanding when people arrived is part of the puzzle, but understanding *how* they arrived, in a trickle, a steady flow or a torrent (Edwards, 2012) is key, but in addition to the timing of colonisation, the pattern of settlement is also unclear and this too is a difficult question to resolve. Two different narratives have emerged from key areas in the north of Iceland: Bolender et al. (2011) see a gradual infilling of the landscape in Skagafjörður between the LTL and Hekla 1104, however Vésteinsson and McGovern (2012) argue that Mývatnsveit was rapidly settled between the LTL and V-Sv tephra of A.D. 938 ± 6. The V-Sv tephra is closely related in time to the Eldgjá tephra and both are mid-tenth century tephra layers of Icelandic origin that are of great importance to the colonisation debate; while the recently discovered V-Sv tephra is distributed over large parts of northeast Iceland the Eldgjá tephra is distributed in the southwest and east.

Tephrochronology, in conjunction with other dating methods such as radiocarbon, offers an effective and rigorous way to resolve debates over the timing and tempo of settlement, because of the presence of tephra layers at around the time of first settlement and in the centuries both before and afterwards.

This paper reassesses the chronology of 300 Viking period settlement sites in Iceland (A.D. ~800-1100), of which 253 can be dated with well-established tephra isochrons. We discuss the dating of tephra deposits in Iceland and the application of tephrochronology with a focus on eighteen tephra horizons ranging between LTL and Hekla 1693. This new analysis suggests there is a distinct spatial patterning to the archaeology of the settlement of Iceland, with the earliest phases clustered in the southwest and a rapid colonisation both in coastal and inland areas by the mid 10th century.

2. Materials and methods

2.1 Archaeological data

Chronologies for Viking settlement sites in Iceland have been based on tephrochronology, radiocarbon and artefactual dating. However, prior to the last decade of the 20th century, these methods rarely produced dates more precise than the 'Viking Age' (Eldjárn, 2000; Grímsdóttir, 1997; Vilhjálmsson, 1991). The wealth of new archaeological data in Iceland, as well as methodological advances in Bayesian analysis, now make it possible to critically reassess the chronological evidence relating to the settlement of Iceland and to aim for a much improved resolution of the timing and pattern of colonisation within the Viking Age (e.g. Batt et al., 2015).

This discussion is based on a new catalogue of 543 archaeological sites that have been dated to the Viking period (Schmid, forthcoming). In this work. secondary source data was gathered from field reports (e.g. reports published by FSÍ, the Institute of Archaeology in Iceland, accessible at: www.nabohome.org) and academic monographs (e.g. Lucas, 2009; Sveinbjarnardóttir, 2012b). The catalogue consists of archaeological interventions including large-scale excavations, trenches and surface collections from the 19th century to 2016. Data gathering was performed with a systematic search of the corpus of field reports site-by-site, supplemented with direct questioning of the researchers involved. The complete catalogue includes all Viking Age sites in Iceland that contain direct evidence of human activity. The discussion in this study is, however, restricted to the sites dated through tephrochronology.

The Icelandic archaeological sites related to early human activity can be separated into three categories: 55% of the sites are settlements (n=300), 24% are burials (n=132) and 21% are assemblages (loose finds, n=111). Since tephra is hardly ever documented at burial sites and is absent from assemblages of loose find, these categories are not considered in this tephrochronological study and we focus exclusively on archaeological evidence that is related to settlement. 253 out of 300 settlement-related sites have associated tephra layers and are listed in SI Table 1 (Fig. 1). These sites can be either a single feature or a cluster of features, such as anthropogenic disturbances associated with farming, charcoal layers, midden deposits, iron production pits, or they can be structures below ground (pit houses or caves), or structures above ground (dwellings, halls, smithies, animal stalls or boundary earthworks). Each archaeological feature or cluster of features is considered a ´site´ when it has been given a separate name by the investigator.

The Viking Age settlement sites considered in this study are primarily dated by reference to three tephra isochrons, the LTL, Eldgjá and V-Sv tephras. Where these tephras are not present, sites are dated by reference to the Hekla tephras from 1104 or 1158 that provide secure *termini ante quos* for the archaeological site. Tephra layers dating between Hekla 1202 and Hekla 1693 are taken into account if they are in combination with one of the 9th or 10th centuries tephra horizons described above because in most cases the archaeological structure or deposit is immediately on top of the 9th and10th century tephra layers and thus likely represents human occupation within the Viking Age. In order to discuss settlement patterns, we separate the data into four geographical areas, the southwest, the northwest, the north and the east (Fig. 1).

2.2 Tephrochronology

Tephrochronology is based on (a) identifying tephra deposits, (b) correlating separate deposits from the same eruption to define isochrons, and (c) establishing calendar or sidereal dates for the tephra (Þórarinsson, 1944; Lowe, 2011). The development of tephrochronology as a geochronological technique was pioneered in Iceland by Sigurður Þórarinsson, who described the theoretical foundations of this dating technique and developed its applications through studies of archaeology, historical sources, geomorphology and environmental change (Þórarinsson, 1944; 1952; 1954; 1956; 1957). In addition to considering proximal areas with visible tephra layers, Þórarinsson also drew attention to the possibility of creating precise teleconnections using ultra-distal tephra deposits—very fine grained deposits that are not visible to the naked eye due to their low concentrations (Þórarinsson, 1981a). These deposits, now known as *cryptotephras* (Lowe and Hunt, 2001), can be used to both extend the geographical coverage of tephrochronology (Davies, 2015), and also enhance stratigraphic resolution (Dugmore et al., 1992).

In this paper, eighteen tephra layers ranging from A.D. 877 to 1693 are used to establish a chronological framework for Viking period features (Table 1). Historically dated tephra layers in Iceland are named after the source volcanic system and the eruption date in years A.D. (-symbol). Some tephra layers that have obtained age independent estimates have been given age independent names, as the date of the eruption can change (~symbol for estimated ages and ± symbol for quantifiable error values).

Dating of tephra deposits in Iceland

In Iceland, strategies to obtain independent age estimates of tephra layers utilize written sources, correlation to annually layered sediments in lakes, the ice core records in Greenland and age depth profiles constructed using sediment accumulation rates constrained by other chronological evidence, such as radiometric dates and written sources (e.g. Þórarinsson, 1967, Grönvold et al., 1995; Zielinski et al., 1997; Dugmore and Newton, 2012, Streeter and Dugmore, 2014).

2.2.1 Sediment accumulation rates (SeAR)

Sediment accumulation rates (SeAR) refer to annual accumulation in different depositional environments. They can be used to estimate the age of undated tephra layers that occur between well-dated ones within suitable stratigraphic sequences (Hafliðason et al., 2000; Streeter and Dugmore, 2014; Sigurgeirsson et al., 2013).

1) Some Icelandic tephra dates have been derived from annually resolved ice-core stratigraphies in Greenland. However, dates of some tephra layers identified in Greenlandic ice cores has not been unambiguous. Sigl et al. (2015) claim to have resolved the discrepancies between ice cores chronologies, by high resolution measuring of ^{10}Be concentrations in four ice cores (NEEM-2011-S1, TUNU2013 and NGRIP from Greenland and the West Antarctic Ice Cheet Divide Core), improved annual–layer counting, reinterpretation of tephra and sulphate spikes and using tree ring and historical records and other independent age information. All tephra dates that are based on ice core chronologies using, or referencing, GICC05 (Vinther et al., 2006) therefore need adjusting. This has important implications for the dating of not only Icelanic tephra

layers, but also other eruptions that rely on ice core chronologies. Baillie and McAneney (2015) discuss issues (tree rings, ice cores and historical records) surrounding the dating of the Eldgjá eruption, which they suggest could be responsible for climatic flucuations observed in A.D. 939-940. Previously, the Eldgjá tephra had been dated to A.D. 938 ± 4 (GISP2 core: Zielinski et al., 1995) and to A.D. 933 ± 1 (GICC05 chronology: Vinther et al., 2006). An adjustment of 6 years is suggested by Baillie and McAneney (2015) and the date of A.D. 939 is used by Sigl et al. (2015). This implies that the age of the LTL tephra layer should also be reassessed. The LTL has previously been dated to A.D. 871 ± 2 (GRIP core/GICC05 chronology: Grönvold et al., 1995; Vinther et al., 2006) and to A.D. 877 ± 4 (GISP2 core: Zielinski et al., 1997). The revised age of the Eldgjá tephra allows bringing forward the often quoted GISP2 age of the LTL by six years to A.D. 877 ± 1 and is therefore in agreement with the mean age of the GRIP chronology.

2) Tephra dates have been derived from regular or rhythmitically deposited lacustrine sediments. A series of layers forming a group named the *Landnám* tephra sequence (LNS) has been analysed from lacustrine sediment cores extracted from Lake Mývatn in the north of Iceland (McGovern et al., 2007; Sigurgeirsson et al., 2013). The date of a distinctive olive-green basaltic tephra layer (V-Sv) found in the LNS was dated using sediment accumulation rates from nine cores from Lake Mývatn and is also found in many terrestrial sediment sequences (Fig. 2). This tephra was erupted from Veiðivötn volcanic system after the LTL and before Hekla 1158 tephra layers. The presence of these well-dated tephra layers provided the chronological control to calculate the age of the V-Sv tephra. The name V-Sv was adopted by Sigurgeirsson et al. (2013), as it is age independent and allows for further revision of the estimate of the dating of its deposition.

The age of the 10th-century Veiðivötn tephra (V-Sv) was estimated by Sigurgeirsson et al. (2013) using the sedimentation rate between the LTL and H-1158 and they calculated the age of the V-Sv tephra by using both Greenland ice core dates (GRIP and GISP) for the LTL. Therefore, if the age of LTL is assumed to be A.D. 871 ± 2 (the GRIP date), then the 10th century Veiðivötn tephra was estimated to be A.D. 933 ± 6 and if the LTL was assumed to be A.D. 877 ± 4 (the GISP2 date), the age of the V-Sv tephra was A.D. 938 ± 6 (Sigurgeirsson et al., 2013). However, the revision of the GICC05-based ice core chronologies (e.g. GISP2) suggested by Baillie and McAneney (2015) and Sigl et al. (2015) means that the resultant A.D. 877 ± 1 age for LTL produces an average age estimate of A.D. 938 ± 6 for the V-Sv tephra. Based on the same approach using sedimentation rates and assuming an age of A.D. 877 ± 1 for the LTL, other tephra layers in the north have been dated to mean ages of A.D. 1239, A.D. 824, A.D. 803, A.D. 795 and A.D. 710 (Sigurgeirsson et al., 2013). Elsewhere, a similar method has been applied to derive calendar dates for K~920 and K~1500 (Hafliðasson et al., 1992).

3) Accumulation rates within aeolian sediments have also been used to infer tephra dates; here accuracy and precision is closely controlled by the approach used. For example, Streeter and Dugmore (2014) estimated the age of two 15th century Grímsvötn tephra layers using aeolian sediment accumulation rates between K-1416 and V-1477 in an area of rapid aggradation. Multiple high-resolution measurements of sediment thickness (n=1960) were used to infer ages of A.D. 1432 ± 5 (mean ± 1SD) and A.D. 1457 ± 5 (mean ± 1SD) and the accuracy was evaluated by using the same method to date a tephra of known age – that of K-1262 (Streeter and Dugmore, 2014). The test used calculations of SeAR between tephras H-1206 and H-1300 (time interval between control

points 96 years), and measurements to an accuracy of ± 2.5 mm; the age inferred for the A.D. 1262 tephra was A.D. 1264 ±10 (mean ± 1SD, n=97). A 'Vj~1000' tephra has been identified in association with early settlement sites in Skagafjörður (e.g. Bolender et al., 2011; Zoëga et al. 2013), but this estimate has significant uncertainty, as it uses SeAR over more than 227 years as opposed to c. 60 years for Streeter and Dugmore's (2014) Grímsvötn dates or 96 years for their test of the Katla layer.

2.2.2 Written sources

Tephra layers that were deposited at times for which written records survive can be dated with both precision and accuracy, sometimes to the year, on occasion to a month, week or day of the eruption (Þórarinsson, 1967). Þórarinsson's seminal works focused on Hekla (Þórarinsson, 1967) and Öræfajökull (Þórarinsson, 1952), he compiled a catalogue of Katla eruptions (Þórarinsson, 1977) and identified layers from other systems such as Grímsvötn (Þórarinsson, 1981b). The approach is not without its critics (e.g. Vilhjálmsson, 1991), but dates derived from written sources for tephra layers such as H-1104, H-1158 and H-1300 have withstood the test of time and are frequently used as reliable *termini post quos* for Viking age sites.

2.3 Identification of tephra deposits

The application of tephrochronology in Icelandic archaeology first began with the use of major tephra layers such as those formed by the A.D. 1104 eruption of Hekla in Þjórsádalur and pre-settlement plinian tephras such as Hekla 3 and Hekla 4 (Þórarinsson, 1944; 1967). Initially reference to a few clearly developed marker horizons can achieve a lot, but in order to engage with crucial detail—such as the decadal scale pattern and timing of initial settlement—greater temporal resolution is needed. Þórarinsson created some of this with his magisterial work on the historic eruptions of Hekla (Þórarinsson, 1967) and this has since been developed through work on other volcanic systems (e.g. Larsen, 2000; Óladóttir et al., 2008). Further enhancement can be achieved by the careful utilization of thin and weakly developed or poorly provenanced tephra layers that occur between the major, well-constrained marker horizons (Dugmore and Newton, 2012).

Rigour is required because fine layers have poorly developed layer colours and may have the same physical appearance as other tephras; deposits that are from the same volcanic source, but from different eruptions, can have a very similar major, minor and indeed trace element chemistry, and thus appear similar in the field. Silicic tephra layers from two 12th century eruptions (H-1104 and H-1158) are both found in the north, where they form very thin horizons. Although they may be confused in the field, it has been demonstrated that they have distinctly different chemistries (Larsen et al. 1999; Newton, 2008). In a comparable way, tephras with similar major element chemistry from K~920 and Eldgjá overlap in the south where either one or both may appear in sections (e.g. at Hrísbrú: Sigurgeirsson, 2014). Veiðivötn tephras formed in the 9th and 10th centuries have a very similar chemistry, with overlapping compositions, but the crucial LTL of A.D. 877 ± 1 is unique as it includes crystals resulting from the interaction of the Veiðivötn and Torfajökull volcanic systems and their simultaneous activity (Larsen, 1982). Silicic tephra layers from Katla (the 'SILK layers of Larsen et al., 2001) can be confidently identified in the field when only a few mm thick because of a combination of a distinctive 'needle grain' shard morphology and their stratigraphic context in relation to other tephra layers (e.g. SILK-un in Dugmore et al., 2000). Thus, confident identification of thin, weakly developed or poorly provenanced tephra layers relies on a combination of precise stratigraphy, the identification of a crystal fraction or distinctive shard morphologies, chemical analysis of the glass fraction, and integration within a well-known local and regional tephrostratigraphic framework.

2.4 Dating archaeological sites using tephra deposits

The presence of well-dated tephra isochrones within the archaeological stratigraphy is a major asset when building site chronologies (Lane et al., 2014; Riede and Thastrup, 2013). Tephra can be preserved *in situ* below and/or above anthropogenic layers where the area has been exposed to atmospheric fallout and aeolian sediment accumulation has not been disturbed (Fig. 3). These sites may include turf structures and layers of midden. Turf is a commonly used building material in Iceland and turf blocks can include tephra layers that were near to the surface when the turf was cut (Fig. 3). As a result, tephra layers can be moved around the landscape within building materials and incorporated into structures. Tephra layers *in situ* above anthropogenic features give secure *termini ante quos*; tephra layers *in situ* below anthropogenic features as well as tephra in turf generally give secure *termini post quos*.

3. Results and discussion

3.1 Presence/absence of tephra at archaeological sites

This study considers a total of 300 archaeological sites related to settlement; 59% are located in the north (n=176), 20% are in the southwest (n=60), 17% in the east (n=51) and 4% in the northwest (n=13) (Fig. 1). It is important to note that these numbers do not reflect the density of settlement, rather they reflect fieldwork activity. In the north 92% of sites include *in situ* tephra layers (162 out of 176), as do 77% in the southwest (46 out of 60 with tephra), 78% in the east (40 out of 51), and proportionally less (38%) in the northwest (5 out of 13) (Table 2).

This regional pattern is biased, because more of the excavations in the north have involved methodologies that maximise the likelihood of successfully using tephrochronology. In contrast, many of the earlier excavation methods employed in the south did not excavate turf walls and thus any tephra deposits *in situ* beneath them were not documented. The absence of tephra for an archaeological site may be a result of impacts of household activities and building construction that removed sediments including tephra layers. Alternatively the absence may be as a result of a lack of tephra layers. In the west, for example, the low frequency of tephra records is a reflection of the location of volcanoes to the east and prevailing westerly winds, which results in a much lower frequency of tephra falls, especially in the West Fjords. Modern excavation techniques, including the identification of cryptotephras, may yet reveal tephra layers at sites, which currently have no record of them.

The tephra layers used to date Viking Age deposits are listed in Table 2. One third of the sites are dated with medieval tephra layers ranging between A.D. 1206 and 1693 (n=71). This highlights one fundamental limitation of tephrochronology as a means of dating archaeological sites in Iceland and elsewhere; tephra layers have to be present and identifiable. Some sparse records, such as sites that only contain tephras produced in late

9th century (LTL) and at the turn of the 17th century (H-1693) may reflect an environmental reality, alternatively cryptotephras may be present but currently unidentified. Cryptotephras represent an untapped potential in Icelandic archaeology, but one that would require further methodological innovations to extract sparse numbers of fine-grained volcanic glass shards from a matrix of volcanically-derived andisols of a similar particle size.

3.2 Spatial distribution of the LTL, Eldgjá and V-Sv tephras

The LTL, Eldgjá and V-Sv tephras cover substantial parts of Iceland and are associated with 58% of early settlement sites (n=173). Isopach maps are available from the LTL and Eldgjá tephra and are illustrated in figure 4. The LTL is preserved at 83 sites, of which 33 are located in the southwest, five in the northwest, 38 in the north and seven sites are located in the east (Table 2). The distribution of the LTL at archaeological sites in the north goes beyond the borders mapped by Larsen (1984; Fig. 4B) and shows how distributions may be extended by additional detailed study. The Eldgjá tephra is primarily found associated with sites in the southwest (n=11) and east (n=10) and is also documented in the north (n=2) (Fig. 4C, Table 2). The V-Sv tephra is primarily found in the north (n=65), but also in the east (n=2) (Fig. 4C, Table 2).

3.3 Chronology of archaeological sites

The range of tephra layers allows a secure periodization of settlement sites in Iceland (SI Table 1). The pre-Landnám period summarizes sites where human activity occurred before the LTL was deposited (Period 1=1%); the Landnám period refers to sites that are sandwiched between the LTL and Eldgjá or V-Sv tephras (Period 2=6%) and the post-Landnám period covers sites that are sandwiched between the Eldgjá or V-Sv tephras and the Hekla tephras of A.D. 1104 or 1158 (Period 3=19%) (Fig. 5). Archaeological sites that were occupied before the deposition of the Vj or Hekla tephras of A.D. 1104 or 1158 are categorized as Viking age (Period 4=38%). Sites considered as potential Viking age are dated post-LTL or between LTL and a 12th-17th century tephra layer (Period 5=17%). Sites are considered as potential post-Landnám are dated post-Eldgjá/V-Sv or between one of these 10th century tephras and a 12th-17th century tephra (Period 6=19%).

There is a pattern to the regional distribution of settlement-related sites connected to the LTL, Eldgjá and V-Sv tephra layers. The two sites with evidence for occupation before the deposition of LTL are both in the southwest (Period 1: Fig. 6A). Sites that are dated between the deposition of the LTL and Eldgjá/V-Sv tephra layers are scattered around the southwest, east and north and found equally in coastal as well as inland regions (Period 2: Fig. 6B). Sites that were occupied after the deposition of the V-Sv tephra are mostly located in the north (Period 3: Fig. 6C) – a function of the distribution of that tephra. Figure 6 illustrates continuity of settlement in the south and north. The distribution of Viking Age sites shows that all inhabitable parts of the island were most likely occupied by the 10th and 11th centuries and the next phase of Viking expansion to Greenland (Period 4: Fig. 7).

The presence of both the LTL and V-Sv tephra layers in the north and the LTL and Eldgjá tephras in the southwest and east has allowed better dating than is possible in regions where tephra layers from the early settlement period have not been identified and the closest available isochrons are formed by H-1104 and H-1158 or even later tephras. This situation could be improved through the application of other dating methods, in particular radiocarbon dating within a Bayesian framework (e.g. Church et al., 2007; Batt et al., 2015).

These results suggest that although colonisation had started before the 870s in the southwest, the bulk of first settlement happened after that date. Other patterns in the data reflect different fieldwork intensities in different regions and the uneven distribution of (identified) tephras. Within the regions where the A.D. 939 Eldgjá and A.D. 938 ± 6 V-Sv tephras have been identified there are a significant number of sites with deposits below those horizons. Indeed, in open area excavation around Lake Mývatn, where the identification of the tephra is far more certain than in limited exposures, anthropogenic layers are below the V-Sv in two out of three sites. Vésteinsson and McGovern (2012) argue that many of these pre-A.D. 938 ± 6 sites represent satellite occupations on less than optimal land, or indeed main occupation sites that are themselves in marginal areas, and this indicates a rapid process of colonisation and near complete occupation of the landscape, encompassing ideal sites and far less than ideal ones, all before the mid-930s.

The new catalogue of early settlement sites shows that none of the pre- A.D. 938 ± 6 archaeological features identified so far in the north are from currently upstanding remains like turf walls. They are all entirely sub-surface features such as pit houses, middens or traces of cultivation. In contrast, most of the post mid-930s dates relate to archaeological remains that are still visible as positive features of relief, such as turf-walls of houses and earthwork systems. Such upstanding features in the modern landscape are much more easily identifiable that buried remains; feature of field surveys and are more likely to be targeted for excavation. Furthermore, when excavated they are more likely to preserve tephra layers by sealing them below archaeological remains or providing obstacles against which tephras can accumulate. As sunken-features such as pit houses and moraine spreads are more difficult to detect they are most likely under-represented in the data (Vésteinsson, 2014). If this is the case then it opens up the possibility that sites dating to just before or after the LTL may be under-represented in the data set.

Only in recent decades has the potential to use multiple tephra layers to precisely date archaeological deposits from the Icelandic colonisation period been widely recognised. While the majority of available tephra dates demonstrate a clear contrast in the number of settlements known between the pre-LTL and the post-LTL most were obtained using methodologies that do not allow further refinement of the dates. Archaeologists have been pre-occupied with the possibility that pre-LTL deposits might be identified, but they have only just begun trying to systematically collect evidence to date the colonisation as a process (e.g. Bolender et al., 2011; Vésteinsson and McGovern, 2012). The data presented here demonstrates the potential to build a much more nuanced understanding of the sequence of colonisation of Iceland, and whether it was a trickle, steady flow or torrent (Edwards, 2012). It suggests that targeting regions with early 10th century tephras would be particularly useful and that dense spatial coverage of sampling points is key to success. The majority of early tephra dates come from trenching campaigns conducted in the last 20 years (see SI Table 1). They have transformed the distribution maps and further work is likely to clarify the picture. Improving the known geographical extent of 9th and 10th century tephras would also help, as this would improve the number of isochrons available at specific locations. Use of either poorly defined layers (Dugmore and Newton, 2012) or cryptotephras (Dugmore et al., 1991) could achieve this – but across much of Iceland the latter would require methodological innovations to isolate low concentrations of very fine-grained tephras within sedimentologically-similar volcanically-derived andosols (Davies, 2015; Ponomareva et al., 2015).

4. Conclusion

Icelandic archaeology benefits from the presence of multiple tephra layers deposited at around the time of initial settlement by the Norse and in the decades and centuries that followed. The tephras are well-dated and have been identified at 253 archaeological sites related to settlement (84% of the known total). The recent revision of the Greenlandic ice core chronologies has improved tephrochronology in Iceland; most importantly the ages of three key tephra isochrons have been revised: the LTL is now dated to A.D. 877 ± 1, the Eldgjá tephra to A.D. 939 and the V-Sv tephra to A.D. 938 ± 6. Tephra layers that are not historically dated are therefore best referred by a name that is independent of a date, e.g. V-Sv.

The LTL allows us to confidently group archaeological sites into two periods, two from before A.D. 877 ± 1 and 81 from after that date. The earliest sites are exclusively located in the southwest of Iceland. After the deposition of the LTL, continuous and large-scale settlement commenced in all inhabitable parts of the island. The identification of the A.D. 938 ± 6 V-Sv tephra in the north and the A.D. 939 Eldgjá tephra in the southwest and east allows further division of the archaeology of settlement sites into the period of Landnám as well as in the period after the Landnám.

Considerable potential exists to apply the tephrochronology of Landnám across regions where key tephra are known to exist. The isochrons defined by tephra layers provide a very effective way to constrain and quantify the timing, scale and tempo of settlement, and thus gain a better understanding of the processes driving colonisation both in Iceland and many other parts of the world affected by tephra deposition, such as the western parts of the Americas and the Pacific Rim. Methodological innovations to isolate low concentrations of very fine grained tephras within sedimentologically similar volcanically-derived andosols would allow cryptotephrochronology to further enhance both the temporal resolution and geographical extent of dating using tephra.

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Highlights

- Icelandic tephra isochrons permit a countrywide comparison of 253 archaeological sites

- The LTL is revised to A.D. 877 ± 1, the Eldgjá tephra to A.D. 939, the V-Sv tephra to A.D. 938 ± 6

- The LTL, Eldgjá and V-Sv tephras allow a periodization of Iceland´s colonization

- The archaeological periods are: pre-Landnám (pre-877), Landnám (877-939), post-Landnám (939-1104)

Figures

Fig. 1: The distribution of 300 settlement sites considered in this study. 85% sites are dated by tepha layers (n=253).

Fig. 2: The preservation of the LTL and V-Sv tephras in situ below a structure at Sveigakot, Mývatnsveit in northern Iceland (picture: Anthony Newton).

Fig. 3: V-Sv tephra in situ below the wall of a hall at Hofstaðir, as well as in turf of the wall (reconstruction after Lucas 2009).

Fig. 4A: The preservation of the LTL at Langanes in southwestern Iceland. ´T´ points to the white silicic Torfajökull component (discontinuous) and ´V´ points to the olive-green basaltic Veiðivötn component.

Fig. 4B: Isopach map of the silicic and basaltic components of LTL (after Larsen, 1984).

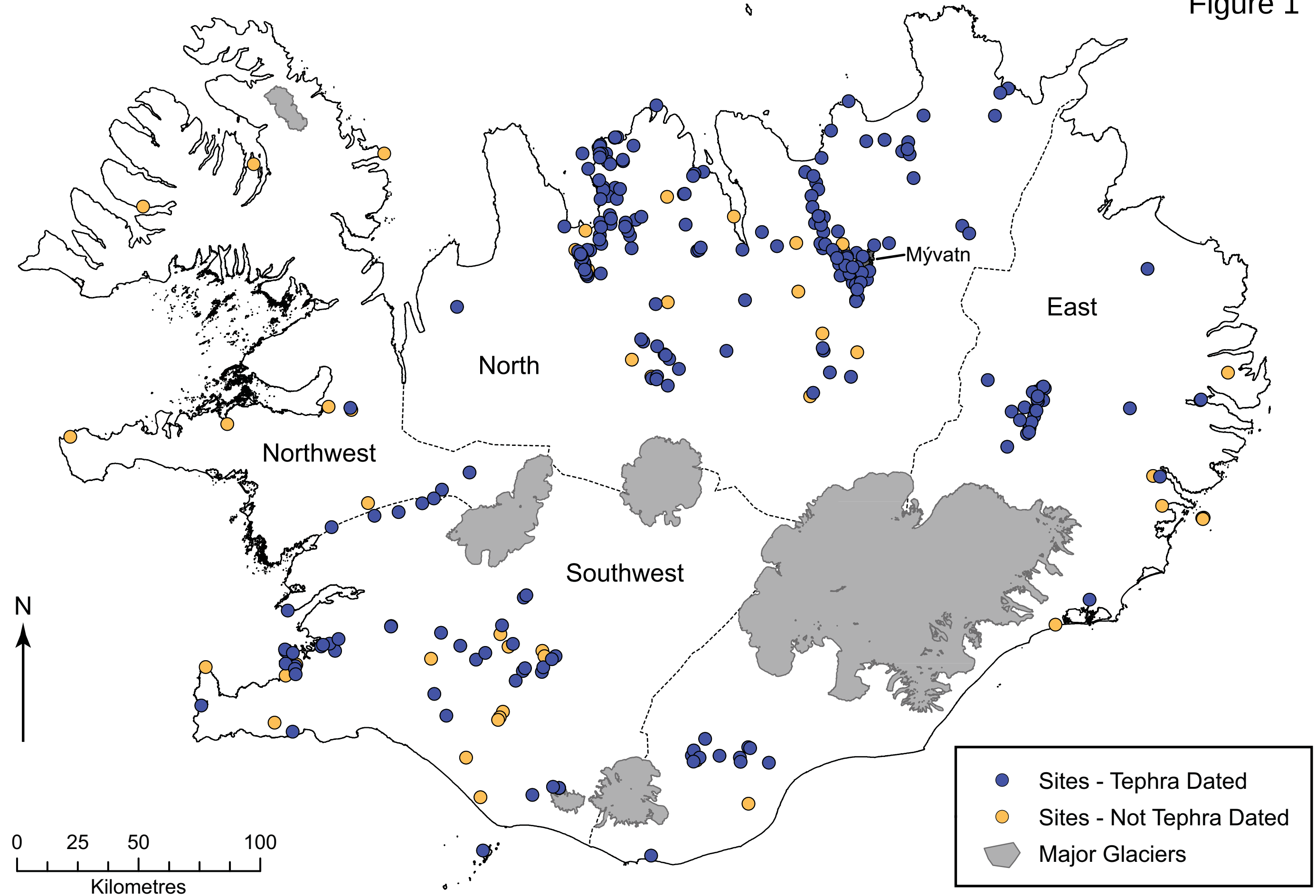
Fig. 4C: Isopach map of the Eldgjá tephra in southern Iceland. M= Mýrdalsjökull; (K)= Katla; V=Vatnajökull (after Larsen, 2010).

Fig. 5: The number of Viking age settlements whose periods can be defined by tephrochronology (n=253).

Fig. 6A: The periodization of Viking Age settlement sites in Iceland. Pre-Landnám (A.D. pre-877; n=2); **B**. Landnám (A.D. 877-939; n=14); **C**. Post-Landnám (A.D. 939-1104; n=47).

Fig. 7: The periodization of Viking Age settlement sites in Iceland: Viking age (A.D. c. 800-1100; n=97).

Figure 1


Mývatn
North
East
Northwest
Southwest
N
0
25
50
100
Kilometres
Sites - Tephra Dated
Sites - Not Tephra Dated
Major Glaciers

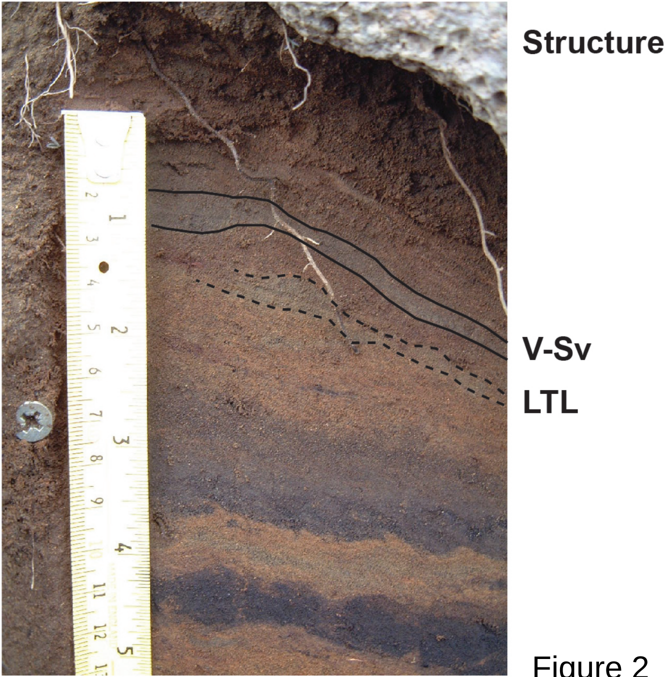
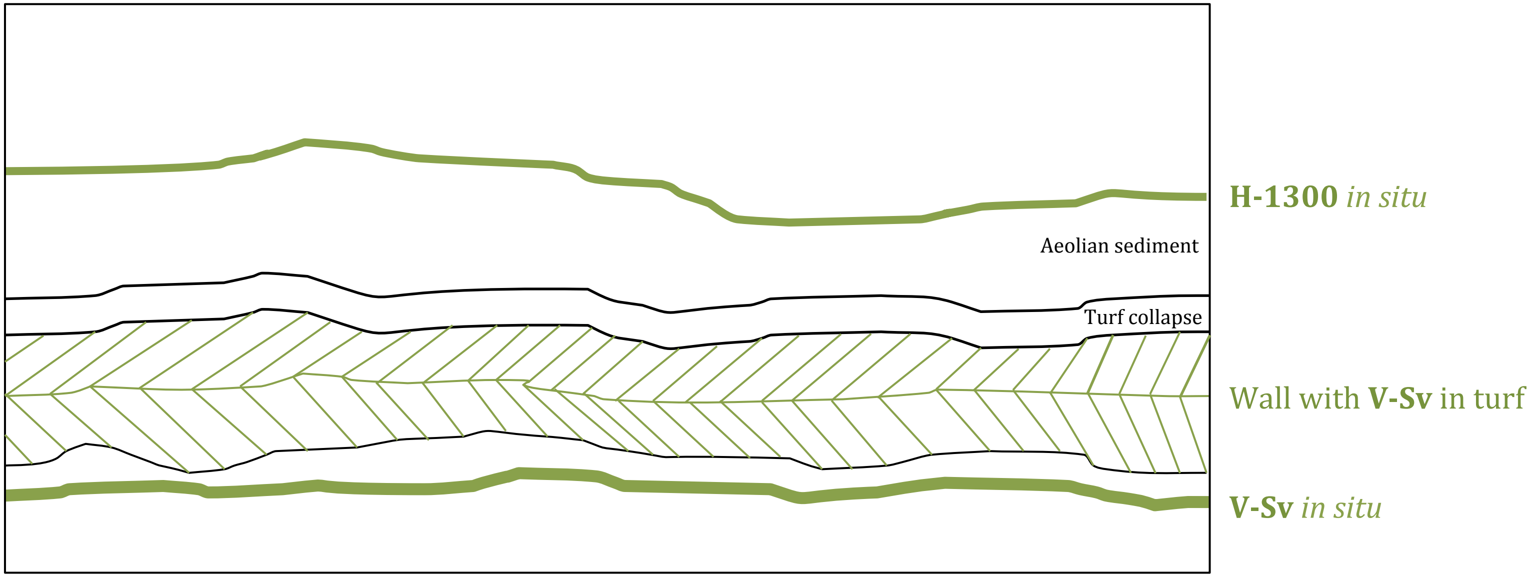


Figure 2



H-1300 *in situ*
Aeolian sediment
Turf collapse
Wall with **V-Sv** in turf
V-Sv *in situ*

Figure 3

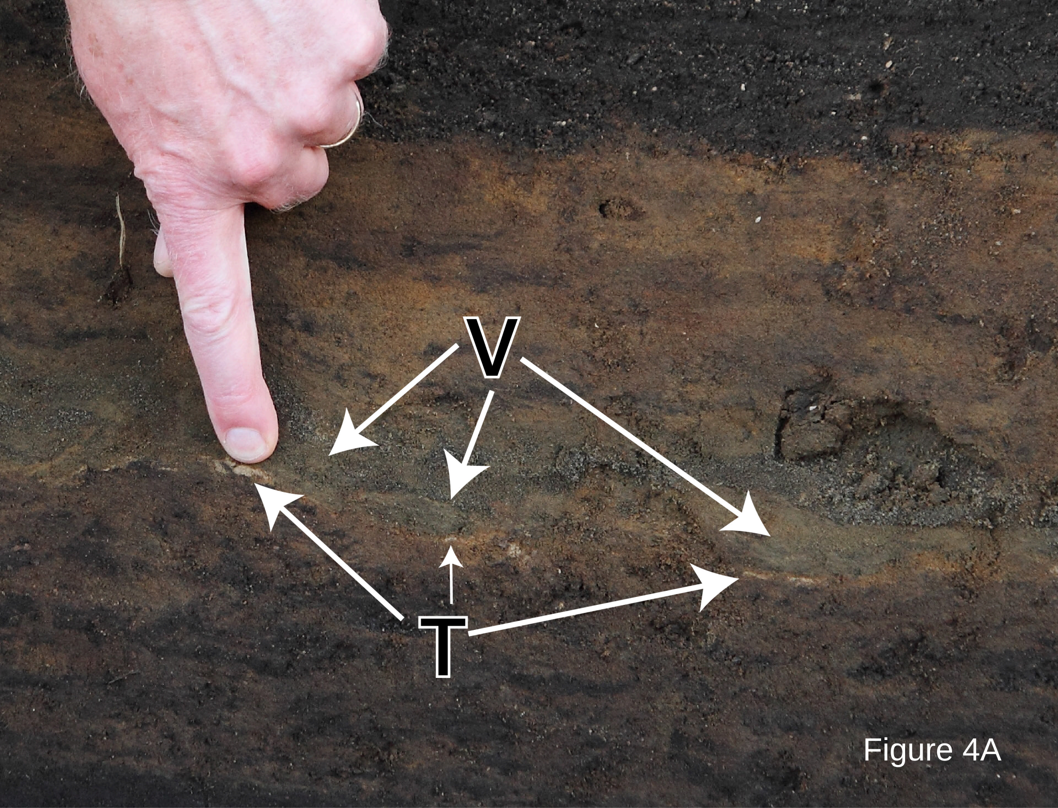
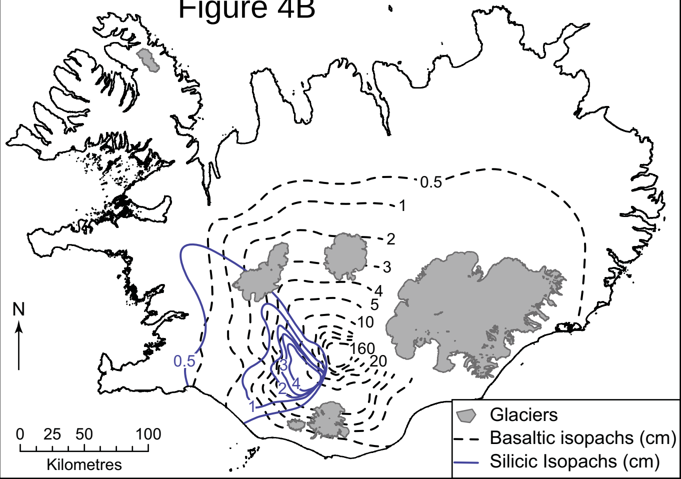


Figure 4A

Figure 4B


0.5
1
2
3
4
5
10
160
20
0.5
3
2
4
1
N
0
25
50
100
Kilometres
Glaciers
Basaltic isopachs (cm)
Silicic Isopachs (cm)

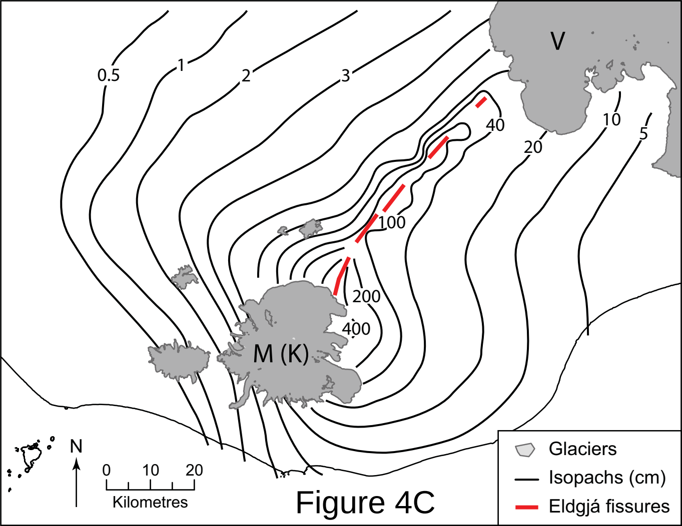

0.5
1
2
3
V
40
10
5
20
100
200
400
M (K)
N
0
10
20
Kilometres
Glaciers
Isopachs (cm)
Eldgjá fissures

Figure 4C

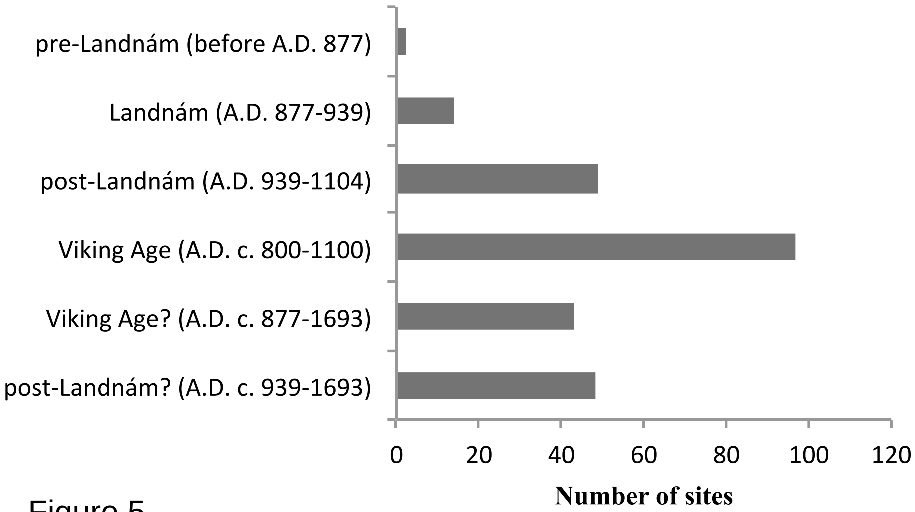

pre-Landnám (before A.D. 877)
Landnám (A.D. 877-939)
post-Landnám (A.D. 939-1104)
Viking Age (A.D. c. 800-1100)
Viking Age? (A.D. c. 877-1693)
post-Landnám? (A.D. c. 939-1693)
0
20
40
60
80
100
120
Number of sites

Figure 5

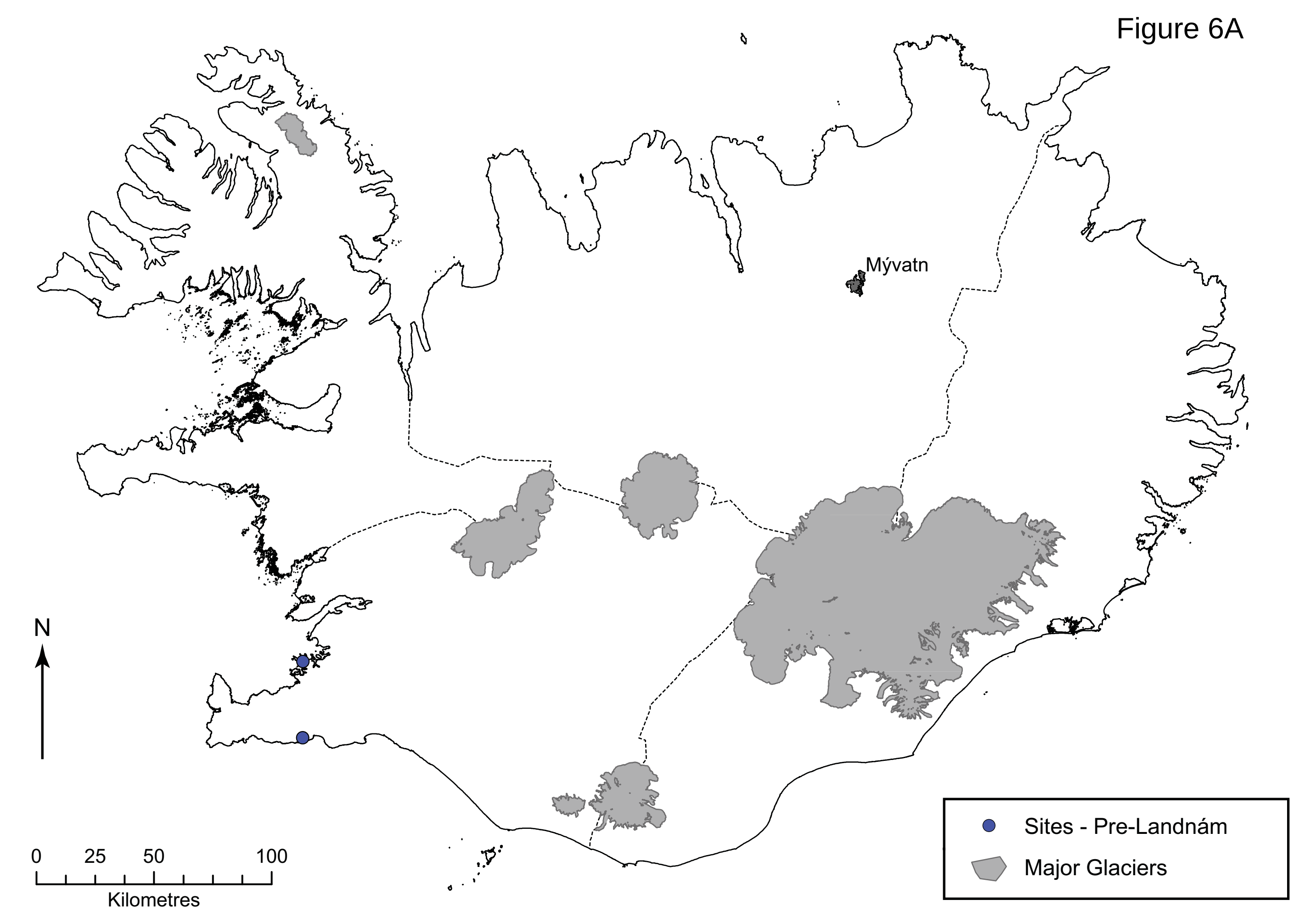


Figure 6A
Mývatn
N
0
25
50
100
Kilometres
Sites - Pre-Landnám
Major Glaciers

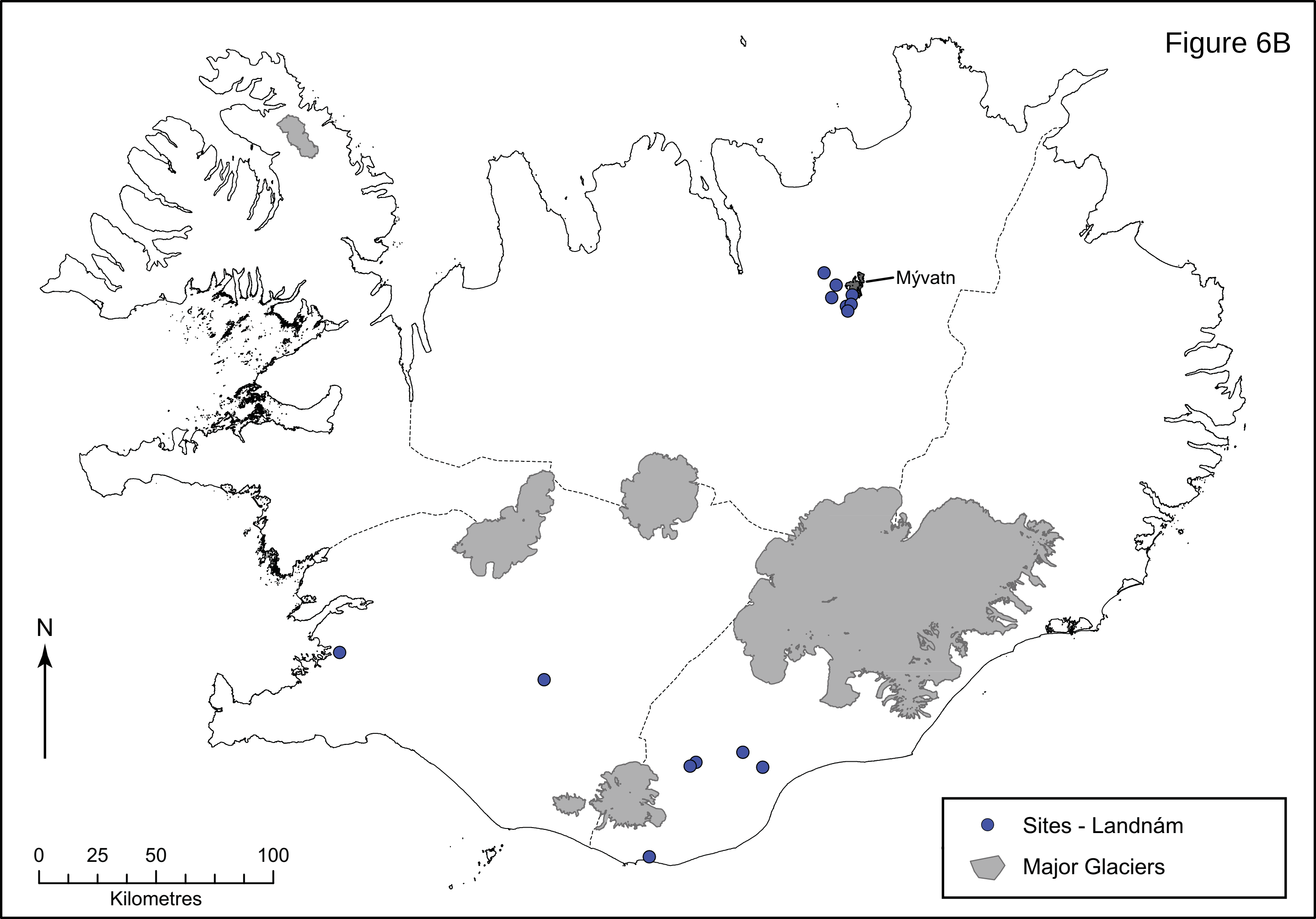
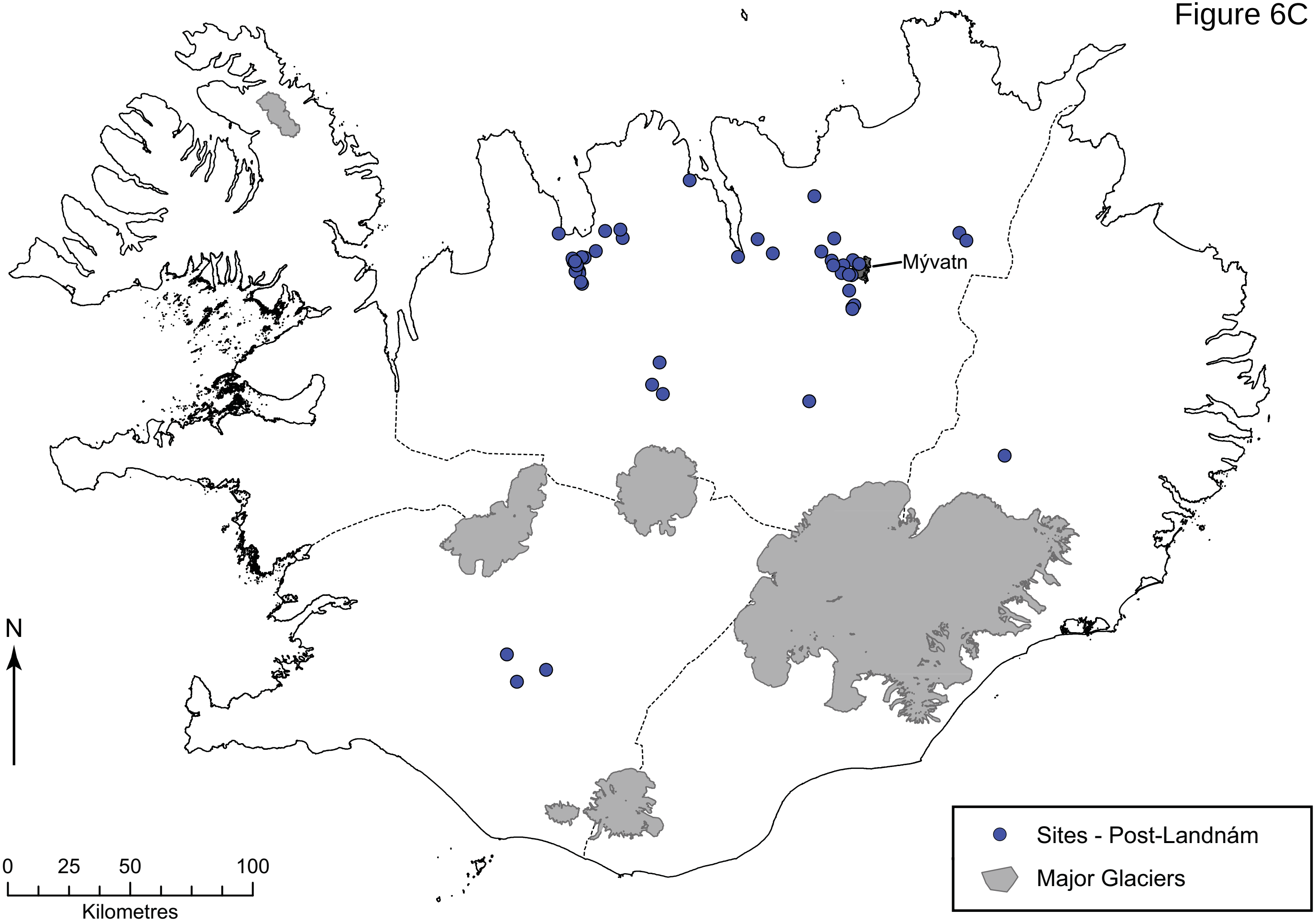


Figure 6B
Mývatn
N
0
25
50
100
Kilometres
Sites - Landnám
Major Glaciers

Figure 6C


Mývatn
N
0
25
50
100
Kilometres
Sites - Post-Landnám
Major Glaciers

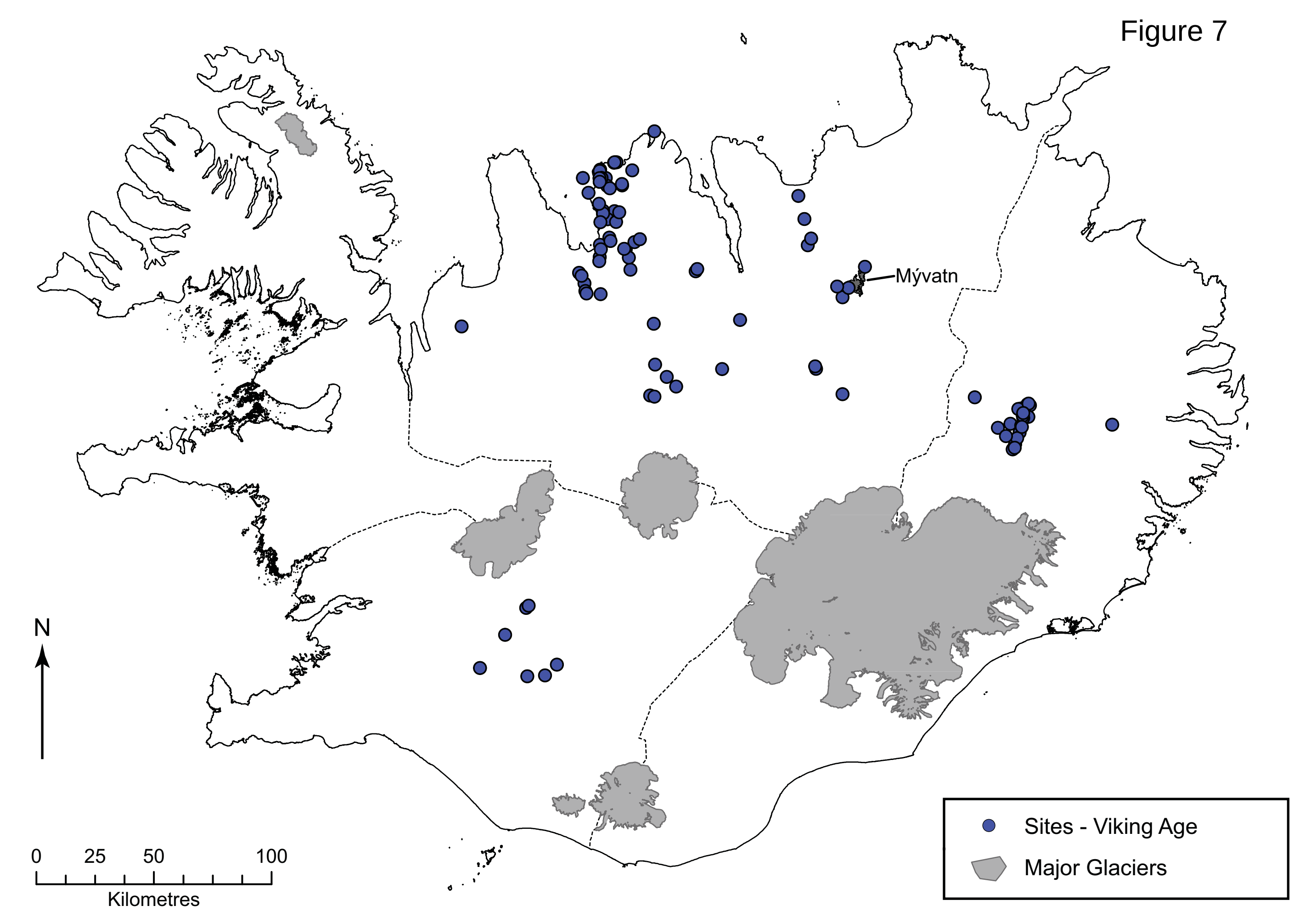


Figure 7
Mývatn
N
0
25
50
100
Kilometres
Sites - Viking Age
Major Glaciers

Table 1: Tephrochronological record in Iceland.

Name of tephra layer	Origin (volcanic system)	Year A.D.	References
LTL [VIIa, VIIb]	Veiðivötn	877 ± 1	Haflidason et al., 1992; Grönvold et al., 1995; Zielinski et al., 1997; Larsen et al., 1999; this study
K~920 [Katla-R]	Katla	~920	Hafliðason et al., 1992
Eldgjá [K~1000]	Katla	939	Hammer et al., 1980; Larsen, 1984; Hafliðason et al., 1992; Zielinski et al., 1995; Sigl et al., 2015; this study
V-Sv [V~950, V~940]	Veiðivötn	938 ± 6	Sigurgeirsson, 2001; Sigurgeirsson et al., 2013; this study
Vj	Veiðivötn	~1000	Sigurgeirsson, 2010
H-1104 [H1]	Hekla	1104	Þórarinsson, 1967; Larsen and Þórarinsson, 1977; Larsen et al., 1999; Sigurðsson, 1982; Hafliðason et al., 2000
H-1158	Hekla	1158	Þórarinsson, 1967; Einarsson et al., 1988; Larsen et al., 1999
V-1159	Veiðivötn	1159	Einarsson et al., 1988; Hafliðason et al., 2000
H-1206	Hekla	1206	Þórarinsson, 1967
R-1226 [‘R-9’]	Reykjaneshryggur	1226	Hafliðason et al., 1992; Sigurgeirsson, 1995
K-1262	Katla	1262	Larsen, 1982; Streeter and Dugmore, 2014
H-1300	Hekla	1300	Þórarinsson, 1967; Einarsson et al., 1988; Hafliðason et al., 2000
H-1341	Hekla	1341	Þórarinsson, 1967; Larsen et al., 1999
Ö-1362	Öræfajökull	1362	Þórarinsson, 1958; Sigurðsson, 1982
V~1410	Veiðivötn	1410	Larsen, 1982; Hafliðason et al., 2000
V~1477 [‘a’]	Veiðivötn	~1477	Þórarinsson, 1958; 1976; Larsen, 1982; 1984; Hafliðason et al., 2000
K~1500	Katla	~1500	Hafliðason et al., 1992
H-1693	Hekla	1693	Þórarinsson, 1967

Table 2: Tephrochronological record of archaeological sites.

Tephra dates	South west	North	East	North west	No. of sites
Pre-LTL	2	-	-	-	2
Post-LTL	10	2	2	5	19
Between LTL and K~920/Eldgjá	1	-	1	-	2
Between LTL and V-Sv	-	7	-	-	7
Between LTL and Vj	-	5	-	-	5
Between LTL and H-1104/H-1158	5	17	2	-	24
Between LTL and R-1226	8	-	-	-	8
Between LTL and H-1262	-	1	-	-	1
Between LTL and H-1300	-	5	-	-	5
Between LTL and H-1341	2	-	-	-	2
Between LTL and Ö-1362	-	-	2	-	2
Between LTL and V-1477	-	1	-	-	1
Between LTL and H-1500	3	-	-	-	3
Between LTL and H-1693	2	-	-	-	2
Between K~920 and Eldgjá	1	-	-	-	1
Pre- Eldgjá	1	-	3	-	4
Between Eldgjá and H-1104	3	1	-	-	4
Between Eldgjá and H-1206	-	-	7	-	7
Between Eldgjá and K-1341	6	-	-	-	6
Between Eldgjá and V~1477	-	1	-	-	1
Post- V-Sv	-	1	-	-	1
Between V-Sv and Vj	-	6	-	-	6
Between V-Sv and H-1104/H-1158/V-1159	-	26	1	-	27
Between V-Sv and K-1262	-	1	-	-	1
Between V-Sv and H-1300	-	18	-	-	18
Between V-Sv and Ö-1362	-	-	1	-	1
Between V-Sv and V-1410	-	1	-	-	1
Between V-Sv and V~1477	-	12	-	-	12
Pre-Vj	-	7	-	-	7
Between Vj and H-1104	-	12	-	-	12
Pre-H-1104/H-1158	2	38	21	-	61
LTL	**33**	**38**	**7**	**5**	**83**
Eldgjá	**11**	**2**	**10**	**-**	**23**
V-Sv	**-**	**65**	**2**	**-**	**67**
Vj/H-1104/H-1158	**2**	**57**	**21**	**-**	**80**
Recorded tephra	**46**	**162**	**40**	**5**	**253**

SI Table 1. Viking Age settlements whose periods can be defined by tephrochronology (n=253). The archaeological sites are grouped into six periods. Period 1: pre-Landnám (A.D. pre-877); period 2: Landnám (A.D. 877-939); period 3: post-Landnám (A.D. 939-1104); period 4: Viking Age (A.D. c. 800-1100); period 5: potential Viking Age (A.D. 877-1693) and period 6: potential post-Landnám (A.D. 939-1693).

Period	Site name	Region	Tephra post-	Tephra pre-	References
1	Húshólmi	SW	/	LTL	Jóhannesson & Einarsson 1988, 83
1	Reykjavík	SW	/	LTL	Roberts et al. 2003, 224-225; Sigurgeirsson 2001b, 103-104
2	Hrísbrú	SW	LTL	K~920/Eldgjá	Byock and Zori, 7
2	í Geirlandsheiði	E	LTL	Eldgjá	Einarsson 2008b, 8-9
2	Beinisstaðir	N	LTL	V-Sv	Vésteinsson 2011, 23-24; Sigurgeirsson 2008a, 47; 2011, 76
2	Gautlandasel	N	LTL	V-Sv	Vésteinsson 2011, 45-47; Sigurgeirsson 2011, 75-76
2	Hrísheimar	N	LTL	V-Sv	Sigurgeirsson 2008a, 47; 2011, 76
2	Skútustaðir	N	LTL	V-Sv	Edwald & McGovern 2009, 6-7
2	Sveigakot	N	LTL	V-Sv	Sigurgeirsson 2001c, 39-40
2	Þorleifsstaðir	N	LTL	V-Sv	Sigurgeirsson 2008a, 46-49
2	Þyrilskot	N	LTL	V-Sv	Vésteinsson 2011, 11; Sigurgeirsson 2011, 73
2	Fagridalur	E	K~920	Eldgjá	Guðmundsson et al. 2004, 94-98
2	Mosholt	E	/	Eldgjá	Hreiðarsdóttir et al. 2014, 39-40
2	Sámsstaðir	SW	/	Eldgjá	Rafnsson 1977, 90
2	"Sólheimar"	E	/	Eldgjá	Einarsson 2008b, 7-8
2	við Kóragil	E	/	Eldgjá	Hreiðarsdóttir et al. 2014, 42
3	Hraunþúfuklaustur	N	Eldgjá	H-1104	Þórarinsson 1977, 33
3	Hrunakrókur	SW	Eldgjá	H-1104	Ólafsson 2010, 4-5, 12
3	Skallakot	SW	Eldgjá	H-1104	Þórarinsson 1943, 32-35; Hansen & Vésteinsson 2002, 11; Sigurgeirsson 2002a, 32-33
3	Stöng	SW	Eldgjá	H-1104	Þórarinsson 1943, 38-40; Vilhjálmsson 1989, 88-89
3	Holtsmúli	N	V-Sv	Vj	Steinberg et al. 2009a, 3
3	Kjartansstaðir	N	V-Sv	Vj	Steinberg et al. 2009b, 3; Sigurgeirsson 2010a, 3
3	Litla Gröf	N	V-Sv	Vj	Steinberg et al. 2009c, 3; Sigurgeirsson 2010a, 4
3	Meðalheimur	N	V-Sv	Vj	Steinberg & Shepard 2007, 2; Steinberg et al. 2009f, 3
3	Stóra Gröf, Ytri	N	V-Sv	Vj	Sigurgeirsson 2010a, 3
3	Stóra Seyla	N	V-Sv	Vj	Sigurgeirsson 2010a, 2
3	Brenna	N	V-Sv	H-1104	Vésteinsson 2004b, 50-53; Sigurgeirsson 2002b, 2

3	Einirlækur	N	V-Sv	H-1104	Sveinbjarnardóttir 1992, 158
3	Hali	N	V-Sv	H-1104	Einarsson & Sigurgeirsson 1996
3	Hamar 2	N	V-Sv	H-1104	Hreiðarsdóttir 2010, 24; Sigurgeirsson 2010b, 36
3	Helgastaðir	N	V-Sv	H-1104	Vésteinsson et al. 2014, 53
3	Hofstaðir í Mývatnsveit	N	V-Sv	H-1104	Lucas 2009, 56-57
3	Hólar	N	V-Sv	H-1104	Traustadóttir et al. 2002, 23-24
3	Húsatóftir	N	V-Sv	H-1104	Sveinbjarnardóttir 1992, 160
3	Naust	N	V-Sv	H-1104	Sigurgeirsson 2008b, 38-41
3	Pálstóftir	E	V-Sv	H-1104	Lucas 2007, 14
3	Raufarhóll	N	V-Sv	H-1104	Vésteinsson 2012, 11-12; Sigurgeirsson 2012b, 66
3	Skógar	N	V-Sv	H-1104	Sigurðarson & Zoëga, 2013, 40; Sigurgeirsson 2013, 1-4.
3	Steindyr	N	V-Sv	H-1104	Hreiðarsdóttir 2010, 20; Sigurgeirsson 2010b, 35-36
3	Girðingar	N	V-Sv	H-1104/1158	Vésteinsson 2011, 25; Sigurgeirsson 2011, 77-78
3	Grasaskarð	N	V-Sv	H-1104/1158	Vésteinsson 2011, 54-55
3	Mýnesás	N	V-Sv	H-1104/1158	Vésteinsson 2011, 30-31; Sigurgeirsson 2011, 77
3	Sellandasel	N	V-Sv	H-1104/1158	Vésteinsson 2011, 49-51
3	Víðatóft	N	V-Sv	H-1104/1158	Vésteinsson 2011, 20-21; Sigurgeirsson 2011, 74-75
3	við Kleifarhólma	N	V-Sv	H-1104/1158	Vésteinsson 2011, 34-35; Sigurgeirsson 2011, 77
3	Hallskot	N	V-Sv	H-1158	Vésteinsson 2011, 16-17; Sigurgeirsson 2011, 74
3	Narfastaðir	N	V-Sv	H-1158	Sigurgeirsson 2005a, 41
3	Nes	N	V-Sv	H-1158	Sigurgeirsson 2005a, 40-41
3	Oddastaðir	N	V-Sv	H-1158	Sigurgeirsson 2002b, 2; Vésteinsson 2004c, 63-66
3	Steinbogi	N	V-Sv	H-1158	Sigurgeirsson 2003b, 40-42
3	Þrælagerði	N	V-Sv	H-1158	Ævarsson 2009, 16
3	Þverá í Laxardal	N	V-Sv	H-1158	Sigurgeirsson 2005a, 41
3	Hóll á Hólsfjöllum	N	V-Sv	H-1158/V-1159	Ævarsson 2009, 6
3	Fossabrekkur	N	Vj	H-1104	Zoëga et al. 2009, 12-13
3	Glaumbær	N	Vj	H-1104	Bolender, 2005, 11
3	Gljúfurárgerði	N	Vj	H-1104	Zoëga et al. 2009, 7-8
3	Grófargil	N	Vj	H-1104	Steinberg & Bolender 2004, 117
3	Hólakot 1	N	Vj	H-1104	Zoëga et al. 2009, 6
3	Halldórsstaðir	N	Vj	H-1104	Steinberg 2008, 3
3	Hamar 1	N	Vj	H-1104	Sigurðarson 2014, 23-25
3	Hæringsbúðir	N	Vj	H-1104	Zoëga et al. 2014, appendix 1-2
3	í Austurdal	N	Vj	H-1104	Zoëga 2007, 18-20
3	Ingimundarhóll	N	Vj?	H-1104	Ólafsson 2013a, 6
3	Keldudalur	N	Vj	H-1104	Zoëga 2006, 4
3	Unastaðasel	N	Vj	H-1104	Zoëga et al. 2014, appendix 1-2

4	Fagrahlíð	N	LTL	Vj	Zoëga 2007, 24-26
4	Marbæli	N	LTL	Vj	Steinberg et al. 2007, 2
4	Stóra Gröf	N	LTL	Vj	Steinberg et al. 2009e, 4-5
4	Torfgarður	N	LTL	Vj	Bolender et al. 2008, 10-11
4	Tungukot	N	LTL	Vj	Zoëga 2007, 5-7
4	Bjarnastaðir í Unadal	N	/	Vj	Zoëga et al. 2014, 18-21
4	Kappastaðir	N	/	Vj	Zoëga et al. 2016, 38, Appendix, 6
4	Litli-Bakki	N	/	Vj	Zoëga et al. 2016, 38, Appendix, 11
4	Páfastaðir	N	/	Vj	Steinberg et al. 2009d, 4; Sigurgeirsson 2010a, 2-3
4	Reynistaður	N	/	Vj	Steinberg & Bolender 2004, 117
4	Reynistaður, Langhúshóll	N	/	Vj	Bolender et al. 2011, 82
4	Syðra-Skörðugil	N	/	Vj	Steinberg et al. 2005, 3-5
4	Efra-Gjáholt	N	LTL	H-1104	Zoëga et al. 2009, 22
4	Flatatunga	N	LTL	H-1104	Zoëga et al. 2014, 33-34
4	Garðhús	N	LTL	H-1104	Zoëga et al. 2009, 23-26
4	Gjáskógar	SW	LTL	H-1104	Eldjárn 1961, 16
4	Grjótgerði í Víðinesi	N	LTL	H-1104	Zoëga et al. 2009, 40-42
4	Hof	N	LTL	H-1104	Carter & Traustadottir, 2012, 12
4	Hvítárholt	SW	LTL	H-1104	Magnússon 1972, 25, 57
4	Öxnadalsheiði - Skógarnes	N	LTL	H-1104	Vésteinsson 2013, 23-25
4	Risamýri	N	LTL	H-1104	Zoëga & Pálsson 2008, 12-14
4	Rógshólar	SW	LTL	H-1104	Þórarinsson 1949, 58
4	Skeljastaðir	SW	LTL	H-1104	Þórarinsson 1943, 38
4	Skuggi	N	LTL	H-1104	Harrison & Roberts, 2014, 15
4	Sólheimar	N	LTL	H-1104	Zoëga et al. 2016, 38, Appendix, 9
4	Stórhólshlið	SW	LTL	H-1104	Þórarinsson 1943, 37-38
4	Svartárkot	N	LTL	H-1104	Vésteinsson 2004e, 54-55; Vésteinsson et al. 2014, 49-50
4	Vatnsleysa	N	LTL	H-1104	Zoëga et al. 2016, 38, Appendix, 13
4	Granastaðir	N	LTL or V-Sv	H-1104	Einarsson 1995, 92, 101; Magnús Sigurgeirsson pers. com.
4	Enni	N	/	H-1104	Zoëga et al. 2014, 35
4	Fjall	N	/	H-1104	Zoëga et al. 2016, 38, Appendix, 7
4	Geirmundarhólar	N	/	H-1104	Zoëga et al. 2016, 38, Appendix, 2
4	Geitakofahóll	N	/	H-1104	Zoëga et al, 2009, 43-44
4	Illugastaðir	N	/	H-1104	Zoëga et al. 2016, 38, Appendix, 10
4	Hlið	SW	/	H-1104	Magnússon 1972, 6
4	Hofgarðar	N	/	H-1104	Þórarinsson 1977, 20
4	Horngarðar	N	/	H-1104	Þórarinsson 1977, 20; Vésteinsson et al. 2014, 49
4	Hrappsá	N	/	H-1104	Zoëga et al. 2013a, 17-22
4	Kaldárkot	N	/	H-1104	Zoëga, 2011, 9-11
4	Kolgrímsstaðir	N	/	H-1104	Sveinbjarnardottir, 1992, 169
4	Kot í landi Stafns	N	/	H-1104	Zoëga et al. 2013a, 23-28;

					Zoëga et al. 2014, 5-8
4	Lækur	N	/	H-1104	Zoëga 2011, 12-16
4	Málmey	N	/	H-1104	Zoëga et al. 2013b, 35
4	Markúsarhóll	N	/	H-1104	Zoëga et al. 2009, 9-10
4	Miðklif	N	/	H-1104	Sveinbjarnardóttir 1992, 170
4	Neðri-Ás	N	/	H-1104	Vesteinsson 1998, 17-18
4	Nýlendi	N	/	H-1104	Zoëga et al. 2013a, 33-35
4	Oddsstaðir	N	/	H-1104	Harrisson 2010, 27
4	Place in Helgustaðir	N	/	H-1104	Zoëga et al. 2016, 38, Appendix, 1
4	Róðhóll	N	/	H-1104	Zoëga et al. 2016, 38, Appendix, 1
4	Siglunes	N	/	H-1104	Lárusdóttir et al. 2012; Sigurgeirsson 2012c, 37-38
4	Sjöundastaðir	N	/	H-1104	Zoëga et al. 2016, 38,
4	Skálárkot	N	/	H-1104	Zoëga et al. 2016, 38, Appendix, 8
4	"skáli"/Skálársel	N	/	H-1104	Zoëga et al. 2016, 38
4	Skógargerði	N	/	H-1104	Zoëga et al. 2016, 38, Appendix, 4
4	Spáná	N	/	H-1104	Zoëga et al. 2013a, 12-14
4	Stórhóll	N	/	H-1104	Zoëga & Gunnarsson 2013, 10-12
4	Straðatunga	N	/	H-1104	Harrison & Roberts, 2014, 17
4	Tjarnarkot	N	/	H-1104	Zoëga et al. 2016, 38, Appendix, 5
4	Víðines	N	/	H-1104	Zoëga 2011, 20
4	við Grindilskrók	N	/	H-1104	Zoëga et al. 2016, 38
4	Þórarinsstaðir	SW	/	H-1104	Þórarinson 1949, 49, 53-54
4	Þrastarstaðir	N	/	H-1104	Zoëga et al. 2014, 31
4	Þrælsgerði	N	/	H-1104	Zoëga et al. 2014, 29-30
4	Þverá í Hrolleifsdal	N	/	H-1104	Zoëga et al. 2016, 38, Appendix, 2
4	Ytri-Heljará	N	/	H-1104	Zoëga et al. 2009, 36-38
4	Selhagi	N	LTL	H-1104/1158	McGovern & Perdikaris 2016, 2
4	Gautlönd	N	/	H-1104/1158	Vésteinsson 2013, 7-8
4	við Víðiker	N	/	H-1104/1158	Vésteinsson 2004d, 80-83
4	Bakkkastaðir	E	LTL	H-1158	Rafnsson 1990, 38-39
4	Hamrar	N	LTL	H-1158	Aldred et al. 2007, 8
4	Hamrar, Helgastaðir & Pálmholt 2	N	LTL	H-1158	Aldred et al. 2007, 8
4	innan við Faxagil	E	LTL	H-1158	Rafnsson 1990, 64-65
4	Rauðaskriða 1	N	LTL	H-1158	Aldred et al. 2007, 8
4	Þegjandadalur 2	N	LTL	H-1158	Aldred et al. 2007, 8
4	Aðalból	E	/	H-1158	Rafnsson 1990, 54-55
4	á Vesturdal	E	/	H-1158	Rafnsson 1990, 85
4	Blesatangi	E	/	H-1158	Rafnsson 1990, 61
4	Breiðavík	N	/	H-1158	Sigurgeirsson 2001a, 33-35
4	Dyngja	E	/	H-1158	Rafnsson 1990, 91
4	Geithús	E	/	H-1158	Rafnsson 1990, 83
4	Glúmsstaðasel	E	/	H-1158	Rafnsson 1990, 68
4	Hringur	E	/	H-1158	Rafnsson 1990, 84
4	Hústóft	E	/	H-1158	Rafnsson 1990, 51

4	í Mógilshálsi	E	/	H-1158	Rafnsson 1990, 42
4	innan við Faxahús	E	/	H-1158	Rafnsson 1990, 61
4	Laugarhús	E	/	H-1158	Rafnsson 1990, 57
4	Orrustustaðir	E	/	H-1158	Rafnsson 1990, 77
4	Skál	E	/	H-1158	Rafnsson 1990, 42
4	Steingrímsstaðir	E	/	H-1158	Rafnsson 1990, 80
4	Steinsgróf	E	/	H-1158	Rafnsson 1990, 76
4	Tobbhóll	E	/	H-1158	Rafnsson 1990, 53
4	undir Smjörtungufellli	E	/	H-1158	Rafnsson 1990, 55
4	Vaðbrekka	E	/	H-1158	Rafnsson 1990, 45
4	Þórisstaðir	E	/	H-1158	Rafnsson 1990, 50
4	Þrándarstaðir	E	/	H-1158	Rafnsson 1990, 49
4	Þuríðarstaðasel	E	/	H-1158	Rafnsson 1990, 66
5	Borg	SW	LTL	/	Davide Zori pers. com.
5	Broddaskáli	E	LTL	/	Sveinbjarnardóttir 1992, 64-67
5	Eiríksstaðir	NW	LTL	/	Ólafsson 1998, 17
5	Gilsbakki	NW	LTL	/	Smith 2008, 25
5	Göltur	SW	LTL	/	Ólafsson 2014, 5
5	Hallmundarhellir	NW	LTL	/	Jóhannesson 1989, 6
5	Helgadalur	SW	LTL	/	Zori & Byock, 2014, 68
5	Herjólfsdalur	SW	LTL	/	Hermanns-Auðardóttir 1989, 49
5	Hjálmsstaðir	SW	LTL	/	Ólafsson 1992, 49
5	Hólmur	E	LTL	/	Einarsson 2008a, 170
5	Kálfaströnd	N	LTL	/	Einarsson 2012b, 6
5	Klausturhús	N	LTL	/	Harrison 2013, 398
5	Kópsvatn	SW	LTL	/	Ólafsson 1999, 5, 8
5	Reykholt	SW	LTL	/	Sveinbjarnardóttir 2012
5	Spöngin	SW	LTL	/	Sigurgeirsson 2005b, 20-21
5	Surtshellir	NW	LTL	/	Ólafsson et al. 2004, 20
5	Víðgelmir	NW	LTL	/	Ólafsson 2011, 10
5	Þjótandi	SW	LTL	/	Einarsson & Einarsdóttir 2008, 1-3; Einarsson & Csillag, 2011, 311-312
5	Þorleifshaugur	SW	LTL	/	Friðriksson et al. 2005, 13-14
5	Bessastaðir	SW	LTL	R-1226	Ólafsson 2013b, 8-9
5	Bygggarðsvör	SW	LTL	R-1226	Hermanns-Auðardóttir 2005, 50-52
5	Heynes	SW	LTL	R-1226	Friðriksson 1991, 9-10, 20
5	Hofsstaðir í Garðabær	SW	LTL	R-1226	Traustadóttir 1995; Sigurgeirsson 1999 unpublished report
5	Leirvogstunga	SW	LTL	R-1226	Zori & Byock, 2014, 67
5	Urriðakot	SW	LTL	R-1226	Traustadóttir et al. 2010, 9, 134
5	Þingnes by Elliðavatn	SW	LTL	R-1226	Ólafsson 2004, 69-70
5	Vogur í Höfnum	SW	LTL	R-1226	Einarsson 2013a, 25

5	Þverá	N	LTL	K-1262	Edvardsson & Hreiðarsdóttir 2003, 15-19
5	Hamrar, Helgastaðir & Pálmholt 1	N	LTL	H-1300	Aldred et al. 2007, 8
5	Rauðaskriða 2	N	LTL	H-1300	Aldred et al. 2007, 8
5	Þegjandadalur 1	N	LTL	H-1300	Aldred et al. 2007, 8
5	Þegjandadalur 3	N	LTL	H-1300	Aldred et al. 2007, 8
5	Ytra-Skörðugil	N	LTL	H-1300	Steinberg et al. 2005, 6-8
5	Háls	SW	LTL	H-1341	Kevin Smith pers. com.
5	Syðsta Mörk (REU 18)	SW	LTL	H-1341	Church et al. 2007, 663
5	Geirsstaðir	E	LTL?	Ö-1362	Kristjánsdóttir 1998, 32
5	Mjóeyri	E	LTL	Ö-1362	Einarsson et al. 2008, 38-40
5	Þegjandadalur 4	N	LTL	V~1477	Aldred et al. 2007, 8
5	Akraland	SW	LTL	K~1500	Rhodes & Trautadóttir 2004, 12-13
5	Nes	SW	LTL	K~1500	Gestsdóttir & Vésteinsson 1996, 20-23
5	Skeggjastaðir	SW	LTL	K~1500	Zori & Byock 2014, 71
5	Snjáleifartóttir	SW	LTL	H-1693	Þórarinsson 1943, 36
5	Þrælagarður	SW	LTL	H-1693	Róbertsdóttir & Jóhannesson 1986, 221-226
6	undir Sandmúla	N	V-Sv	/	Vésteinsson et al. 2014, 51-52
6	Einarsstaðir	N	V-Sv	K-1262	Sigurgeirsson 2009b, 53-55
6	Eystri Brú	N	V-Sv	H-1300	Vésteinsson 2012, 43
6	Hjálmarvík	N	V-Sv	H-1300	Sigurgeirsson 2014, 62-63
6	Hólakot 2	N	V-Sv	H-1300	Sigurgeirsson 2010c, 14
6	Höfðagerði	N	V-Sv	H-1300	Aldred & Friðriksson 2003, 12-13
6	Ingveldarstaðir	N	V-Sv	H-1300	Hreiðarsdóttir & Ólafsson 2012, 30-32; Sigurgeirsson 2012a, 43
6	Kúðá	N	V-Sv	H-1300	Sigurgeirsson 2014, 63
6	Litlu-Gautlönd	N	V-Sv	H-1300	Sigurgeirsson 2008a, 47
6	Mánárbakki	N	V-Sv	H-1300	Sigurgeirssson 2003c, 12-13
6	Maríugerði	N	V-Sv	H-1300	Pálsdóttir 2010, 10, 20
6	Narfastaðasel	N	V-Sv	H-1300	Sigurgeirsson 2009a, 56-57
6	Öndólfsstaðir	N	V-Sv	H-1300	Sigurgeirsson 2012b, 68
6	Sakka	N	V-Sv	H-1300	Hreiðarsdóttir 2010, 19; Sigurgeirsson 2010b, 36
6	Saltvík	N	V-Sv	H-1300	Vésteinsson 2004a, 28
6	Selholt	N	V-Sv	H-1300	Sigurgeirsson 2008a, 47
6	Svalbarð	N	V-Sv	H-1300	Sigurgeirsson 2014, 64-65
6	Svínadalur	N	V-Sv	H-1300	Vésteinsson 2012, 52-55
6	Sýrnes	N	V-Sv	H-1300	Sigurgeirsson 2005a, 41
6	Tinnársel	N	V-Sv	H-1300	Sveinbjarnardóttir 1992, 139
6	Sómastaðagerði	E	V-Sv	Ö-1362	Sigurgeirsson 2003a, 26
6	Fremri Fjöll	N	V-Sv	V~1410	Hreiðarsdóttir & Ólafsson 2012, 20; Sigurgeirsson 2012a, 41
6	Arnarvatnssel	N	V-Sv	V~1477	Vésteinsson 2011, 42-44; Sigurgeirsson 2011, 75
6	Eyvík	N	V-Sv	V~1477	Hansson 2007, 7

6	Geldingatættur	N	V-Sv	V~1477	Sigurgeirsson 2008a, 47-48
6	Grænavatn	N	V-Sv	V-1477	Vésteinsson 2008, 34
6	Hálskot	N	V-Sv	V~1477	Hreiðarsdóttir 2010, 25; Sigurgeirsson 2010b, 36
6	Hraungerði	N	V-Sv	V~1477	Sigurgeirsson 2012a, 42
6	Hraunstakkaborg	N	V-Sv	V~1477	Sigurgeirsson 2012a, 42
6	Kirkjulaut	N	V-Sv	V~1477	Sigurgeirsson 2012b, 67-68
6	Langgarður í landi Garðs	N	V-Sv	V~1477	Sigurgeirsson 2012a, 42
6	milli Ingveldarstaða og Tóveggs	N	V-Sv	V~1477	Sigurgeirsson 2012, 42
6	Tungufell 1	N	V-Sv	V~1477	Hreiðarsdóttir 2010, 14; Sigurgeirsson 2010b, 35
6	Tungufell 2	N	V-Sv	V~1477	Hreiðarsdóttir 2010, 16-17; Sigurgeirsson 2010b, 35
6	Fjárhóll	E	Eldgjá	H-1206	Einarsson 2012a, 7
6	Hróðnýjarstaðir	E	Eldgjá	H-1206	Hreiðarsdóttir et al. 2014, 11
6	Leiðólfsfell	E	Eldgjá	H-1206	Einarsson 2010b, 5-6
6	Litli-Svartinúpur	E	Eldgjá	H-1206	Hreiðarsdóttir et al. 2014, 32-34
6	milli Merkurár og Sláttugils	E	Eldgjá	H-1206	Einarsson 2013b, 6-7
6	Streyta	E	Eldgjá	H-1206	Einarson 2014, 6
6	við Fjaðrárgljúfur	E	Eldgjá	H-1206	Einarsson 2010a, 7
6	Langanes I (REU 23)	SW	Eldgjá	H-1341	Church et al. 2007, 663
6	Langanes II (CP 1)	SW	Eldgjá	H-1341	Church et al. 2007, 663
6	Langanes III (CP 4)	SW	Eldgjá	H-1341	Church et al. 2007, 663
6	Langanes IV (AS1)	SW	Eldgjá	H-1341	Church et al. 2007, 663
6	Langanes V (AS2)	SW	Eldgjá	H-1341	Church et al. 2007, 663
6	Markarfljót Valley (REU17)	SW	Eldgjá	H-1341	Church et al. 2007, 663
6	Ljótarstaðir	N	Eldgjá	V~1477	Hreiðarsdóttir et al. 2014, 17-18

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