Vikings, peat formation and settlement abandonment: a multi-method chronological approach from Shetland

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Abstract

Understanding the chronology of Norse settlement is crucial for deciphering the archaeology of many sites across the North Atlantic region and developing a timeline of human-environment interactions. There is ambiguity in the chronology of settlements in areas such as the Northern Isles of Scotland, arising from the lack of published sites that have been scientifically dated, the presence of plateaus in the radiocarbon calibration curve, and the use of inappropriate samples for dating. This novel study uses four absolute dating techniques (AMS radiocarbon, tephrochronology, spheroidal carbonaceous particles and archaeomagnetism) to date a Norse house (the "Upper House"), Underhoull, Unst, Shetland Isles and to interpret the chronology of settlement and peat which envelops the site. Dates were produced from hearths, activity surfaces within the structure, and peat accumulations adjacent to and above the structure. Stratigraphic evidence was used to assess sequences of dates within a Bayesian framework, constraining the chronology for the site as well as providing modelled estimates for key events in its life, namely the use, modification and abandonment of the settlement. The majority of the absolute dating methods produced consistent and coherent datasets. The overall results show that occupation at the site was not a short, single phase, as suggested initially from the excavated remains, but instead a settlement that continued throughout the Norse period. The occupants of the site built the longhouse in a location adjacent to an active peatland, and continued to live there despite the encroachment of peat onto its margins. We estimate that the Underhoull longhouse was constructed in the period *cal. AD 805–1050* (95% probability), and probably in *cal. AD 880–1000* (68% probability). Activity within the house ceased in the period *cal. AD 1230–1495* (95% probability), and most probably in *cal. AD 1260–1380* (68% probability). The Upper House at Underhoull provides important context to the expansion and abandonment of Norse settlement across the wider North Atlantic region.

1. Introduction

The overall aim of this paper is to establish a multi-method chronology of settlement and environment changes at the site of Underhoull in Unst, Shetland Isles. This is important for both Quaternary science and global environmental change research because it typifies the challenges of dating the Viking Age-Medieval Scandinavian colonisation of the North Atlantic islands. The term ‘Viking’ usually refers to raiding activity and the initial territorial expansion of Scandinavian peoples from the last decades of 8^{th} century to the 11^{th} century, whereas ‘Norse’ covers the whole cultural period from first settlement to the mid-15th century in the Northern Isles when the islands were ceded to the Scottish crown (Batey and Sheehan, 2000). This movement of people involved the migration into, and enduring occupation of, both long settled-lands in Atlantic Scotland and mid-oceanic islands that were some of the last places on Earth to be colonised by people. The former provide instructive cases of culture contact, the latter provide recent case studies of the impact of people on pristine environments with clear pre-human environmental baselines. Both provide ‘completed experiments’ of human interactions with the environment during the Medieval Climate Anomaly (a time of warm climate lasting from ~AD 950 to AD 1250) in NW Europe (Goosse et al., 2012) that are relevant to contemporary debates about global change that include societal resilience, the basis of sustainability over multi-century time scales, causes of human insecurity, climate change adaptation and the limits to adaptation (e.g. Nelson et al., 2016).

Increasing attention has been paid to the study of Norse sites across the North Atlantic and the Distributed Long-Term Observing Network of the Past (DONOP) that they provide (Hambrecht et al., 2018). The investigation of DONOP has involved archaeological excavation and related multi-proxy environmental studies which can be used to address Grand Challenges in archaeology, including questions of 1) societal resilience, persistence and collapse; 2) the movement, mobility and migration of people, and 3) human environment interactions (Kintigh et al., 2014). The drivers of the Scandinavian migrations and the expansion of the Viking Age settlements across this region have been attributed to a variety of factors, such as stresses of population change (Fossier, 1999), climate (Dugmore et al., 2007), economic factors and political tension (Frei et al., 2015; Pálsson and Edwards 1981; Sawyer, 2003), while similar theories have been postulated for the abandonment of Norse settlements in Greenland (Dugmore et al., 2012). An accurate and precise chronology is essential for the assessment of specific Norse sites and their utilisation as DONOP to allow the archaeological evidence to be directly compared and understood across this vast geographical area, and be mobilised to address Grand Challenges (Kintigh et al., 2014, Nelson et al., 2016).

Over the last 30 years, the chronological assessment of Norse sites across the North Atlantic realm have made widespread use of radiocarbon or in the case of Iceland, radiocarbon and the use of visible tephra layers (e.g. Barrett et al*.,* 2000; Dugmore et al*.,* 2005; Arge et al*.,* 2005; Lawson et al*.,* 2005; Church et al., 2005; 2007; Schmid et al., 2017). However, many existing chronological frameworks have significant limitations due to a primary reliance on artefact and structural typologies (e.g. Hamilton, 1956; Small, 1966; Stummann Hansen, 2000) or on scientific dating approaches that utilise inappropriate materials, including non-native species such as Spruce (*Picea*) or mixtures of materials. In Iceland, classic tephrochronology, based on the identification and correlation of layers of volcanic ash (tephra), is a very powerful dating tool for establishing a robust chronology for the Viking Age settlement. The utility and accuracy of classic tephrochronology stems from the very widespread distribution of the Landnám tephra as a visible layer, and the extensive occurrence of a series of other visible tephra layers within the 10^{th} century, such as the Katla c. AD 920 tephra and the Eldgjá tephra from AD 939 (Schmid et al., 2017). The great precision of classic tephrochronology in Viking Age Iceland is because two of these crucial layers- the Landnám tephra and the Eldgjá tephra- have been traced to Greenland and dated in ice core records (Grönvold et al., 1995; Zielinski et al., 1995, 1997; Sigl et al., 2015; Schmid et al., 2017). While the use of visible tephra layers is routine in Icelandic archaeology, the use of cryptotephras in archaeological sites elsewhere in the North Atlantic is not, despite their discovery in terrestrial

Scottish peat deposits 30 years ago (Dugmore 1989, Dugmore et al., 1995a; 1995b). This represents significant opportunity for archaeology, because of the continental scale dispersal of the tephras as crypto deposits, and their very precise dating- either through connections with ice cores, or through contemporary written sources, such as the dating of Hekla eruptions to AD 1104 and AD 1158.

Cryptotephrochronology is making vital contributions to the precise correlation of long-term proxy records of Quaternary environments (e.g. Davies, 2015; Lane et al., 2012). The great potential for the use of cryptotephras in archaeology and correlating archaeological DONOP (e.g. Lane et al., 2014) is largely untapped. As its potential is realised, an effective integration of cryptotephrochronology with other Quaternary dating techniques presents particularly interesting opportunities. Thus, we present an integrated chronology for the establishment, use and abandonment of a peat-covered Norse longhouse at the site of Underhoull, Shetland, UK (60.71888ºN, 0.94735ºW) using the novel combination of radiocarbon, cryptotephra, spheroidal carbonaceous particles and archaeomagnetic dating. We critically assess and compare these techniques within a Bayesian framework in order to produce a robust chronology for the site. We address the following research questions: 1. When was the site occupied and then subsequently abandoned? 2. What is the chronostratigraphic relationship between the longhouse and peat accumulation? The answers to these questions contribute significantly to evaluation of Norse settlement in Shetland and demonstrate methodologies applicable across Northwest Europe and North America.

2. Study site selection and context

Archaeological sites in Shetland, such as Old Scatness (Dockrill et al., 2010), Norwick (Ballin Smith, 2007), Hamar and Underhoull (Bond et al., 2013) form a DONOP and provide a window into the culturally turbulent Viking Age, set within the equable conditions of the Medieval Climate Anomaly.

The site of Underhoull is located on Unst, the most northerly of the Shetland Isles, and of Britain (Figure 1). Unst is particularly significant because it may have played an important role in the westwards expansion of the Viking/Norse populations, acting as a staging post between Norway, Britain and the islands further west (Ritchie, 1996; Graham-Campbell and Batey, 1998). Recent discoveries have produced early dates for Scandinavian settlement in the Northern Isles (Orkney and Shetland), which have important implications for understanding the timing, pace and nature of the westward migrations of the Viking Age. The site of Norwick, for example, now has evidence for an early phase of Scandinavian settlement in the 7th–9th centuries AD (Ballin Smith, 2007). If the pattern from Norwick is replicated elsewhere, it would stretch the chronology of westward Norse expansion earlier, and modify ideas of its development and consequences.

A large number of Norse longhouses have been recorded on Unst, with Dyer et al. (2013) identifying some 30 individual sites, together with another 20 possible longhouses. This implies that the island played a very significant role in the westwards expansion of the Norse. Despite this significance, only a small number of Norse sites have been investigated to date, including Sandwick (Bigelow, 1985), Underhoull (Small, 1966), Norwick (Ballin Smith, 2007), Hamar (Bond et al., 2013) and Belmont (Larsen et al., 2013). At Underhoull, Small (1966) recorded a Norse structure that sealed an Iron Age roundhouse and souterrain, demonstrating one of many Shetlandic examples of site continuity linked to transformative cultural changes (Figure 2). A 10th century date was assigned to the Norse site following Small's work based on the artefact evidence, although a later date has been suggested by a reassessment of the structural and artefact typologies (Graham-Campbell and Batey, 1998). Radiometric dating evidence has been produced for the sites of Sandwick, Norwick, Hamar and Belmont (Figure 1), although only the sites of Hamar and Belmont have been fully published to date. The remaining published site chronologies in Shetland, such as the iconic site of Jarlshof (Hamilton, 1956), are largely based on artefact typologies. While these traditional approaches provide a general framework, they have limited precision. More rigorous chronologies based on a wider range of approaches and scientific methodologies will provide an enhanced understanding of the pattern and timing of Norse occupation of Shetland, the longevity of settlement and its wider significance within the Norse diaspora.

3. Establishing chronology: The sampled contexts

The site discussed within this paper is located upslope from the excavations carried out by Small (1966), and so to avoid confusion with this earlier work it will be referred to as the "Upper House", Underhoull. The Upper House site (Figure 2) consists of a longhouse with two associated annexes. The addition of annexes to longhouses has been considered a characteristic feature of Late Norse longhouses, recorded on sites such as Underhoull, Hamar and Belmont (Graham-Campbell and Batey, 1998; Bond et al., 2013; Larsen et al., 2013), which suggests that the surviving structure at Underhoull dates to the late 10th century at the earliest. Several features were recorded within the structure including a paved area in the western end of the main structure and three hearths, one in each of the annexes and a third in the eastern part of the main structure. An area of paving (context [029]) was also identified to the south of the main structure overlying the peat, and has been interpreted as an attempt by the occupants to maintain a dry area around the longhouse despite the close proximity to the peat accumulations.

Understanding the formation processes is crucial in the selection of appropriate samples, as well as the interpretation of the results, so the formation processes of the anthropogenic deposits are summarised under the heading 'depositional context'. A classification of deposits in terms of chronological significance is derived from the work of Schiffer (1987) and Dockrill et al. (2006), and is summarised in Table 1. The peat dates were not categorised using this approach due to the potential mobility of the different fractions. The materials finally selected for dating formed two groups: the deposits associated with the occupation of the structure, and the peat located in the south-west area of the site. The dates have been summarised in Table 2 (radiocarbon), Table 3 (archaeomagnetic) and Table 4 (tephra).

The deposits located within the structure were dated by AMS radiocarbon and archaeomagnetic dating techniques, including occupation surfaces (contexts [189] & [185]), hearths (contexts [166], [214] and [201]), a surface interpreted as a yard to the north of the main structure (context [170]), and a possible industrial deposit (context [093]). The peat accumulations adjacent to the longhouse were sampled for cryptotephra and for AMS radiocarbon dating; the flagged surface (context [029]) associated with the structural remains effectively acted as a horizon dividing the peat layers into those that pre- and post-dated the construction of the longhouse (Figure 3). The dating evidence produced from these deposits therefore brackets this event, providing an opportunity to investigate when the occupation of the Upper House commenced relative to the peat and the impact that the peat development had on the occupation of Underhoull. The date of the paved surface [029] is also important as it provides the upper limit for the construction of the longhouse, as well as dating an attempt by the occupants to maintain the site.

4. Materials and methods

Three dating methods (AMS radiocarbon, archaeomagnetic dating and cryptotephrochronology) were employed in addition to the conventional archaeological methods of stratigraphy and typology. In addition to these approaches, spheroidal carbonaceous particles (SCPs) within the peat were used to infer a post 19th-century date for the top of the sampled sequences (e.g. Swindles, 2010). All of the dates presented here are quoted at 2 sigma (σ)/95.4% confidence levels with the exception of the SCPs (post-AD1850 markers) and the tephra isochrones dated to the 12^{th} century AD based on historical observation and documentary evidence. The Hekla-Selsund tephra (also referred to as the Kebister tephra by Dugmore et al., 1995b) has been previously wiggle-match ^{14}C dated (Wastegård et al., 2008).

4.1 AMS Radiocarbon dating

AMS radiocarbon determinations (Table 2) were produced by the Scottish Universities Environmental Research Centre (SUERC), and the Natural Environment Research Council (NERC) Radiocarbon Facility, East Kilbride, and calibrated using OxCal v4.3 (Bronk Ramsey, 2012), with IntCal13 (Reimer et al., 2013).

The materials selected for dating included charred grains of barley (*Hordeum* sp.) and *Sphagnum* remains extracted from the peat (although *Sphagnum* was only found in a 5-cm horizon in one of the peat monoliths), as these represent chronologically coherent entities that did not require a marine correction (Harris, 1987). Barley grains represent a single entity produced in a single season's growth, removing some of the problems of 'old' carbon being incorporated (Ashmore, 1999), and were selected from discrete contexts such as hearths, floor surfaces and a yard area. Both the barley grains and *Sphagnum* leaves and stems were hand-picked from samples using tweezers under a low-power binocular microscope. Above-ground macrofossils (e.g. *Sphagnum* remains) were mostly not present or in low abundance in the peats, therefore the humin and humic acid fractions of humified peats were extracted from discrete samples for dating.

The composition of peat varies depending on the plant communities, the accumulation rate, the water-table level, bioturbation, root penetration, and the incorporation of residual material, as well as any anthropogenic activity in the area (Rydin and Jeglum, 2008). It can therefore be argued that no two accumulations of peat are the same, making it difficult to state with confidence which of the fractions would represent the 'true' age of peat accumulation as all of these factors are site specific (Tonneijck et al., 2006; Wüst et al*.*, 2008; Brock et al*.*, 2011). A number of radiocarbon dates were produced for this study using both the humic and humin fractions from the same sample, allowing these processes to be evaluated.

The charred barley grains and *Sphagnum* remains were pre-treated using the standard acid-base-acid procedure for removal of carbonates and organic acids (Ascough et al., 2007). The peat humin fraction was extracted through the digestion of the peat in 2M HCl (80°C, 8 hours) followed by 1M KOH (80°C, 2 hours) until no further humic material was extracted. The residue was then rinsed free of alkali, before being immersed in 1M HCl (80°C, 2 hours), rinsed free of acid, dried and then homogenised. The peat humic acid fraction was extracted using a similar approach, but the filtrate was retained and the humic fraction precipitated following the addition of 2M H_2SO_4. The precipitate was recovered, rinsed free of acid, dried and homogenised (Gulliver, 2011). The pre-treated remains were then converted to graphite for subsequent AMS analysis using standard methods defined by Slota et al. (1987). The $\delta^{13}C$ value of the sample CO_2 was determined on a VG SIRA 10 stable isotope mass spectrometer using NBS standards 22 (oil) and 19 (marble) to determine the 45/44 and 46/44 mass ratios, from which a sample $\delta^{13}C$ value could be calculated (Ascough et al., 2007). The $\delta^{13}C$ ratios were used to correct the sample ^{14}C activities for fractionation by normalisation to −25‰.

The potential problem of post-depositional movement of the barley grains or the mobility of the different fractions of peat was investigated through the production of multiple dates analysed in stratigraphic order, a comparison of paired dates produced on different fractions and by a comparison between different methods.

4.2 Archaeomagnetic dating

Archaeomagnetic dating can yield significant chronological information as the dated event relates to the last use of the features which usually corresponds to anthropogenic activity (Clark et al., 1988; Batt et al., 2017). Three features were sampled for archaeomagnetic dating from Underhoull: hearths located in each of the two annexes (contexts [166] and [214]) and a possible industrial feature (context [093]) located to the North of the site (Table 3). A fourth hearth was identified within the main structure (context [201]), but it did not contain sufficient material for archaeomagnetic dating. Plastic tubes were inserted into the fired material using the methodology defined by Clark et al. (1988). A magnetic compass was used to record the orientation of the samples; this method can be problematic as the feature itself may deflect the compass, introducing errors into the sampling procedure. A sun compass can be used, but due to the variable nature of the sun in Shetland, a magnetic compass was deemed more reliable. All of the features sampled were assessed in the field prior to the use of the magnetic compass and it was concluded that no distortion was present (Meng and Noel, 1989; Lange and Murphy, 1990).

The direction of remanent magnetisation of the samples was measured using a Molspin spinner magnetometer. The stability of this magnetisation was then determined by step-wise alternating field demagnetisation of pilot samples to allow removal of any less stable magnetisations acquired after the firing event, leaving the magnetisation of archaeological interest, known as the characteristic remanent magnetisation (ChRM).

Pilot samples were selected as they represented the range of characteristics displayed by the assemblage. The demagnetisation data were assessed using methods defined by Tarling and Symons (1967), Kirschvink (1980) and Sagnotti (2013) and principal component analysis (PCA) was used to investigate the linearity of the magnetic vector throughout the demagnetisation process and to select the field used to remove the unstable component of the magnetisation, leaving the magnetisation of archaeological interest. Values of less than 2° were taken as evidence that the plots were acceptably linear between the selected vector, and that the magnetisation was likely to be stable (Linford, 2006). It was noted that a field of 5mT was suitable to remove the less stable component for all of the samples investigated.

The magnetic directions of the samples collected from a feature were combined to give a mean direction, the precision of which is defined using Fisherian statistics (Fisher, 1953). The alpha-95 (α_{95}) value represents a 95% probability that the true direction lies with that cone of confidence around the observed mean direction, and should be less than 5° for dating purposes (Tarling and Dobson, 1995). A value larger than this indicates that the magnetic directions of the samples are scattered and therefore do not all record the same magnetic field, making the material undatable. Outlier samples were statistically defined using the approaches defined by Beck (1983) and McElhinny and McFadden (2000); if the values failed these tests they were statistically classified as lying significantly from the mean and therefore removed from the analysis.

Context [166] was sampled twice as a portion of the sampled feature lay underneath an unexcavated area of the site. When the area of excavation was extended the remaining part of the feature was exposed and sampled (AM150). The mean directions were shown to be statistically indistinguishable (McFadden and Lowes, 1981) and so they were combined to give a single magnetic direction.

4.3 Cryptotephrochronology

Tephrochronology is based on the identification and correlation of tephra layers (Thórarinsson, 1944). The recognition and correlation of cryptotephra deposits (those hidden from view) has extended the precision of tephrochronological correlations to continental scales (Dugmore, 1989; Dugmore et al., 1995a; Swindles et al., 2010; Watson et al., 2017). Calendar dates for the various tephra layers have been obtained through the use of written records (e.g. Thórarinsson, 1967), correlation to precise timescales such as those provided by ice cores (e.g. Zielinski et al., 1995; 1997; Sigl et al., 2015), or complementary dating techniques such as radiocarbon (Dugmore et al., 1995a; 1995b; Wastegård et al., 2008; Swindles et al., 2011). The precision of the associated radiocarbon dates have been greatly improved in recent years through the application of both radiocarbon wiggle-matching and sophisticated age-depth models, including Bayesian approaches, and for some tephra layers this exceeds the available precision associated with a single radiocarbon determination for the same period of time (Hall and Pilcher, 2002; Wastegård et al., 2003).

Despite the potential of tephrochronology for both chronological and palaeoenvironmental studies, only limited work has been carried out in Shetland (Dugmore 1991; Bennett et al., 1992; Swindles et al., 2013). A number of cryptotephra layers may have been deposited on Shetland during the periods that pre- and post-date the settlements at Underhoull (Dugmore et al., 1995b; Hall and Pilcher, 2002; Swindles et al., 2011). These aid the chronological constraint of the sites, as well as allowing the evidence recorded at Underhoull to be unambiguously linked to sites across the North Atlantic and major paleoclimate archives.

Monolith samples were extracted from peat faces at the site using box guttering (de Vleeschouwer et al., 2010). A series of three cores were collected from the accumulations of peat under- and over-lying the archaeology in the south-west area of the site (Figures 3 and 4): 'SF238/239', 'SCHO', and 'UHM'. The peat cores were stored at 4°C prior to sub-sampling at contiguous 1-cm intervals. Tephra layers in each profile were determined using the conventional ashing and extraction technique (following Swindles et al., 2010). As the samples contained some minerogenic material, LST Fastfloat (2.3–2.5 g cm^{-3}) was used to concentrate the shards. The total number of tephra shards within a 1 cm^3 sample was counted under light microscopy at 100× magnification. No basaltic shards were encountered in the samples.

Peat samples from depths of peak shard concentration were selected for subsequent geochemical analysis. Approximately 5cm^3 of peat was acid digested (H_2SO_4 and HNO_3) following standard procedures (Dugmore et al., 1992, Pilcher and Hall, 1992) and density separation was undertaken as before. The samples were sieved through a 10μm mesh and washed with deionised water, before being centrifuged to concentrate the tephra shards. The tephra were then mounted onto glass slides, which were polished using 0.25-μm diamond paste, before being carbon coated (Swindles et al., 2010).

Geochemical analysis was carried out at the NERC Tephra Analytical Unit at the University of Edinburgh. A CAMECA SX100 electron microprobe with a beam current of 2nA and diameter of 5μm was used. The microprobe was calibrated using Lipari obsidian and synthetic oxides with X-PHI correction, undertaken on PeakSight version 4.0 software. Energy-dispersive spectroscopy (EDS) using the Princeton Gamma Tech Spirit EDS system was used to aid in the detection of tephra shards. Once a shard was located, the beam was moved to a flat section of the shard (avoiding vesicles) for wavelength-dispersive spectroscopy and all analyses with a value of >95 wt% were logged.

It has been suggested that acid digestion can alter the geochemistry of tephra shards (Blockley et al., 2005). However, the use of this method allows 'like-with-like' comparisons with type data which have been prepared in this way (e.g. Dugmore et al., 1992). The case for chemical alteration by acid digestion has also been refuted in subsequent studies (Roland et al., 2015; Watson et al., 2016). Biplots were used to compare our data to those on Tephrabase (Newton et al., 2007), with the identified tephra layers summarised in Table 4.

4.4 Spheroidal carbonaceous particles

Spheroidal carbonaceous particles (SCPs) are formed following the high-temperature combustion of fossil fuels and are predominately composed of elemental carbon. SCPs are associated with industrial activities that occurred from the mid-19th century onwards, and so the presence of SCPs within a deposit can therefore be used to indicate a post-AD1850 date for the layer (Rose, 1994;

Swindles, 2010; Swindles et al., 2015). The SCPs were extracted from the peat cores using the methodology defined by Swindles (2010).

4.5. Data analysis

The chronological information from the Upper House, Underhoull was investigated within a Bayesian framework, which utilises prior information to interrogate and refine the scientific dates (Buck et al., 1991; 1994). All the chronological modelling was undertaken using OxCal v4.3 (Bronk Ramsey, 2012). The samples selected have been discussed above, and were recovered from a number of discrete and secure contexts. Primary contexts were prioritised, such as hearth deposits, with short-lived species of charred and waterlogged plant remains preferred so as to avoid the 'old-wood-effect'. Radiocarbon ages were all calibrated using the international agreed northern hemisphere calibration curve (IntCal13) of Reimer et al. (2013). Archaeomagnetic dates were incorporated into the model as prior probabilities, which were derived from their individual calibrations using the Rendate software and the UK secular variation calibration dataset (Batt et al., 2017). The dates of tephra layers were incorporated as normal probability distributions using a mean and standard deviation with the C_Date parameter in OxCal.

Inclusion of stratigraphic information can refine the resulting age ranges through the production of posterior density estimates but it is important to note that the resulting age ranges are the result of a statistical model imposed on the data and the interpretation of the stratigraphy within the field. Any new information, such as additional dating evidence or a different model being imposed on the data, will produce different posterior density estimates. The *modelled estimates* are given in *italics* when discussed within the text to differentiate them from the raw calibrated age ranges.

5. Results

The dates produced for the Upper House site have been summarised in Tables 2-4. A summary of each of the results of the dating programme are provided in this section before the chronology of the site is discussed.

5.1 ^{14}C dating

A total of 22 AMS radiocarbon dates were produced for the Upper House, Underhoull, with the majority sampling either the humin or humic acid fractions extracted from the peat (owing to lack of suitable macrofossils). An assessment of the dates obtained from the peat demonstrated that several of the radiocarbon dates (humin fractions) were not in chronological order and appeared to be too old for their stratigraphic position when compared to the tephra dates (Table 2; Figure 4).

Two radiocarbon dates were produced on the same sample of peat: SUERC-33130 and SUERC-34106 sampled the humic acid fraction and humin fractions respectively, which allowed the dates produced on different fractions of the same sample to be directly compared. It was clear that SUERC-34106 (humin fraction) gave an older age estimate than SUERC-33130 (humic acid fraction; see Table 2), which may be due to the peat formation processes (Brock et al., 2011). The discrepancy noted between the fractions radiocarbon dated may relate to the microscopic charcoal present throughout the peat profiles of the 'SCHO' core (Edwards et al., 2013, Fig 4.6b) and the 'UHM' core (Figure 5). The small size of the fragments of charcoal made it impossible to identify the species, which may have provided information about the origin of the material and whether the charcoal related to local species, bog- or drift wood. In situations where wood is scarce, such as the Northern Isles, the use of recycled wood, bog- or drift wood can result in 'old' material becoming incorporated into the archaeological record (Schiffer, 1986). It was therefore also possible that the discrepancy noted in the dates may have resulted from the presence of residual charcoal within the humin fraction. The resulting radiocarbon age would therefore lie between the age of the charcoal present and the peat, rather than giving a date for the accumulation of the peat.

The presence of the peat accumulations so close to a domestic structure would have provided regular opportunities for burnt material to have become incorporated into the peat, for example, from the burning of bog- or drift wood or 'old' peat as a fuel source within the structure itself or in the industrial feature to the north of the site. In addition, burnt material may have been carried to site as hill-wash, or from the land clearance activities to create grazing land for sheep and cattle.

5.2 Archaeomagnetic dating

A total of three features were sampled for archaeomagnetic dating, two of which related to hearths located in the S and SW annexes (contexts [166] and [214 respectively) and one to a possible industrial feature (context [093]) to the north of the longhouse. Context [093] butted against the outer wall of the longhouse and was therefore created at a later stage. All of the sampled features recorded remanent magnetisation that was considered stable, with the directions being generally well grouped, as demonstrated by small alpha-95 values (Table 3). An assessment of the samples demonstrated that the magnetisation was stable, but there were a small number of outliers. These samples may have been disturbed in antiquity: all of the anomalous samples were on the edge of the features, the area that is vulnerable to slumping or being trampled on by activity within the structure.

The calibrated archaeomagnetic dates (Batt et al., 2017) suggest two different phases of activity. The feature sampled in the SW Annexe represented the earliest area of burning sampled at Underhoull, with a date of AD 800–1080 (AM151). The calibrated date is broad due to slow changes in the geomagnetic field between AD 900–1100, limiting the precision available within this period. A radiocarbon date on material interpreted as the occupation deposits associated with the hearth (SUERC-34111), produced a calibrated date of *cal.* AD 1045-1265, which suggests that the latter part of the archaeomagnetic range may better represent the 'true' age of the feature, and placing the last use to the 11th century AD at the earliest.

The feature sampled by AM149/AM150 gave a later date than AM151, AD 1240–1310, suggesting that the activity in the S Annexe continued after the SW Annexe went out of use. This date is supported by a radiocarbon date (SUERC-34108) of *cal.* AD 1045–1260 produced on charred grains recovered from the hearth. A comparison of these two dates suggests that the later part of the radiocarbon range may represent the 'true' age of the feature, indicating that the hearth in the S Annexe was in use in the 13th century, but potentially earlier if the full range of the radiocarbon date is considered.

The archaeomagnetic date for the industrial feature (AM148), AD 1280–1430, indicates that it could have been in use at the same time as the hearth in the S Annexe but it is likely to represent the last area of burning on the site. This is supported by the archaeological evidence which suggests that activity at the Upper House may have continued as late as the early 16th century, to the very end of the Late Norse period and in to the Medieval period.

5.3 Tephra and SCPs

Several cryptotephra layers were identified in the peat profiles (Figure 6, Supplementary file 1). The identification of tephra layers, through analysis of major element oxides, is illustrated through biplots shown in Figure 7. The tephras discovered include the Hekla-Selsund (Kebister) tephra in the SCHO profile that has been dated to 1800–1750 *cal.* BC by Wastegård et al. (2008). In addition, the historically dated Hekla-1104 and Hekla-1158 tephras (Thórarinsson, 1967) were identified in UHM and Hekla 1158 was identified in SF238-239. A mixed tephra layer was found between 32-42 cm in the SCHO profile that could not be assigned to a specific eruption (see Swindles et al., 2013).

The Hekla-1158 tephra provides a precise way of correlating the UHM and SF238-239 peat sections, with the Hekla-Selsund tephra dating the start of peat formation at the site. SCPs were found in the uppermost 3 cm of the UHM and SCHO profiles indicating a post 19th-century date.

5.4 Underhoull longhouse chronological model

A Bayesian approach was taken to the development of a chronological framework for the peat accumulations and longhouse settlement at Underhoull (Supplementary file 2). In addition to the stratigraphic relationships of the accumulations and the archaeological features, additional information, such as the pollen recorded with the peat deposits, was used to 'tie' the three peat sequences together. Edwards et al. (2013) have noted that the sediment accumulation rate may have varied over time. It could have been slower following the accumulation of context [055], and a change in land use (or putative phase of abandonment) between the Iron Age and Norse period, as indicated by the reduction in the grassland and the increase in heath between contexts [041] and [026] (Edwards et al., 2013).

A single chronological model was constructed that allowed for the evaluation and interpretation of both the longhouse settlement and its temporal relationship with the surrounding peatland. The broad chronological narrative sees a period of peat formation at the site (contexts [055] and [041]), with longhouse walls constructed overtop of [041]. Peat continued to accumulate (context [026]), eventually sealing the walls of the longhouse structure. At some point during the use of the longhouse, a paved surface was laid over context [026], which itself formed over a cleared area of bedrock. The chronological model is given in the form of a simplified Harris matrix (Figure 8), which can be related directly to the OxCal model and the description that follows.

The chronological model is separated into two main sequences. The first includes the peat formation prior to the longhouse construction (peat sequences SCHO and SF238/239), as well the archaeological activity associated with the longhouse. The second sequence focuses on the beginning of the formation of the upper layers of peat (context [026]) that eventually cover the longhouse and the construction of the paved surface. Tephra deposits from the Hekla eruptions of AD 1104 and AD 1158 occur within context [026].

The first sequence begins with a date (SUERC-24946) on the humic acid fraction of a sample of peat from the base of context [055]. Within [055] and overlying this peat sample was a layer of tephra from the Hekla-Selsund eruption. The previous wiggle-match date of 1800–1750 cal. BC (Wastegård et al., 2008) is included in this model as a C_Date of 1775 ±25 years BC. Above the tephra, and still within [055], a second radiocarbon result is available (SUERC-33130) on the humic acid fraction of a sample of peat. The two peat samples are separated by only approximately 2 cm within the SCHO sequence. [055] transitions into context [041] and the humic acid fraction was dated (SUERC-33129) on a sample of peat from near the base of the layer in sequence SCHO. A second sample of peat, from sequence SF238/239, had its humic acid fraction dated (SUERC-33131). Although the relative depths would suggest SUERC-33129 is earlier than SUERC-33131, because the two results are from different peat sequences they have been placed in an unordered group. The longhouse was constructed on top of [041], and since it is impossible to know what, if any, peat was removed during the construction, the model separates the pre-longhouse peat sequence from the dating associated with the longhouse activity, while respecting the relative order of the two groups of dates. None of the scientific dates from the structure are stratigraphically related to one another and are modelled as part of a single phase of activity that post-dates the underlying peat. There are five radiocarbon dates (SUERC-24945, -34108, and -34111–3) on individual charred barley grains recovered in various contexts from the main structure, the two annexes, and the yard. Furthermore, there are three archaeomagnetic dates from two hearths (AM149/150 and AM151) associated with the longhouse and an area of burning north of the house

(AM148). This portion of the model also includes a cross-reference to a date estimate for the laying of the paved surface derived from the dating in the second sequence.

The second sequence is derived primarily from peat sequence UHM, which comprises dating evidence from throughout context [026]. Although the humin fractions from the peat in [026] were deemed unreliable due to the potential inclusion of allochthonous carbon, a sample of identifiable *Sphagnum* leaves and stems (Figure 5) was collected and dated (SUERC-24946) from 8 cm above a paving stone. Two tephra dates are available from levels above this radiocarbon sample, from Hekla-1104 and Hekla-1158. It is important to note that the exceptional precision recorded for two of the tephra layers (Hekla-1104 and Hekla-1158) is due to the fact that both of these eruptions occurred within historical time periods and so the specific date of the eruption is known. At some point after [026] began forming, but before the Hekla-1104 eruption, stone paving [029] was laid, which butted against the outer wall face of the longhouse. As stated above, this sequence is linked to the primary longhouse sequence through the dating estimate for the laying of the stone paving.

The chronological model has good agreement between the different dating techniques and the observed stratigraphic relationships (Amodel=82). Although relatively imprecise, the dating evidence estimates that peat formation began by *2795–1770 cal. BC* (95% probability; Figure 9; *start: peat formation*), and probably by *2135–1795 cal. BC* (68% probability). The transition in the peat sequence from [055] to [041], which the pollen indicated shows a sharp change from heath to grazing land, occurred in *675 cal. BC–cal. AD 235* (95% probability; Figure 9; *transition [055]/[041]*), and probably in *495 cal. BC–cal. AD 130* (68% probability). A considerable amount of time passed between the start of agricultural improvement in the area and the construction of the longhouse, with the model estimating the span covering *670–1625 years* (95% probability; Figure 10; *span: start [041] and longhouse construction*), and probably *825–1425 years* (68% probability). The Underhoull longhouse was constructed in *cal. AD 805–1050* (95% probability; Figure 9; *start:*

Underhoull longhouse), and probably in *cal. AD 880–1000* (68% probability). The longhouse was in use for *225–630 years* (95% probability; Figure 10; *span: Underhoull longhouse*), and probably *295–485 years* (68% probability). Activity within the house ended in *cal. AD 1230–1495* (95% probability; Figure 10; *end: Underhoull longhouse*), and probably in *cal. AD 1260–1380* (68% probability).

The modelling estimates the stone paving was laid in *cal. AD 1035–1105* (95% probability; Figure 9; *Paved surface laid*), and probably in *cal. AD 1070–1105* (68% probability). This would indicate that *25–280 years* (95% probability; Figure 10; *span: longhouse construction and paving laid*), and probably *80–205 years* (68% probability), passed between the initial construction of the longhouse and the laying of the paved surface.

6. Discussion

6.1 Before the Norse occupation of the site

The dates show that peat began to accumulate in the early second millennium BC, or during the beginning of the Early-Middle Bronze Age. This peat initiation may have been triggered by climate change (e.g. Morris et al., 2018), but recent studies have warned against this interpretation. For example, Lawson et al. (2007) assessed the timing of peat formation in the Faroe Islands, which occurred before any known human settlement of the archipelago, and concluded that no strong evidence could be found to suggest that climate change influenced the timing of peat initiation. Peat formation in the Shetland Isles may be driven by similar processes to those in the Faroe Islands, but despite some similarities in terms of climate and biota, one crucial factor is the very different history of human settlement.

The dating evidence reported here for a discontinuity in the peat between contexts [055] and [041] is consistent with sharp changes in the pollen stratigraphy reported by Edwards et al. (2013) indicative of a change in the landscape from heath to pasture. This event probably occurred between *495 cal. BC–cal. AD 130* (68% probability; Figure 9), placing it firmly within the Iron Age. It is possible that the identified landscape changes identified around Underhoull may be relate to the construction and use of the nearby broch tower.

6.2 The construction of the longhouse

We estimate that the longhouse was constructed in *cal. AD 880-1000* (68% probability; Figure 9). This compares to the late 7th to late 9th century dates for the establishment of the early Viking occupation of Norwick (Ballin Smith, 2007) and the probable 9th to 10th century earliest phase of the longhouse at Belmont (Larsen et al., 2013). The 9th century dates for these longhouses are contemporaneous with the settlement of Iceland (Schmid et al., 2017) and while this is consistent with the possibility that Shetland could have played an important part in the westward expansion of the Norse, it also highlights the rapid extension of Norse settlement westwards from Norway in the 9th -10th centuries.

6.3 The occupation of the structure

The end of the longhouse occupation at Underhoull occurred between *cal. AD 1260-1380* (68% probability; Figure 9). These dates also compare well with those produced for other longhouse sites in Unst, where the primary occupations of the longhouses at Hamar and Belmont were placed to the 11th-13th centuries AD (Larsen et al., 2013; Bond et al., 2013). However, it is important to note that the chronological evidence from Hamar and Belmont has not yet been fully investigated and so greater resolution may be available in the future.

The dating evidence and modelled estimates produced from the Upper House structure appear to fit within a developing pattern in Shetland and the wider region of Atlantic Scotland, for extensive settlement late in 9th and through the 10th centuries AD. Conventionally, sites such as the Upper House, Underhoull and Hamar have been interpreted as representing short-lived, single-phase settlements based on a survey of the visible structural remains and surface features. However, now that a number of these structures been excavated, there is evidence the structures underwent several phases of use and modification over a prolonged time period. This included the division of the structures into separate rooms, the addition of annexes, and use through to the end of the Late Norse period (Bond et al., 2013; Larsen et al., 2013). Collectively, evidence produced from the Upper House, Underhoull combined with data from recently excavated sites of Hamar and Belmont indicates that established ideas about the nature and use of such sites needs reassessment, in the light of longer, more complex and nuanced stories of settlement.

6.4. The abandonment of the structure and peat development

Following the production of posterior density estimates, dates associated with the use of the structure, place occupation within the *cal.* 10th-13th centuries AD. The youngest features recorded on the site relate to a possible industrial area associated with large quantities of fuel-ash slag and an area of burning (context [093]). An archaeomagnetic date of AD 1280-1430 (AM148) was produced on the area of burning. This suggests that activities at the site continued through the 13th-15th centuries, placing them between the very end of the Late Norse period and into the Medieval period. This correlates well with other examples of other well-dated Norse settlements in the Northern and Western Isles of Scotland, such as Bornais (Sharples, 2005), Cille Pheadair (Sharples et al*.*, 2004), and Pool (Hunter, 2007). Unfortunately, no material suitable for dating was recovered from the final phase of occupation at Hamar (Phase 5), although an archaeomagnetic date of AD 1100-1330 (AM154) produced for a hearth assigned to the Phase 3 occupation can be used to provide a *terminus post quem* for the final phase of activity (Bond et al., 2013). The dating evidence from these sites may place their abandonment into a period of climate change, increased winter storminess (Dugmore et al., 2009), and "famine, war, and plague" that affected Atlantic Europe from the 14th century (McGovern, 2000; Dugmore et al., 2007). It is unclear at present why the Upper House site was abandoned and whether this related to environmental or economic factors that resulted in a change in the activities carried out in the area or a decline in the status of the site.

The excavation of the Upper House, Underhoull shows that the occupants built the longhouse in an area where peat was already accumulating, which raises the possibility that continued peat growth contributed to the abandonment of the site. The dates obtained for the construction of the paved surface over the peat (context [029]), could be interpreted as an attempt by the occupants to manage the site and maintain a dry and stable area around the longhouse despite the close proximity to the peat. A modelled estimate of *cal. AD 1070-1105* (68% probability; Figure 9) obtained for the paved surface, places its construction in the 11th century AD at the earliest, but possibly as late as the early 12th century. When this is compared to the estimates obtained for the construction of the longhouse, it is possible to argue that the features were contemporary as the modelled estimates overlap, but it is also possible that the paving related to a later phase of activity. This uncertainty illustrates the challenges of site interpretation, even in the context of high resolution, multi-method chronology.

When the occupation of the structure is compared to the dates of peat accumulation two of the deposits sampled from within the structure (SUERC-24945 and SUERC-34113) and the possible industrial feature (AM148) are found to be younger than the Hekla-1158 tephra recorded in the peat located 7 cm above the paved surface to the south of the structure. Two of these dates (SUERC-24945 and AM148) sampled primary, *in situ* contexts and indicate that the occupation of the longhouse and the activity on the site continued even when the peat had encroached on the structure and paved surface. This was unexpected and suggests that the abandonment of the site cannot be attributed solely to the growth of peat on the site. This illustrates how well-constrained chronologies demand more nuanced explanations for settlement change (e.g. Dugmore et al., 2012) than the mono-causal drivers that are often invoked.

7. Conclusions

The development of the chronology for the Upper House site at Underhoull demonstrates the strength of using a multi-method approach including cryptotephrochronology; the different dating techniques sampled different materials and targeted different dated events, which provided a more complete assessment of the chronology. It was noted that the dates produced on the peat humin fraction appeared to sample residual material. It can be concluded that the anthropogenic activity in the area adjacent to the peat has encouraged the incorporation of residual material, such as 'old' wood or peat into the peat following their use as a fuel source on the site. This has complicated the determination of the chronology and acts as a warning to other studies that aim to produce dates on the humin fraction of peat sampled so close to settlement/activity sites. Hand-picked plant macrofossils (e.g. *Sphagnum* remains), when present, are best for reliable dates from peats from archaeological contexts. We found that ^{14}C dates on charred barley grains correlate well with archaeomagnetic dates on hearths as both reflect the latest use of the feature.

The accurate and precise dating of the Upper House site, Underhoull required the detailed consideration of the contexts, the stratigraphy, and the scientific dates. The integration of specialists (dating and environmental) both in the planning stages of the project, and in the field, aided the development of the chronology. In addition, the assessment of dates in sequence further enhanced the development of a robust chronology, combining the strengths of each method, compensating for their weaknesses and identifying any anomalous dates. One of the greatest advantages of this approach was the ability to produce modelled estimates for key events in the life of the site that could not be directly dated, such as the construction of the longhouse and the truncation events recorded within the peat that were indicative of the rearrangement of the landscape. The best results were achieved when several dates from a sequence could be assessed, allowing the internal consistency of the dates from each context to be determined as well as using the stratigraphic relationships of the samples to refine the age ranges further.

The construction of the longhouse c. *cal. AD 880-1000* lies between the very first phases of the settlement of Iceland and the settlement of Greenland, indicating that the Norse were consolidating settlement in the eastern North Atlantic region while simultaneously extending westward. The abandonment of the site echoes the demise of Norse settlement in Greenland (e.g. Dugmore et al., 2012). This reinforces the idea that settlement contraction was not happening simply at the margins of European settlement, but instead was more widespread, for example in Atlantic Scotland and the more-marginal areas of Iceland (Vésteinsson et al., 2014). Multi-method chronologies combined in Bayesian analysis offer exciting opportunities to realise the potential of archaeology as Distributed Long-term Observing Networks of the Past (DONOP - Hambrecht et al., 2018), to tackle Grand Challenge agendas in archaeology (Kintigh et al., 2014), and also provide detailed and extensive data on the changing lived environment of wide relevance in Quaternary science.

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Figure captions:

Figure 1: Location map of Shetland and the island of Unst, highlighting the Norse sites excavated to date. The Upper House site, Underhoull is located at 60.72°N, 0.95°W.

Figure 2: (a) The key archaeological sites located in the Westing area of Unst; (b) the Norse longhouse excavated at Underhoull as part of the Viking Unst Project, referred to as the 'Upper House'.

Figure 3: Extent of peat accumulations recorded adjacent to the Upper House site, Underhoull.

Figure 4: The relative positions of the three cores used to sample the peat. The position of the material sampled for dating has been highlighted.

Figure 5: Summary of the concentration of charcoal present within the 'UHM' core following extraction using a 63 µm sieve. The presence of *Sphagnum* remains in the UHM core is also shown.

Figure 6: Tephrostratigraphy of the three peat profiles (number of tephra shards per cm^3). The horizon representing the first appearance of SCPs (dated to *c.* AD 1850 or later) are also shown

Figure 7: Tephra geochemistry biplots. Type analyses from tephrabase (Newton et al., 2007) are shown for comparison.

Figure 8: Simplified Harris matrix for the Upper House at Underhoull.

Figure 9. The chronological model for the Upper House at Underhoull.

Figure 10. Timing of key events associated with the Upper House at Underhoull.

Table captions:

Table 1: The definition of the types of deposits recorded at the Upper House, Underhoull using the methodology defined by Schiffer (1987) and Dockrill et al. (2006).

Table 2: Summary of the AMS radiocarbon dates, calibrated using IntCal13 (Reimer et al., 2013).

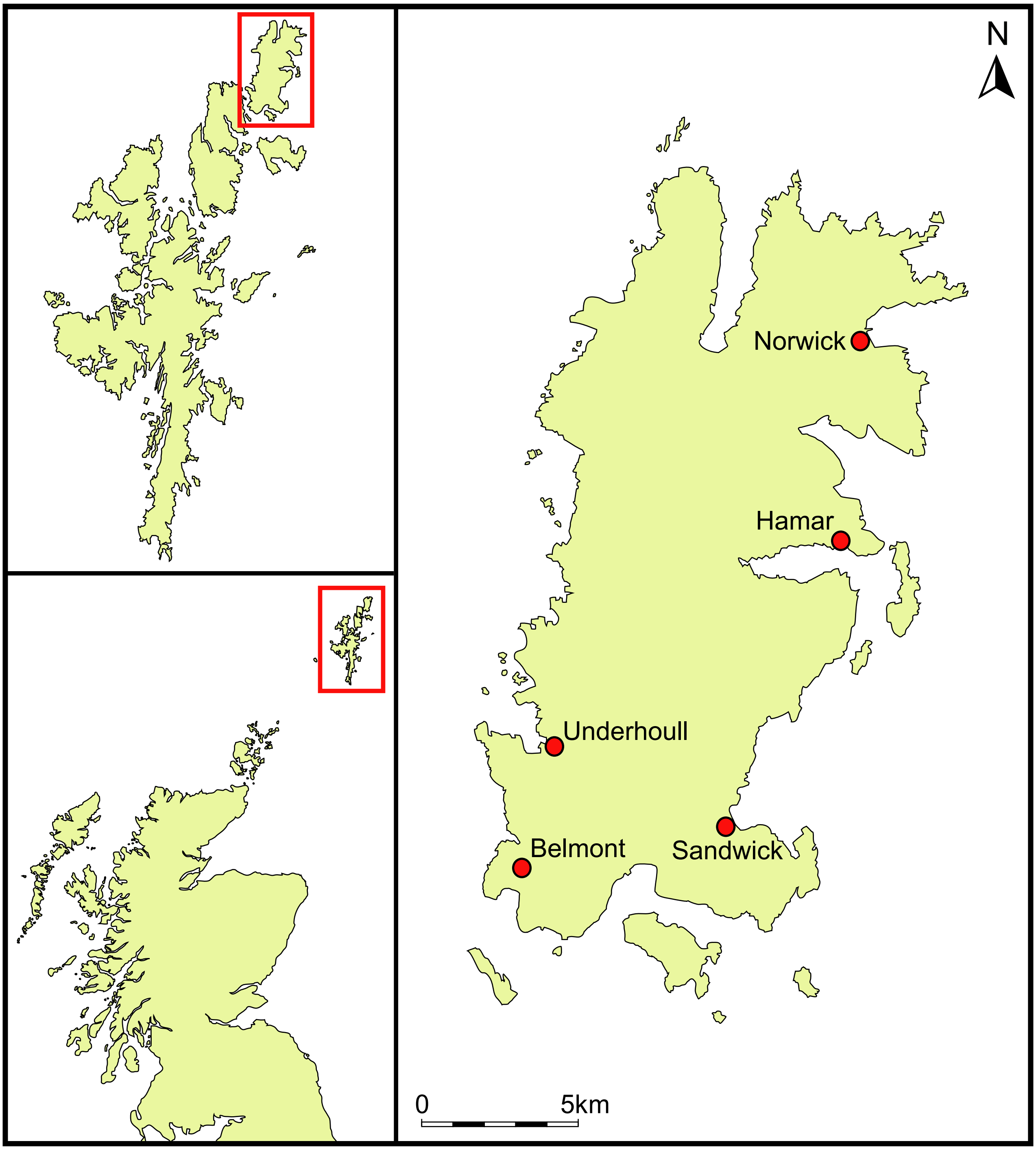
Table 3: Summary of the archaeomagnetic dates produced from the Upper House, Underhoull. All of the sampled deposits represented primary deposits. The mean directions are the characteristic remanent magnetisation directions at the site and have been calibrated using ARCH-UK.1 (Batt et al., 2017).

Table 4: Summary of the tephra horizons recovered from the peat.

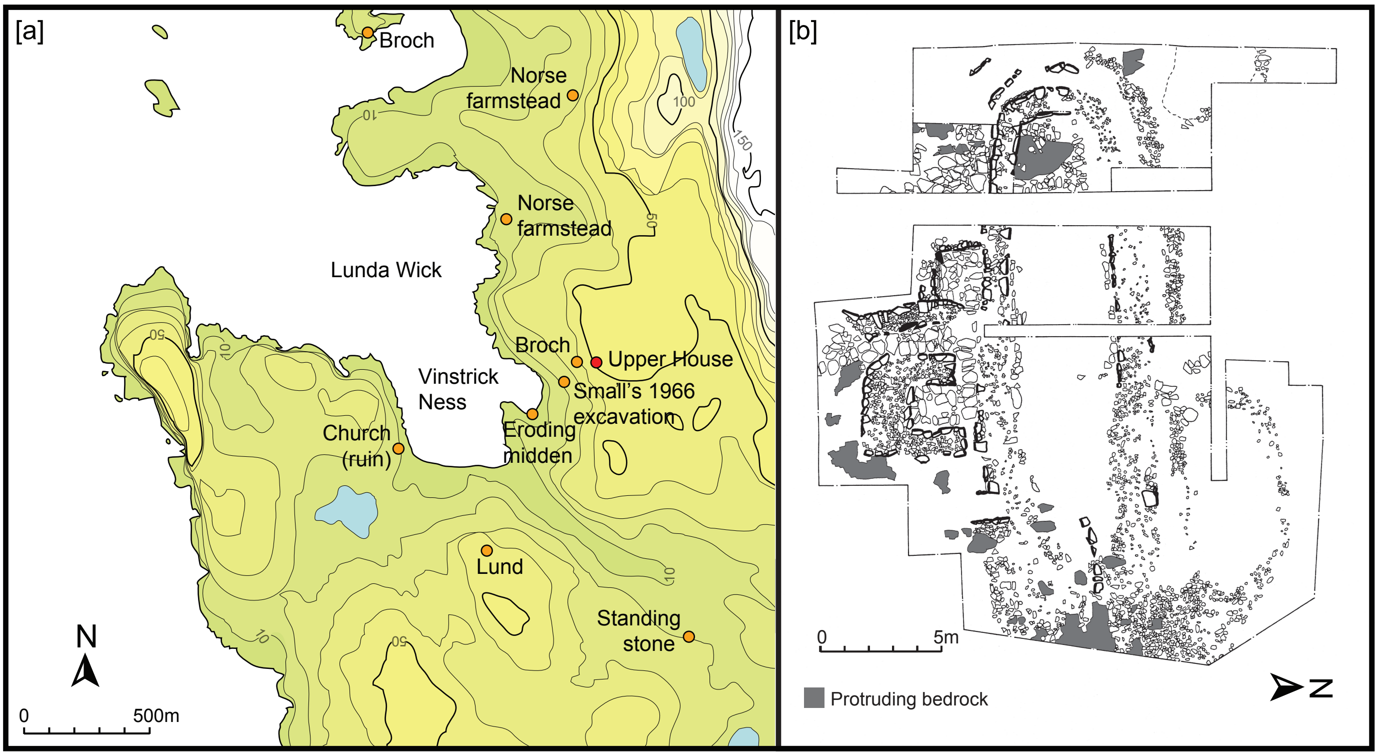
Supplementary files:

Supplementary file 1: Tephra geochemical data.

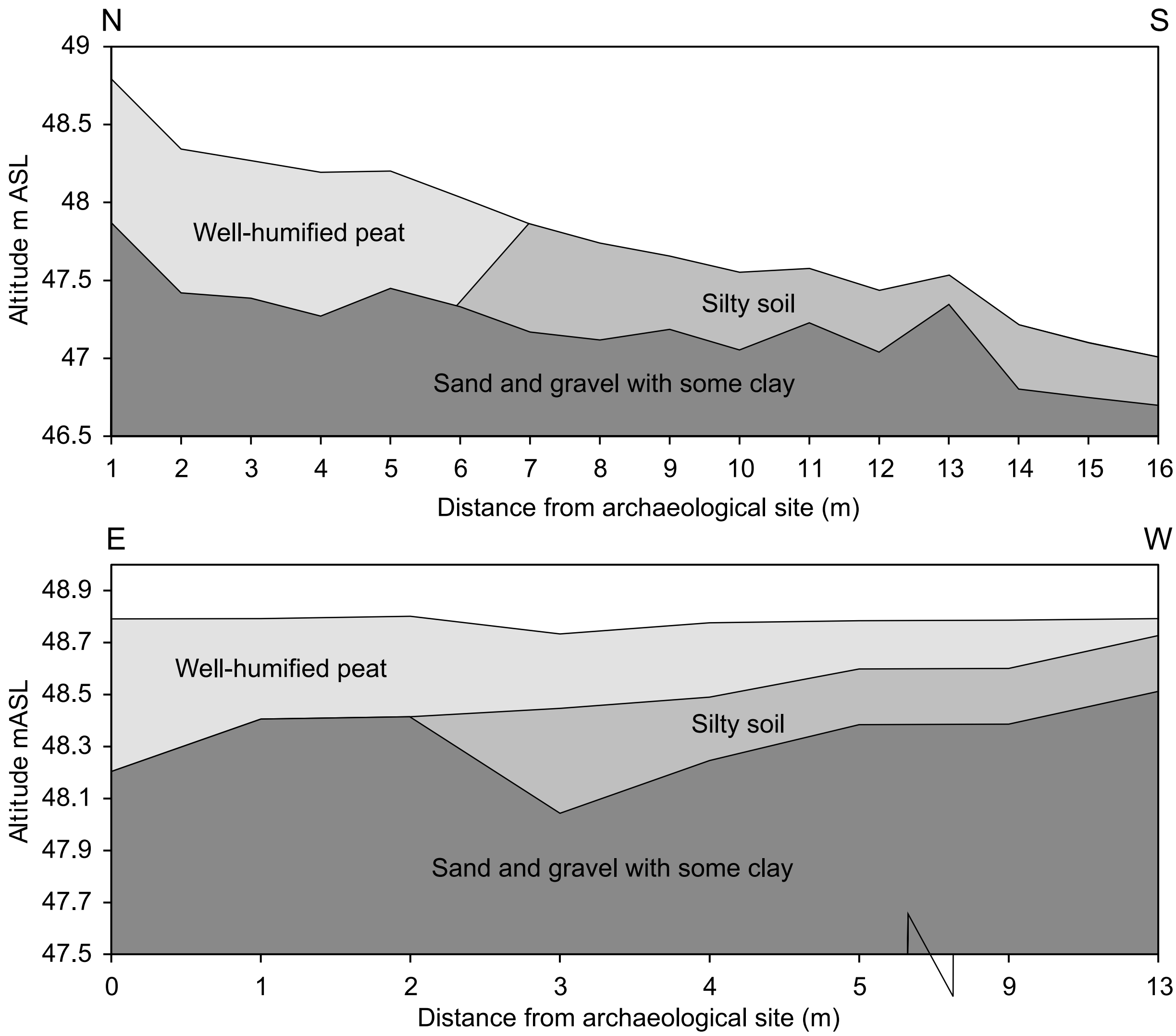
Supplementary file 2: Bayesian model code and prior files for the archaeomagnetic dates.

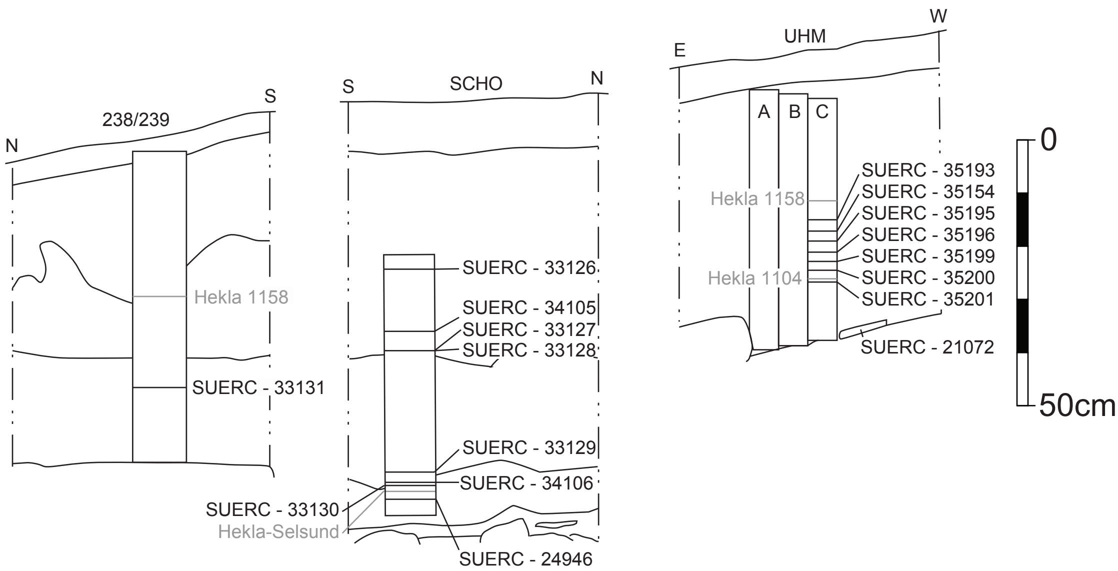


N
Norwick
Hamar
Underhoull
Belmont
Sandwick
0
5km

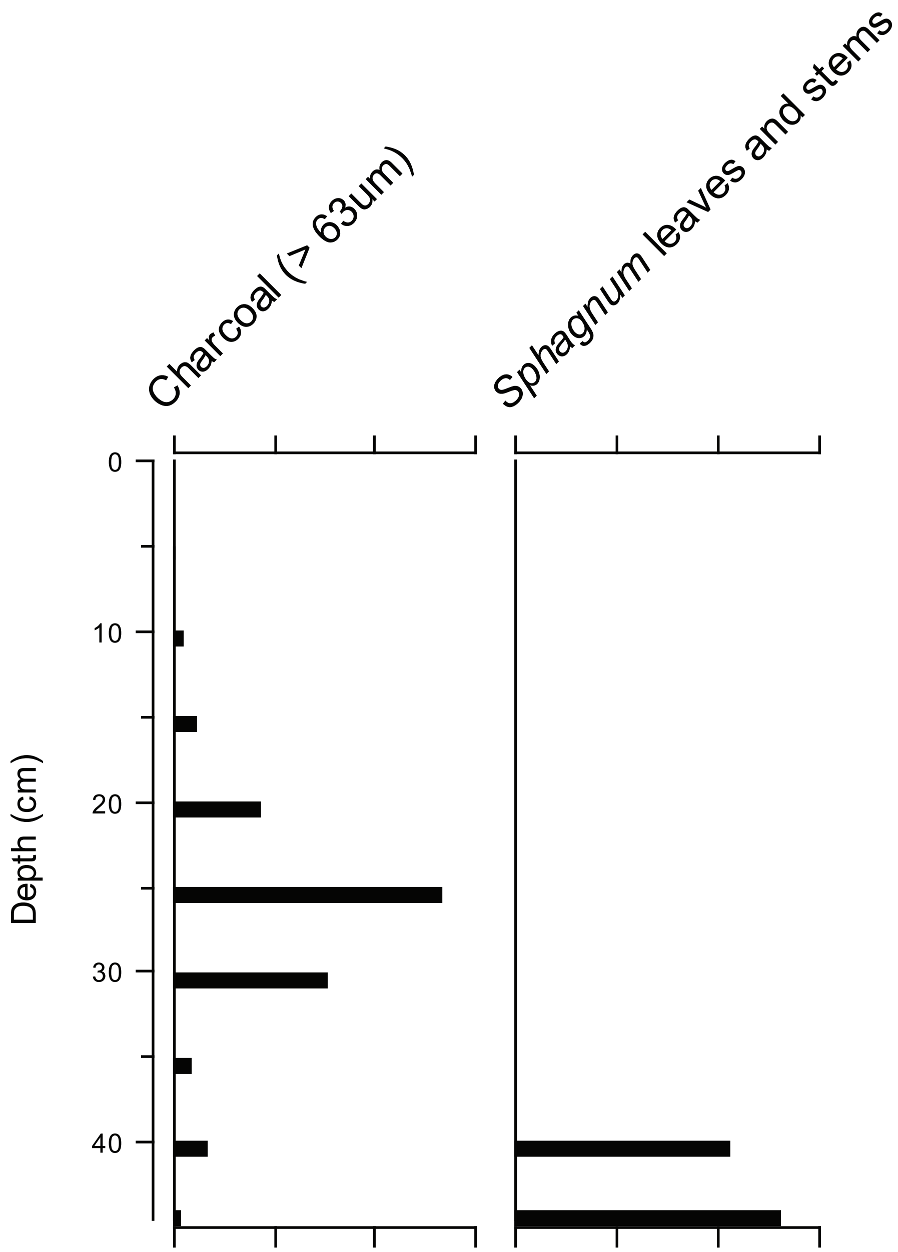


[a]
Broch
Norse farmstead
Norse farmstead
Lunda Wick
Broch
Upper House
Vinstrick Ness
Small's 1966 excavation
Eroding midden
Church (ruin)
Lund
Standing stone
10
50
100
150
N
0
500m
[b]
0
5m
Protruding bedrock
N

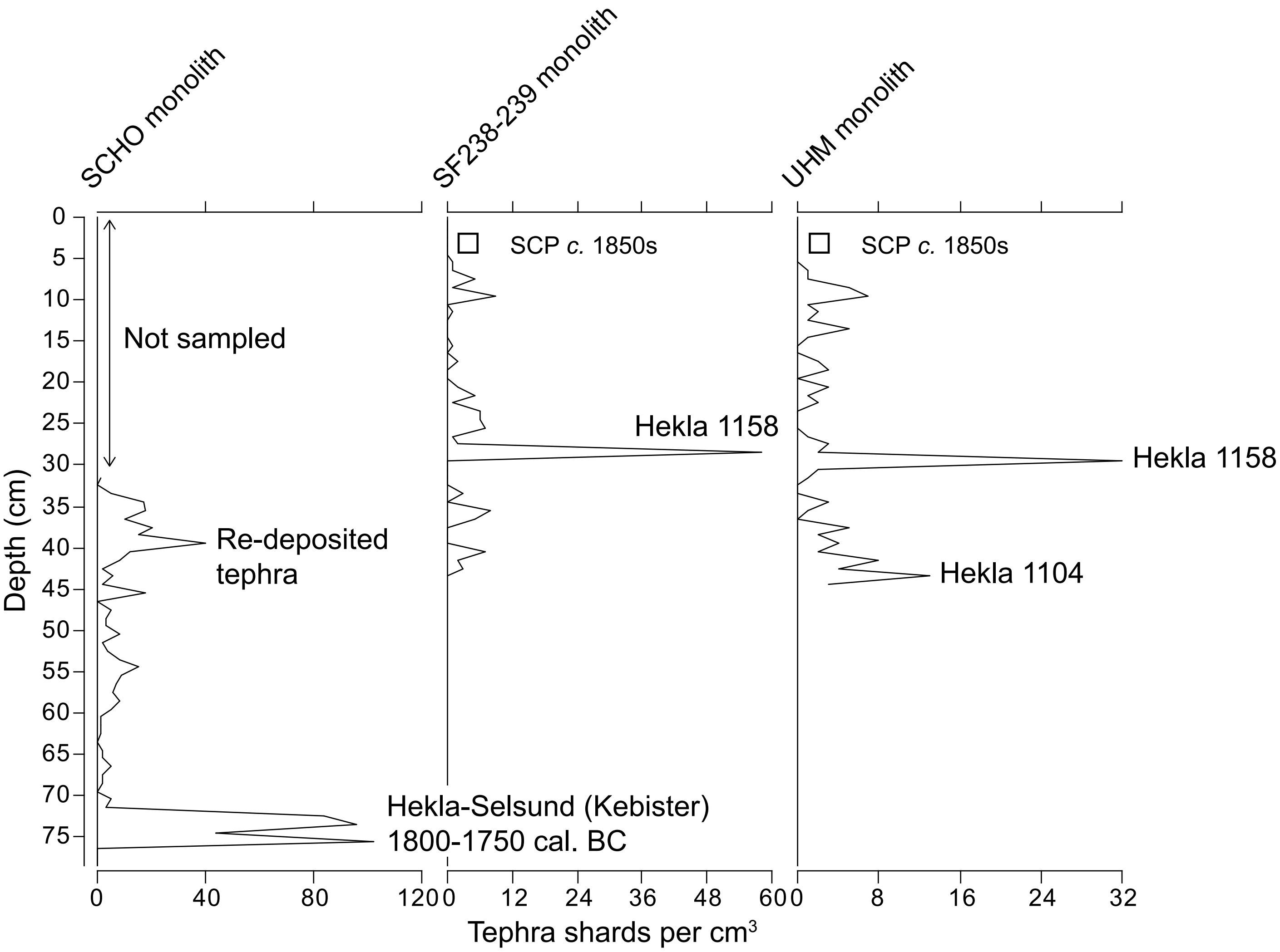

N
S
49
48.5
48
47.5
47
46.5
Altitude m ASL
Well-humified peat
Silty soil
Sand and gravel with some clay
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Distance from archaeological site (m)
E
W
48.9
48.7
48.5
48.3
48.1
47.9
47.7
47.5
Altitude mASL
Well-humified peat
Silty soil
Sand and gravel with some clay
0
1
2
3
4
5
9
13
Distance from archaeological site (m)



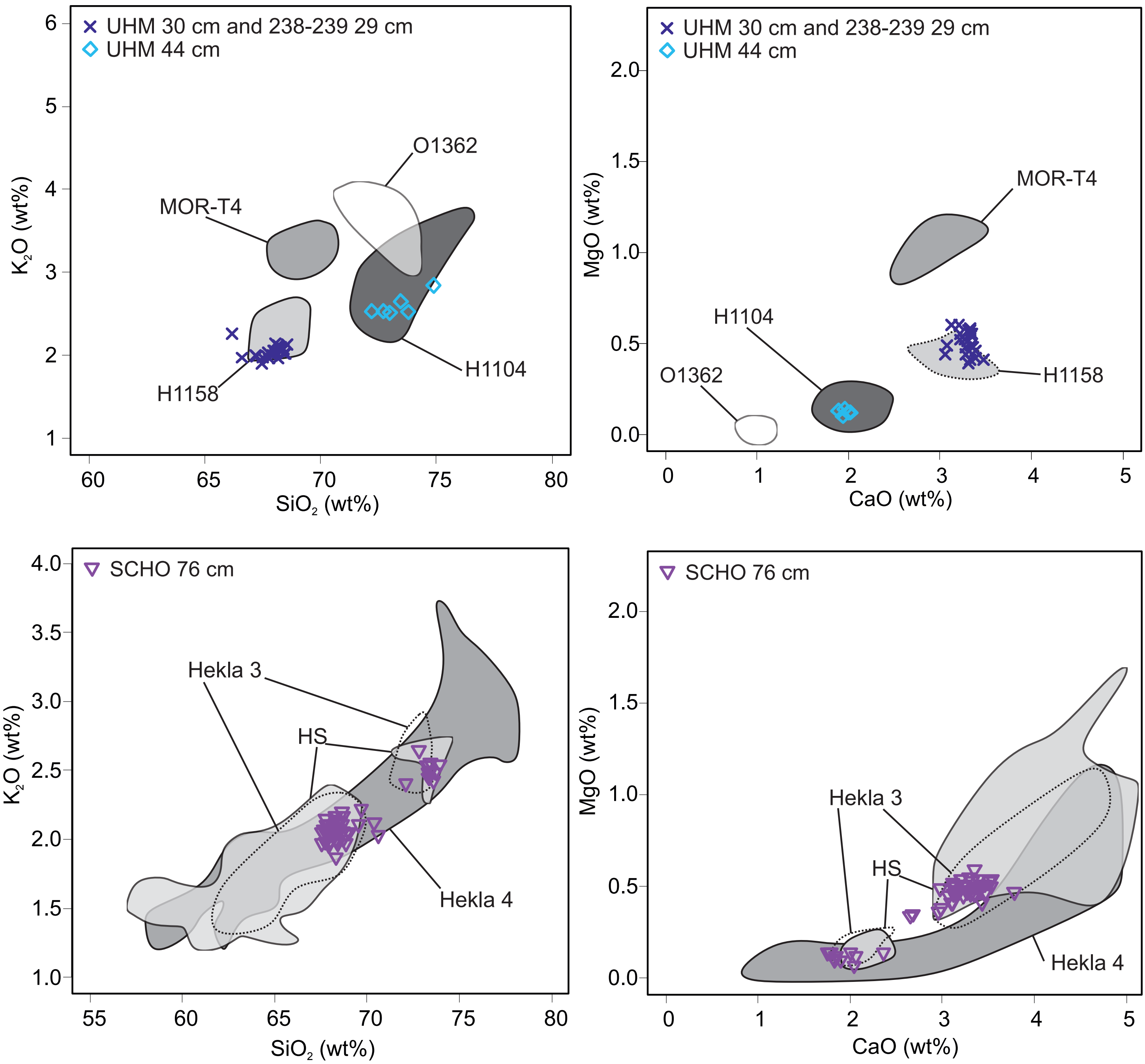
238/239
N
S
Hekla 1158
SUERC - 33131
SCHO
S
N
SUERC - 33126
SUERC - 34105
SUERC - 33127
SUERC - 33128
SUERC - 33129
SUERC - 34106
SUERC - 33130
Hekla-Selsund
SUERC - 24946
UHM
E
W
A
B
C
Hekla 1158
Hekla 1104
SUERC - 35193
SUERC - 35154
SUERC - 35195
SUERC - 35196
SUERC - 35199
SUERC - 35200
SUERC - 35201
SUERC - 21072
0
50cm



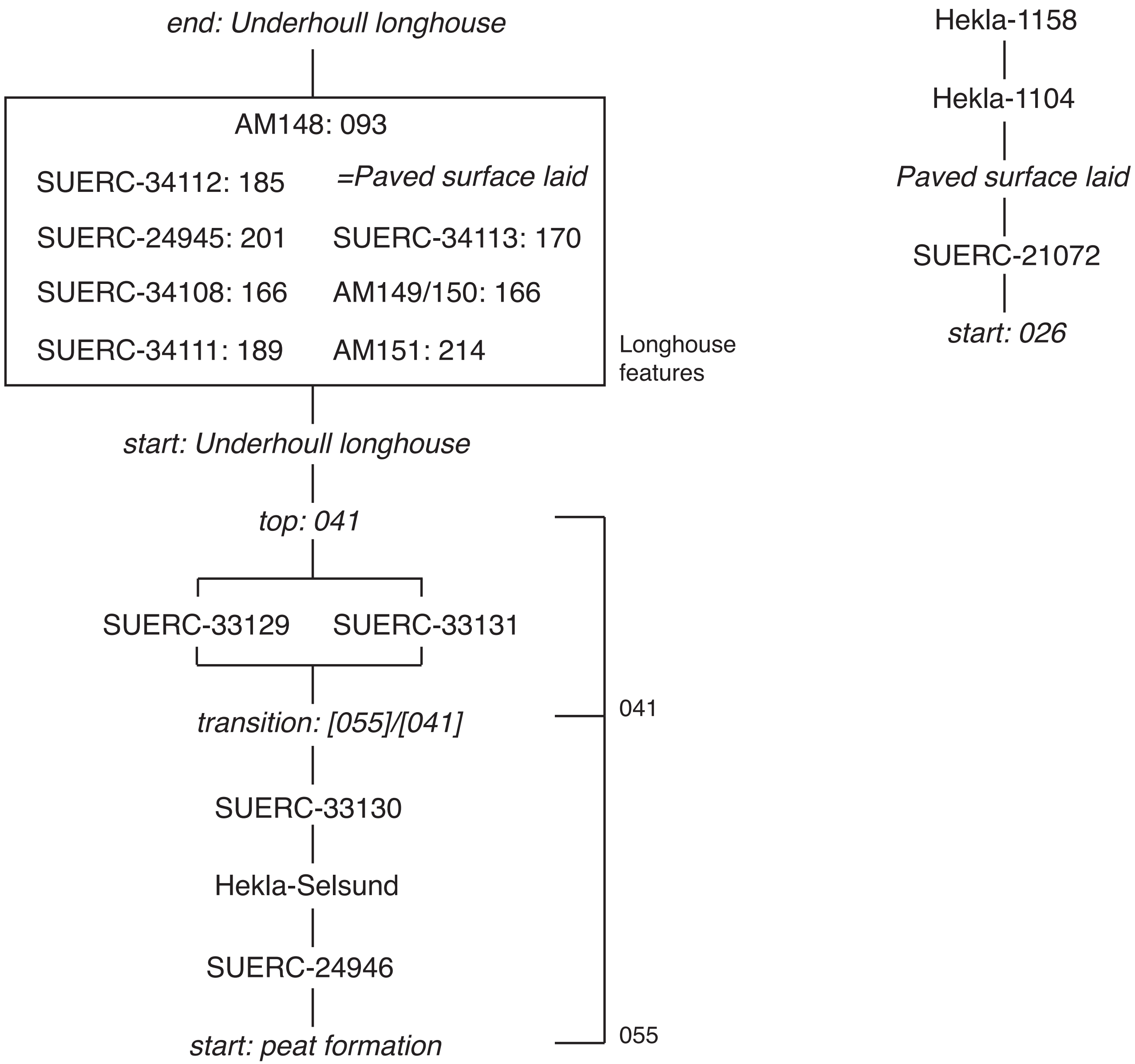
Charcoal (> 63um)
Sphagnum leaves and stems
Depth (cm)
0
10
20
30
40
0
300
600
900
0
16
32
48
n per cm³
n per cm³



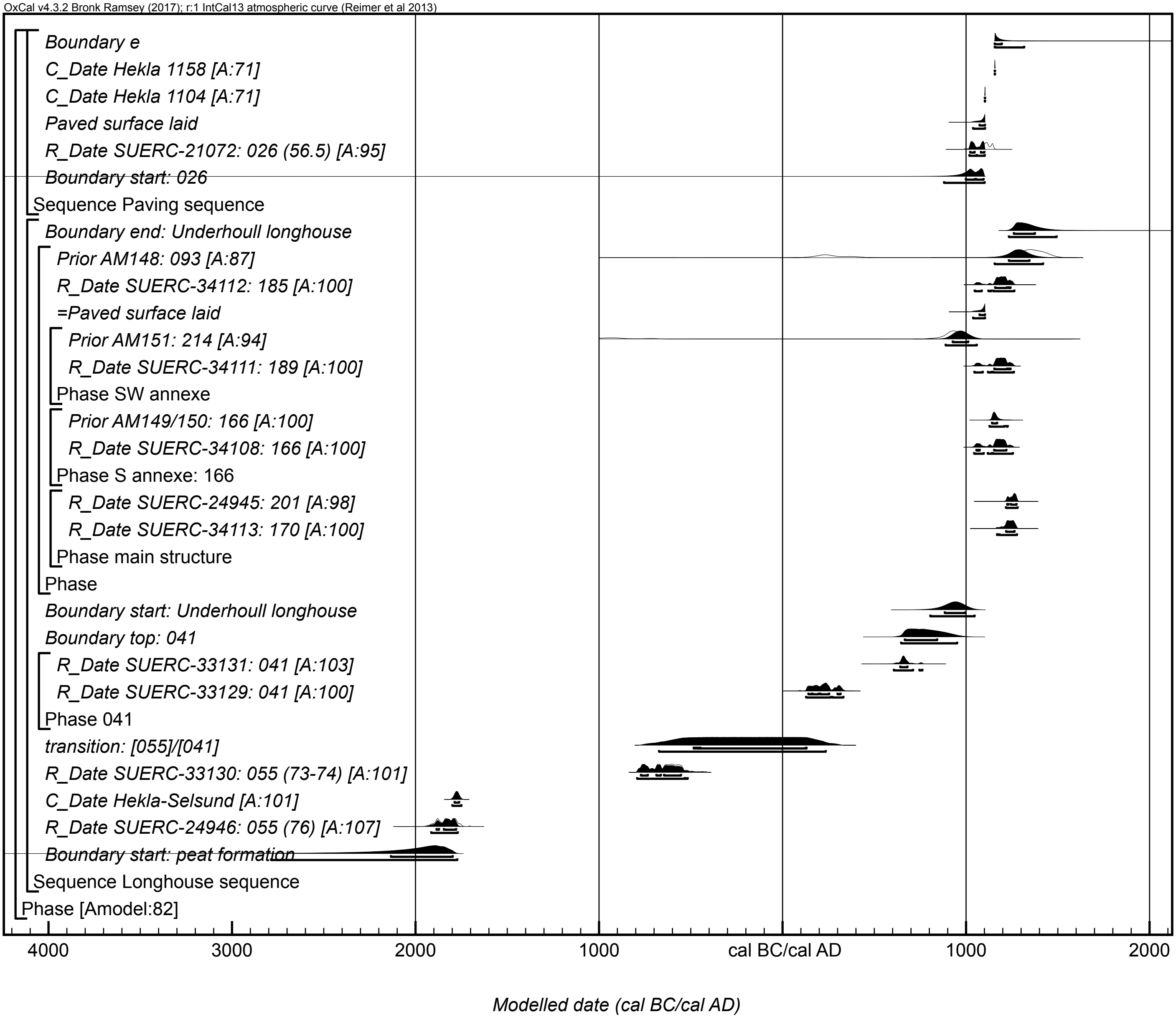
SCHO monolith
SF238-239 monolith
UHM monolith
Depth (cm)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
Not sampled
Re-deposited
tephra
Hekla-Selsund (Kebister)
1800-1750 cal. BC
SCP *c.* 1850s
Hekla 1158
SCP *c.* 1850s
Hekla 1158
Hekla 1104
0 40 80 120
0 12 24 36 48 60
0 8 16 24 32
Tephra shards per cm³

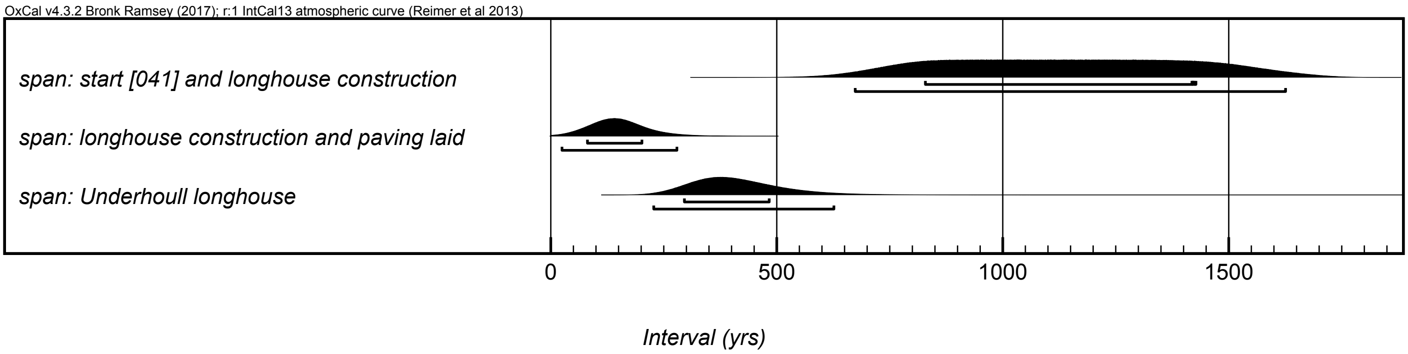


UHM 30 cm and 238-239 29 cm
UHM 44 cm
O1362
MOR-T4
H1104
H1158
K_2O (wt%)
SiO_2 (wt%)
MgO (wt%)
CaO (wt%)
SCHO 76 cm
Hekla 3
HS
Hekla 4



end: Underhoull longhouse
AM148: 093
SUERC-34112: 185
=Paved surface laid
SUERC-24945: 201
SUERC-34113: 170
SUERC-34108: 166
AM149/150: 166
SUERC-34111: 189
AM151: 214
Longhouse features
start: Underhoull longhouse
top: 041
SUERC-33129
SUERC-33131
transition: [055]/[041]
SUERC-33130
Hekla-Selsund
SUERC-24946
start: peat formation
041
055
Hekla-1158
Hekla-1104
Paved surface laid
SUERC-21072
start: 026


OxCal v4.3.2 Bronk Ramsey (2017); r:1 IntCal13 atmospheric curve (Reimer et al 2013)
Boundary e
C_Date Hekla 1158 [A:71]
C_Date Hekla 1104 [A:71]
Paved surface laid
R_Date SUERC-21072: 026 (56.5) [A:95]
Boundary start: 026
Sequence Paving sequence
Boundary end: Underhoull longhouse
Prior AM148: 093 [A:87]
R_Date SUERC-34112: 185 [A:100]
=Paved surface laid
Prior AM151: 214 [A:94]
R_Date SUERC-34111: 189 [A:100]
Phase SW annexe
Prior AM149/150: 166 [A:100]
R_Date SUERC-34108: 166 [A:100]
Phase S annexe: 166
R_Date SUERC-24945: 201 [A:98]
R_Date SUERC-34113: 170 [A:100]
Phase main structure
Phase
Boundary start: Underhoull longhouse
Boundary top: 041
R_Date SUERC-33131: 041 [A:103]
R_Date SUERC-33129: 041 [A:100]
Phase 041
transition: [055]/[041]
R_Date SUERC-33130: 055 (73-74) [A:101]
C_Date Hekla-Selsund [A:101]
R_Date SUERC-24946: 055 (76) [A:107]
Boundary start: peat formation
Sequence Longhouse sequence
Phase [Amodel:82]
4000
3000
2000
1000
cal BC/cal AD
1000
2000
Modelled date (cal BC/cal AD)


OxCal v4.3.2 Bronk Ramsey (2017); r:1 IntCal13 atmospheric curve (Reimer et al 2013)
span: start [041] and longhouse construction
span: longhouse construction and paving laid
span: Underhoull longhouse
0
500
1000
1500
Interval (yrs)

Deposit type	Min. number of times the material has been moved	Description and key features for identification	Example	Reference
Primary	None	An *in situ* deposit	Hearth deposits, dedicatory deposits, Microrefuse trodden into a floor	Schiffer, 1987, p.58
Secondary	Once	The boundaries separating deposits would be clear and distinct	A midden, the material raked out from a hearth	Schiffer, 1987, p.58; Dockrill et al., 2006
Tertiary	Twice	The deposits would be homogenised. The boundaries separating deposits may be merging and diffuse	The use of a midden deposits to level an area	Dockrill et al., 2006

	Context	Description	Lab. Ref. SUERC-	Material	Monolith	Depth from surface (cm)	Depositional context	Uncalibrated *Years BP*	Calibrated *95% confidence*	$\delta^{13}C$ ‰
Deposits associated with the structure	**201**	Dark red ashy material running down the edge of the interior, interpreted as a possible hearth	24945	Charred barley			Secondary	765±30	AD1220-1280	-26.5
	166	Orange/red hard baked ash hearth within S annexe	34108	Charred barley			Primary	866±35	AD1045-1260	-24.8
	189	Occupation deposit in the SW annexe	34111	Charred barley			Secondary	856±37	AD1045-1265	-23.0
	185	Occupation deposit in the centre of the structure	34112	Charred barley			Secondary	849±37	AD1045-1265	-23.7
	170	Steatite and charcoal rich deposit in the yard area to the N of the structure	34113	Charred barley			Secondary/Tertiary	792±35	AD1175-1280	-24.0
Peat	**026**	Purple/black peat overlying the bedrock	35193	Humin fraction	UHM	32.5	Primary	1769±37	AD135-380	-28.6
			35154	Humin fraction	UHM	34.5	Primary	1434±35	AD565-660	-28.6
			35195	Humin fraction	UHM	36.5	Primary	1578±35	AD410-560	-29.0
			35196	Humin fraction	UHM	38.5	Primary	2314±37	510-210BC	-29.3
			35199	Humin fraction	UHM	40.5	Primary	2158±37	360-60BC	-30.1
			35200	Humin fraction	UHM	42.5	Primary	1558±37	AD420-580	-29.5

			35201	Humin fraction	UHM	44.5	Primary	1622±35	AD345-540	-29.0
			21072	Sphagnum leaves & stems	UHM	56.5	Primary	970±30	AD1015-1155	-27.4
	041	Brown peat sealed by flagstones [029] and peat [026]	33131	Humic acid	SF239	45-46	Primary-Tertiary	1358±37	AD610-770	-29.0
	026	Purple/black peat overlying the bedrock	33126	Humic acid	SCO	31-32	Primary-Tertiary	1688±37	AD255-425	-28.9
			34105	Humin fraction	SCO	44-45	Primary	1905±37	AD20-220	-29.8
			33127	Humic acid	SCO	44-45	Primary-Tertiary	1708±37	AD250-410	-29.4
			33128	Humic acid	SCO	47-48	Primary-Tertiary	1604±37	AD385-550	-29.3
	041	Brown peat sealed by flagstones [029] and peat [026]	33129	Humic acid	SCO	71-72	Primary-Tertiary	1799±35	AD130-335	-29.4
	055	Dark peaty material sealed by [041]	33130	Humic acid	SCO	73-74	Primary-Tertiary	2504±37	790-425BC	-29.3
			34106	Humin fraction	SCO	73-74	Primary	2774±37	1010-830BC	-30.1
			24946	Humic acid	SCO	76	Primary-Tertiary	3515±30	1920-1750BC	-29.0

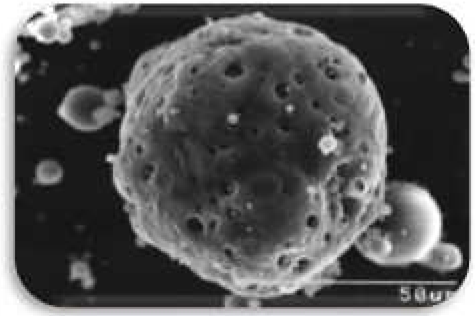
Context	Description	Lab. Ref. (Bradford)	Number of samples	Mean Declination *Degrees*	Mean Inclination *Degrees*	Alpha-95 *Degrees*	Precision parameter	Stability index	Calibrated age range *95% confidence*
214	Orange/red hard baked ash hearth material within SW annexe	AM151	14	28.1	70.4	4.1	115.5	Stable	AD800-1080
166	Orange/red hard baked ash hearth within S annexe	AM149 & AM150	51 (26 + 25)	10.2	58.1	1.9	122.7	Stable-Very stable	AD1240-1310
093	Large area of burning associated with a possible industrial activity	AM148	20	-8.5	59.5	4.8	63.5	Stable	AD1280-1430

Context	Description	Core	Depth from surface *cm*	Volcano	Date
026	Purple/black peat overlying the bedrock	UHM	29.5	Hekla	January 19th AD1158
		239	28.5	Hekla	January 19th AD1158
		UHM	42.5	Hekla	October AD1104
055	Dark peaty material sealed by [041]	SCO	74.5	Hekla (Selsund)	1600-1650 cal. BC

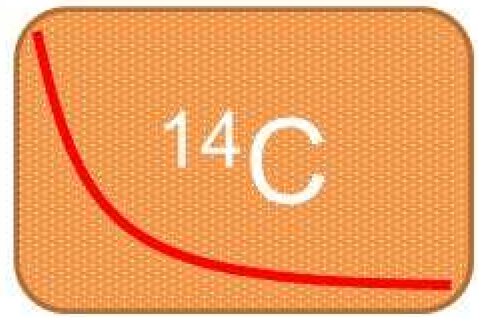
Underhoull longhouse
Shetland Isles, UK

Peat sampling

Tephra



SCPs



Radiocarbon

Archaeo-
magnetism

1. We investigate the chronology of a Norse house in the Shetland Isles, UK.
2. A multi-method approach including ^{14}C, tephra and archaeomagnetic dating is used.
3. The results have implications for Norse expansion across the North Atlantic.