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ORIGINAL ARTICLE

# The vegetation and land use histories of two farms in Iceland: settlement, monasticism, and tenancy

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## Abstract

Palaeoecological research in Iceland has rarely considered the environmental consequences of landlord-tenant relations and has only recently begun to investigate the impact of medieval monasticism on Icelandic environment and society. Through the medium of two tenant farm sites, this investigation seeks to discern whether or not monastic landlords were influencing resource exploitation and the land management practices of their tenants. In particular, sedimentary and phyto-social contexts were examined and set within a chronological and palaeoecological framework from the late 9th century down to the 16th century. How this relates to medieval European monasticism is also considered while the prevailing influences of climate and volcanism are acknowledged. Palaeoecological data shed light upon the process of occupation at the two farms during the settlement period, with resources and land use trajectories already well-established by the time they were acquired by monastic institutions. This suggests that the tenant farms investigated were largely unaffected ecologically by absorption into a manorial system overseen by monasticism. This could be a consequence of prevailing environmental contexts that inhibited the development of alternative agricultural strategies, or simply that a different emphasis with regard to resource exploitation was paramount.

**Keywords** Pollen · Iceland · Medieval · Monasteries · Tenancy · Land use

## Introduction

Here, through the application of palaeoecological methods (sedimentology and palynology), the vegetation and land use histories of the farms of Helgadalur and Ásbjarnarnes in Iceland (Fig. 1) are examined. Seeking to expand upon ongoing investigations regarding the impact of medieval monasteries on Icelandic society and the environment (Kristjánsdóttir 2017; Riddell et al. 2018b), the aim is to discern how much influence Icelandic monasteries exerted over their tenants with regard to resource exploitation and land management practices. This may be expressed as an alteration in otherwise prevailing trends in sediments and vegetation and/or the appearance of plants that were hitherto absent from within the vegetation communities. This is considered within the wider context of medieval European monasticism (Kristjánsdóttir 2017; Riddell et al. 2018b), as well as a desire to appreciate better the relationship between tenants and their landlords more generally in medieval Iceland (Júlíusson et al. 2020). Palaeoecological material is derived from two wetland sites from within the landholdings of the respective tenant farms, its interpretation enhanced through the use of tephrochronology (Thorarinsson 1967) and reference to Icelandic historical sources (Haldon et al. 2018).

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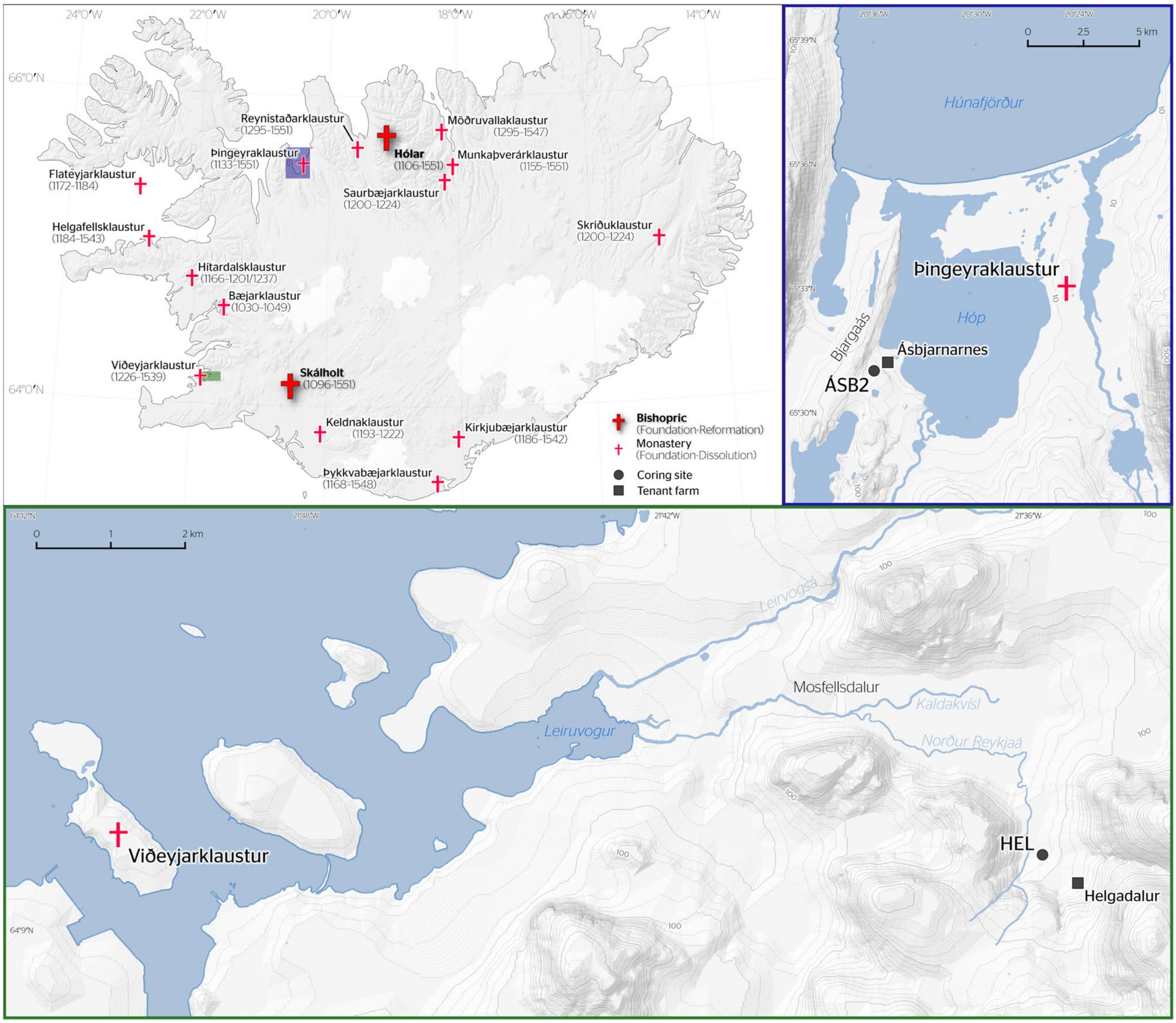


**Fig. 1** Map of Iceland indicating the distribution of monasteries and the location of coring sites, tenant farms, and landlords, as discussed in text (map courtesy of Benjamin D. Hennig, University of Iceland)

## Medieval monasticism, tenancy and environment in Iceland

Recent archaeological studies have sought to improve the understanding of Icelandic monasteries in the Middle Ages, particularly concerning their relationship with wider Icelandic society (Kristjánsdóttir 2017). Archaeological evidence demonstrates a clear link between the medieval Icelandic monastic tradition and that of Europe; architecturally and with regard to mission i.e. the provision of medical care to the lay population (Kristjánsdóttir 2010). On the continent, medieval European monasticism is strongly associated with altered landscapes (Aston 2000; Bond 2004; Gilchrist 2014) including woodland clearance (assarting), pasture development, cultivation (Wimble et al. 2000; Noël et al. 2001; Lomas-Clarke and Barber 2004; Breitenlechner et al. 2010; Hjelle et al. 2010; Stolz and Grunert 2010) and technological innovation e.g. nitrogen-fixing plant species (Tipping 1997) and hemp-retting (Laine et al. 2010). There is similar palaeoecological evidence to show that this may also have been the case with regard to monasticism in Iceland (Fig. 1) e.g. the clearance of birch scrub for fuel and pasture at the monastery of Þingeyrar (Riddell et al. 2018b) and the introduction (or intensification) of cereal cultivation at the monastery of Viðey (Hallsdóttir 1993). Notably, the scale of landscape change associated with continental monasteries could extend beyond the immediate cloister, monastic reach influencing tenancies subject to their estate (Wimble et al. 2000; Tipping 2010).

The majority of Icelandic monasteries were founded in the 12th century (Fig. 1). Contemporaneously, many formerly independent landholdings were transitioning into tenancies subject to a manor-type farm (Júlíusson 2010; Jakobsson 2013) and a peasant society evolved (Júlíusson 2007; Vésteinsson 2007). As landownership became increasingly centralised, outwith niche markets and marine commodities, subsistence shifted toward cultivating a surplus in woollen goods for export, the latter evident in altered bovine/caprine bone ratios from medieval farm middens (McGovern et al. 2017). It was under such a regime that by the 14th century, the monasteries of Iceland had amassed a large number of landholdings, tenancies submitting rental payments in the form of fish, dairy, meat, woollens, charcoal etc. (Jakobsson 2013; Júlíusson 2014). Indeed, zooarchaeological evidence from medieval tenant farms in Hörgárdalur (northern Iceland) suggests that the monastery of Möðruvellir (Fig. 1) may have been exerting significant control in relation to the production of woollens and beef there (Harrison 2014).

However, from both an archaeological and historical perspective, although considerable effort has been given to investigating the household economics of individual farms in Iceland on the one hand, and the macro-economics of international trade on the other, there remains a gap in understanding as to how this may apply to farms which were, for the most part, tenanted (Lucas 2012; Pálsson 2018; Bolender et al. 2020; Júlíusson et al. 2020). This certainly holds true for palaeoecology too, with associated methodologies only recently being deployed to consider questions pertaining to socio-economic circumstances in Iceland's past, e.g. social status (Riddell et al. 2018a) and the management of commons (Sigurmundsson et al. 2014). Therefore, any appreciation of landlord-tenant relations in Iceland through palaeoecology can only enhance our understanding of natural resource utilisation in the past (Vésteinsson 1998–2001; Erlendsson et al. 2006) and the manner in which the ecosystems that underpin it are to be sustained into the future (Edwards et al. 2019).

It is important to acknowledge that human influence upon the environment of Iceland does not operate in isolation (Dugmore et al. 2009) and that climate and volcanism (Eddudóttir et al. 2015, 2017, 2020; Tinganelli et al. 2018) represent significant agents with regard to modelling the Icelandic landscape. The climate regime in the North Atlantic at this time spans both the Medieval Climatic Optimum (MCO) AD 900–1500 (Mann 2002a) and the Little Ice Age (LIA) AD 1500–1900 (Mann 2002b). With regard to Iceland, both marine (Eiríksson et al. 2000) and lacustrine cores (Larsen et al. 2012) suggest that the MCO occurred AD 800–1350 followed by the LIA which persisted until AD 1900. Such regional variation forms the basis of arguments that criticise the concept of an LIA (Ogilvie and Jónsson 2001; Mann 2002b). Indeed, within Iceland, reference to Icelandic historical material suggests that the LIA is comprised of two distinct phases (Ogilvie and Jónsson 2001). Between AD 1250 and AD 1500 (the period that encompasses this study), the prevailing conditions in Iceland were relatively mild but punctuated by short periods of harsh climate. From AD 1500 until AD 1900, the incidence and severity of conditions became far more exacting in terms of cooler temperatures, glacier advance, sea ice, and storminess.

## Study sites

### Helgadalur

Helgadalur (97 m a.s.l.) is situated in southwest Iceland, ca. 25 km east of Reykjavík (Fig. 1). The valley is bounded to the west, south and east by upland, culminating in Grímannsfell (482 m a.s.l.), with a basic/intermediate, Upper Pliocene and Lower Pleistocene (0.8–3.3 my) geology. The drift geology is of rock exposure, glacial till and Holocene histosols and andosols of volcanic origin (Arnalds et al. 2001). Pasture, hayfields, and mixed-broadleaved/conifer plantations (Ottósson et al. 2016) are maintained through a 20th century drainage system that feeds into the Norður-Reykjaá. The valley basin of Helgadalur is categorised as experiencing "none" or "little" erosion (Arnalds et al. 2001). In contrast, the surrounding uplands are subject to "considerable" erosion. Where upland vegetation persists, it is comprised of a matrix of moss, grassland and heath (Ottósson et al. 2016). Regional mean annual temperature and precipitation data are derived from Reykjavík (Table 1) but as seasonal and daily insolation are limited by the surrounding uplands (Pétursdóttir 2014), temperatures are likely to be lower at Helgadalur. Similarly, precipitation is probably higher at Helgadalur due to its altitude. The prevailing wind is from the east.

Charcoal, burnt bone and compacted soil, revealed during archaeological survey (Zori and Byock 2014), testify that Helgadalur has been occupied since the deposition of the AD 877 Landnám Tephra Layer (LTL). This is also apparent palaeoecologically with land use focussed upon the development of a pastoral regime between AD 877 and AD 1226 (Riddell et al. 2018a). The earliest historical reference to Helgadalur comes from AD 1395 (DI-III 1857–1986). Here it is said that Helgadalur came into the ownership of the Augustinian monastery of Viðeyjarklaustur (Fig. 1) during the rule of Abbot Páll Magnússon (AD 1379–1403), i.e. within the 16 years between the Abbot's ordination in AD 1379 and the compilation of the inventory of AD 1395 (Kristjánsdóttir 2017). A relatively low value of 12 hundreds is given for the tenancy at Helgadalur. Representatives of the Danish Crown attacked Viðeyjarklaustur in the name of Reformation on Whitsun AD 1539. Following dissolution, Viðeyjarklaustur

**Table 1** Climatological data for the study sites (Icelandic Meteorological Office (Veðurstofa Íslands) 2007)

| Data/weather station | Reykjavík | Blönduós/Hjaltabakki[a] |
|---|---|---|
| Location | N 65° 36′ 54″ W 19° 57′ 15″ | N 65° 42′ 10″ W 20° 10′ 24″/N 65° 39′ 42″ W 20° 15′ 1″ |
| Recording period | 1961–1990 | 1961–1999[a] |
| Elevation (m a.s.l.) | 52 | 8/~23 |
| Avg. temp °C tritherm (June–August) | 10.0 | 8.7 |
| Avg. temp °C July | 10.6 | 9.4 |
| Avg. temp °C January | − 0.5 | − 2.5 |
| Avg. precipitation mm year$^{-1}$ | 799 | 458 |

[a]Blönduós 1961–1965 and 1981–1999, Hjaltabakki 1967–1981

and approximately 60 tenancies (Júlíusson 2014), including Helgadalur, effectively became a royal fiefdom (Karlsson 2000), remaining so into the 18th century (Magnússon and Vídalín 1926).

### Ásbjarnarnes

The farm of Ásbjarnarnes is situated by a peninsula on the western shore of Hóp, a semi-saline, coastal lagoon in Vestur-Húnavatnssýsla, northwest Iceland (Fig. 1). The ridge of Bjargaás (95 m a.s.l., northeast-southwest axis), a dominant landscape feature within the landholding, is formed of Upper Pleistocene basalts and is situated within a geological landscape largely defined by Tertiary basalts (Jóhannesson and Sæmundsson 1998). The drift geology is comprised of rock exposure, glacial till, coastal and riverine deposits, and Holocene histosols and andosols of volcanic origin (Moriwaki 1990; Arnalds et al. 2001; Thordarson and Hoskuldsson 2002). Much of the landholding is subject to "considerable" erosion (Arnalds et al. 2001). Vegetated areas comprise a matrix of heath and fen, grassland, and modified pasture (Ottósson et al. 2016). Land is still grazed but no one resides at Ásbjarnarnes permanently today. Temperature and precipitation data are derived from Blönduós/Hjaltabakki (Table 1). The prevailing wind is from the southwest.

Reference to Ásbjarnarnes in historical sources (also known as *Nes í Víðidalur*, *Nes í Vestur Hóp*, *Ásbjarnarnes í Þverárhreppi*) begins in the early 14th century in association with the Benedictine monastery of Þingeyraklaustur. This material is concerned with shore rights such as sealing and beached whales (*Diplomatarium Islandicum*: DI-II 1857–1986). However, in AD 1361, half of the Ásbjarnarnes landholding, including the home farm and an extensive area of woodland, is bequeathed to Þingeyraklaustur by the farmer Árni Bárðarsson (DI-III 1857–1986). Subsequent inventories show that this portion of Ásbjarnarnes remained a tenancy of Þingeyraklaustur, along with around 62 other tenancies (Júlíusson 2014), until the Reformation (DI-IX 1857–1986; DI-VIII 1857–1986; DI-XII 1857–1986).

## Methodology

### Site selection and fieldwork

Both historical and geographical factors influenced the selection of the coring sites. Confirmation that a farm site was formerly a tenancy of a monastery (in association with a date of acquisition) was required and effected via the *Diplomatarium Islandicum* (DI-I-XVI 1857–1986), a collection of medieval letters, inventories, and deeds, originating from ca. AD 1150 to ca. 1550. Moreover, an association with an Icelandic monastery for which there is some indication of the modification of ecological conditions in their immediate environs at the time of foundation was also preferred; in this instance Viðeyjarklaustur (Hallsdóttir 1993) and Þingeyraklaustur (Riddell et al. 2018b).

The presence of a wetland within the landholding of the selected tenant farm was necessary. The identification of suitable wetlands was achieved via a consideration of aerial photographs and site visits. Pollen profiles derived from cores from such contexts are considered to be representative of past plant communities within and around wetlands (Rymer 1973; Moore et al. 1991; Caseldine and Hatton 1994). Therefore, as a central area for human activity, close proximity to the farmstead was desirable regarding the detection of land use practices. However, this also depends upon the presence (determined through the sampling of selected wetlands with a JMC "Backsaver") of a relatively intact sedimentary sequence that contains dateable tephra layers. In Iceland, sediments can often be damaged or interrupted by peat (fuel) and turf (construction) cutting, and modern agricultural practices (drainage, levelling of pasture, etc.), especially in the immediate vicinity of farmsteads. Hence, any wetland with an intact sedimentary sequence within the landholding was deemed suitable on the premise that it will capture some degree of human activity.

Helgadalur was chosen as it complied with the historical requirements of the selection criteria, and because there was already a core to hand from the landholding that had been previously processed for pollen for an earlier period of the sites history (Riddell et al. 2018a). This 1 m core (HEL) was extracted from a modified wetland, ca. 600 m northwest (64° 9′ 49.19″ N, 21° 35′ 38.65″ W) of the modern farmstead of Helgadalur (Fig. 1). The exact extent of the original mire at Helgadalur is unclear given its conversion to pasture, but it is at least 0.27 $km^2$ and situated at the head of a relatively enclosed valley. Poaceae (grass) is dominant within the current vegetation community with Cyperaceae (sedge) sub-dominant.

Ásbjarnarnes was selected as it complied with all criteria (although upper strata subsequently proved to be devoid of identifiable tephra layers and $^{14}C$ dates were necessary). The 75 cm core (ÁSB2) was extracted from Sund (65° 31′ 8.44″ N, 20° 35′ 32.48″ W), a relatively intact wetland (ca. 0.4 $km^2$) situated between Bjargaás and some small, eroded hillocks ca. 90 m southwest of the remains of Ásbjarnarnes farm (Fig. 1). Regarding the present vegetation community, *Eriophorum angustifolium* is dominant with *Betula nana*, *Salix callicarpaea* and *Vaccinium uliginosum* also present.

## Sedimentology

Strata for both sites were described according to Troels-Smith (1955) as modified by Aaby and Berglund (1986), supplemented by Munsell soil color charts (2009). Each column was measured every 0.5 cm for magnetic susceptibility (MS) with a Bartington MS2 meter and MS2E probe (Dearing 1994), before being processed for soil properties. Measures of dry bulk density (DBD; g/$m^3$) and organic matter (OM; %) were acquired for every 1 cm. The dry weight was obtained by heating samples at 105 °C for 24 h. DBD was calculated by dividing the dry weight of the sample by sample volume (1.2 $cm^3$) (Brady and Weil 1996). OM was calculated by combusting 1.2 $cm^3$ of sediment at 550 ºC for 4 h (Heiri et al. 2001).

## Age determination

Tephra samples were extracted from distinct horizons identified within the sediment profiles (visually or via MS). In order to discern the origin of the tephra samples, each was cleaned of humic material, sieved (63 µm), mounted, polished and carbon-coated for geochemical analysis. Tephra geochemistry was analysed at the University of Iceland using a JEOL JXA-8230 electron probe micro-analyser (EPMA). The acceleration voltage was 15 kV, the beam current 10 nA, with a beam diameter of 10 µm, except for intermediate or rhyolitic tephra which were set at 5 µm (due to crystallisation and thin walls). The standards A99 (for basaltic tephra), ATHO and Lipari Obsidian (both for silicic and intermediate tephra), were measured prior to, and after, the analyses in order to verify consistency in analytical conditions. Data were then inspected for, and cleaned of, anomalies and analyses with sums < 96% and > 101%. Sometimes it is necessary to seek $^{14}C$ dates in Icelandic contexts if there is a shortfall in the presence of tephra layers i.e. where sites lie beyond isopach range. Therefore, three $^{14}C$ dates were acquired to supplement the tephra sequence for ÁSB2 by sieving (< 250 µm) sediment samples and selecting suitable material for analyses, in this instance, wood and bark. This material was analysed by ETH Zurich, Switzerland, and the results were calibrated using IntCal20 (Reimer et al 2020). Smooth-spline age-depth models were derived from tephra and $^{14}C$ data and constructed using the clam package in R (Blaauw 2010).

## Palynology

A total of 45 samples were prepared for HEL and 39 samples for ÁSB2. HEL samples for depths 6.75 to 28.25 cm were taken at 0.5 and 1 cm intervals with a volume of 2 $cm^3$ per sample. The greater resolution (0.5 cm intervals) applies to HEL samples situated between the Katla AD 1500 (20 cm) and Medieval AD 1226 (28.25 cm) tephra layers as there was confidence in capturing the period of monastic oversight associated with the tenancy (AD 1379–1539). The processing of HEL samples for the depths 29.50–43.25 cm (volume of 1 $cm^3$ per sample) is described in Riddell et al. (2018a), with these samples only revisited in order to acquire microscopic charcoal data. ÁSB2 was sampled at 1 cm intervals with a volume of 2 or 3 $cm^3$ per sample, with greater sample size used where low pollen concentration was anticipated.

The volumes of HEL and ÁSB2 samples were determined by displacement in 10% HCL (Bonny 1972). One *Lycopodium clavatum* tablet (Batch no. 124961 for ÁSB2 and HEL 6.75–28.25 cm, Batch no. 1031 for HEL 29.5–43.25) was added to each sample in order to determine pollen concentration (Stockmarr 1971). Samples were rinsed in 10% HCL to remove residual glue from the control tablet, 10% NaOH to break down humic material, and sieved (through a 150 µm mesh) to remove coarse material (Moore et al. 1991). Minerogenic material was removed by dense media separation utilising LST Fastfloat, density 1.9 g/ml (Björck et al. 1978; Nakagawa et al. 1998). Acetolysis allowed for the separation of pollen grains from other organic material (Moore et al. 1991). Pollen grains were slide-mounted with silicone oil of 12,500 cSt. viscosity and counted by using a microscope at ×400 to ×1,000 magnification (Moore et al. 1991).

Moore et al. (1991) was used as the primary pollen key, with pollen and spore taxonomy adapted according to the Icelandic context (Erlendsson 2007), as was plant nomenclature (Kristinsson 1986). Total land pollen (TLP) values per sample for HEL range between 210 and 640 while that for ÁSB2 is 299 to 933. Preferably, these numbers would be higher given the low pollen productivity of Icelandic vegetation (Caseldine and Hatton 1994) but in this instance, high chronological resolution has been favoured over large counts per sample. A minimum of 100 non-Cyperaceae pollen grains were counted for each sample in order to overcome the dominance of Cyperaceae in Icelandic pollen profiles (Caseldine and Hatton 1994). In order to determine the relative proportions of pollen and spore taxa within the sample, palynological interpretation is based primarily upon pollen percentage data (Birks and Birks 1980). The TLP for each sample underpins the base sum on which the percentages for all taxa are calculated. As a result, percentages for some non-pollen palynomorphs (NPP) can exceed 100%. Furthermore, as these values are co-dependent, Cyperaceae values will suppress the values of other taxa (Moore et al. 1991). Therefore, palynomorph concentration data are used to supplement the interpretation.

Recorded NPP's are comprised of cryptogram spores (Moore et al. 1991), microscopic charcoal (Patterson III et al. 1987), and coprophilous fungal spores (CFS) (van Geel et al. 2003; Cugny et al. 2010). Charcoal and CFS are considered part of a suite of environmental proxies indicative of human activity and the presence of livestock in Iceland (Edwards et al. 2011). All Poaceae pollen grains were evaluated as potential cereal-type pollen i.e. a mean grain diameter > 37 µm and an annulus diameter > 8 µm (Andersen 1979). Pollen data and NPP count data were entered into TILIA (version 2.0.41) and subjected to a total sum of squares analysis (CONISS), producing a stratigraphically constrained dendrogram (Grimm 2011). Visual evaluation of the dendrograms allowed data to be divided into Local Pollen Assemblage Zones (LPAZ). In order to better understand the nature of the relationship between LPAZ, ordination analyses were applied to the HEL and ÁSB2 datasets via the package vegan in R (Oksanen et al. 2016). Principal Component Analysis (PCA) was performed on Hellinger-transformed data incorporating terrestrial pollen and spore taxa as well as coprophilous fungal spores with abundances ≥ 1%.

## Results

### Age determination

Age/depth models for the HEL and ÁSB2 (Fig. 2a, b) cores provide the chronological framework required to interpret palynological and sedimentary data and were constructed with reference to known tephra layers and $^{14}$C dates. Tephra layers (Tables 2 and 3) were identified for HEL and ÁSB2 based upon their geochemical composition (ESM1 Tables 1 and 2) in comparison with other published material pertaining to tephra and palaeoecological studies in southwest and northern Iceland (Tables 2 and 3).

A cryptic tephra at HEL 7.5 cm was identified by MS and is thought to originate from Katla (Table 2 and ESM1 Table 2). However, it is impossible to narrow this down to any specific eruption and this tephra is excluded from the age/depth model. Similarly, although the HEL tephra layer situated at 37 cm does share characteristics with tephra from the Katla AD 920 eruption (Hafliðason et al. 1992;

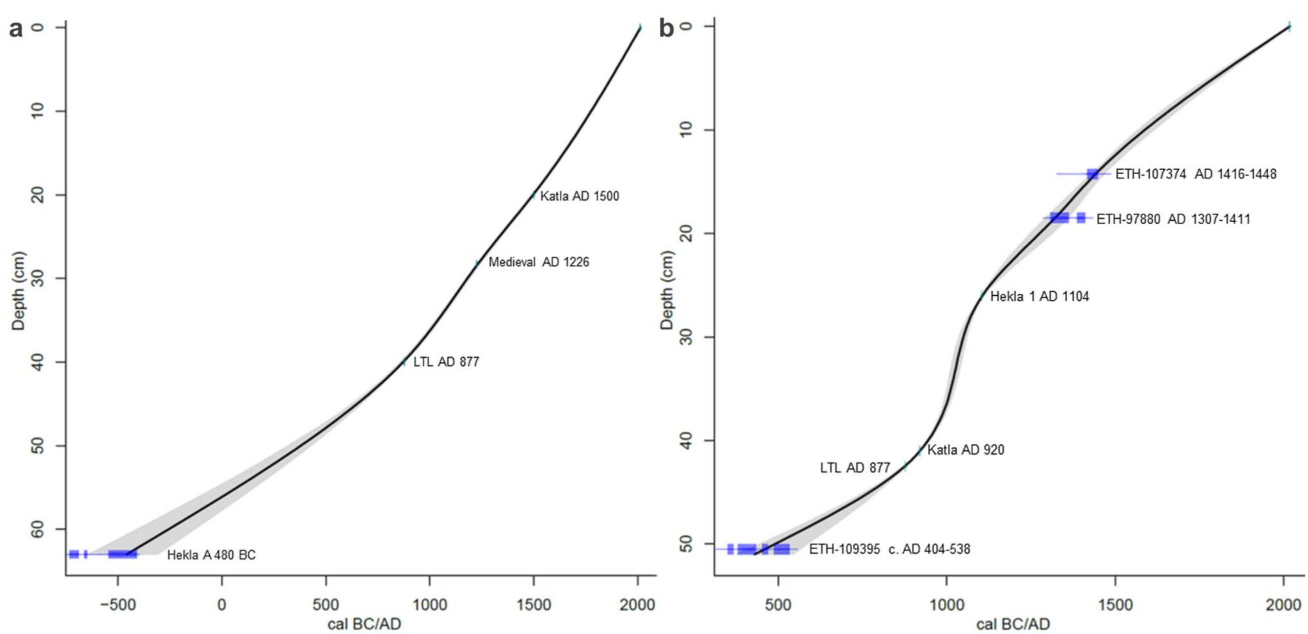


**Fig. 2** Age-depth model for HEL (**a**) and ÁSB2 (**b**)

Erlendsson et al. 2014; Riddell et al. 2018a), its geochemical signal is obscured by tephra shards of Vatnaöldur origin (perhaps reworked fragments from the LTL at 38–40 cm) and is also excluded (Table 2 and ESM1 Table 2). Radiocarbon data for ÁSB2 are presented in Table 4.

## Palynology and sedimentology

All HEL and ÁSB2 pollen (Figs. 3, 4, 5 and 6) and sediment (Fig. 7a, b: MS, DBD and OM) charts include a chronology, LPAZ, and a simplified sediment stratigraphy (for detail see ESM2 Table 3). Supplementary material pertaining to pollen percentage values (≥ 1% TLP) that exclude Cyperaceae are given in ESM2 Figs. 1 and 2 (respectively). Ordination data is featured in Fig. 8a and 8b.

## LPAZ and sediment properties for HEL I-IV

### HEL I (Fig. 3, 43.50–37.75 cm, ca. AD 711–885)

Woody peats define sediments until they are truncated by the AD 877 LTL (40 cm) with OM values (Fig. 7a) as high as 84.5% (64.5–40 cm). DBD and MS (Fig. 7a) are low (< 0.5 g/cm$^3$ and 10 SI respectively) with increases only associated with the AD 877 LTL. Cyperaceae (40.9% to 61.7%) is increasingly dominant while *Betula* and *Empetrum nigrum* initially vie for sub-dominance before *Betula* (38%) ultimately replaces *E. nigrum* (5%) at 38.25 cm (ca. AD 864), the initial shift arising at 41.25 cm (ca. AD 819). This change also sees values for Ericales (3.9% to 0%), *Filipendula ulmaria* (8.3% to < 3%) and *Angelica* indet. (1.7% to < 1%) fall, as do those of *Sphagnum* (182.5% to 28%). These alterations in the ratios between species and taxa are also apparent with regard to pollen concentrations (Fig. 4). PCA (Fig. 8a) clearly distinguishes HEL I from the later LPAZ with taxa characteristic of natural vegetation where grazing is absent, e.g. *Betula*, Ericales, *Angelica* indet. and *F. ulmaria*. Traces of microscopic charcoal are present (≤ 5%).

### HEL II (Fig. 3, 37.75–28 cm, ca. AD 885–1235)

The sedimentary context is now defined by a silty peat and is truncated by tephra deposits at 37 cm (ca. AD 917) and 28.50 cm (ca. AD 1219). Both tephra deposits have a negative impact upon OM values (Fig. 7a) with the interim period characterised by a peak OM of 60.2% (34.50 cm) and OM does not recover to the level of HEL I. Cyperaceae is dominant with values higher than those of HEL I, sustained within a range of 70.8% (33.5 cm) and 84.4% (36.25 cm).

**Table 2** Interpretation of tephra layers for HEL

| Depth (cm) | Origin | Name | Cal BP (1950) | BC/AD | References |
|---|---|---|---|---|---|
| 7.5 | Katla | n/a | n/a | n/a | n/a |
| 18–20 | Katla | n/a | 450 | AD 1500 | Hafliðason et al. (1992) and Eiríksson et al. (2000) |
| 28–28.5 | Reykjanes (marine) | Medieval | 724 | AD 1226 | Jóhannesson and Einarsson (1988) |
| 37 | Katla? | n/a | 1030? | AD 920? | Hafliðason et al. (1992) |
| 38–40 | Veiðivötn/Torfajökull | LTL | 1073 | AD 877 | Schmid et al. (2017) |
| 54.5–55 | Katla | n/a | n/a | n/a | n/a |
| 63–64 | Hekla | A | 2430 | 480 BC | Larsen et al. (2020) |

**Table 3** Tephra layers and dates for ÁSB2

| Depth (cm) | Origin | Name | Cal BP (1950) | Cal. AD | Reference |
|---|---|---|---|---|---|
| 25.5–26 | Hekla | H1 | 846 | 1104 | Eiríksson et al. (2000) |
| 40.5–41 | Katla | n/a | 1030 | 920 | Hafliðason et al. (1992) |
| 42–42.5 | Veiðivötn | LTL | 1073 | 877 | Schmid et al. (2017) |

**Table 4** Radiocarbon dates for ÁSB2

| Code | Depth (cm) | $^{14}$C date (BP) | Error 1σ | δ $^{13}$C (‰) | Cal. age (AD) 2σ | Weight (mg) | Material |
|---|---|---|---|---|---|---|---|
| ETH-107374 | 14–14.5 | 476 | 21 | – 29.9 | 1416–1448 | 1.5 | Wood and bark |
| ETH-97880 | 18–19 | 584 | 20 | – 29.7 | 1307–1411 | 1.5 | Wood |
| ETH-109395 | 50–51 | 1630 | 23 | 29.10 | 404–538 | 1.5 | Wood and bark |

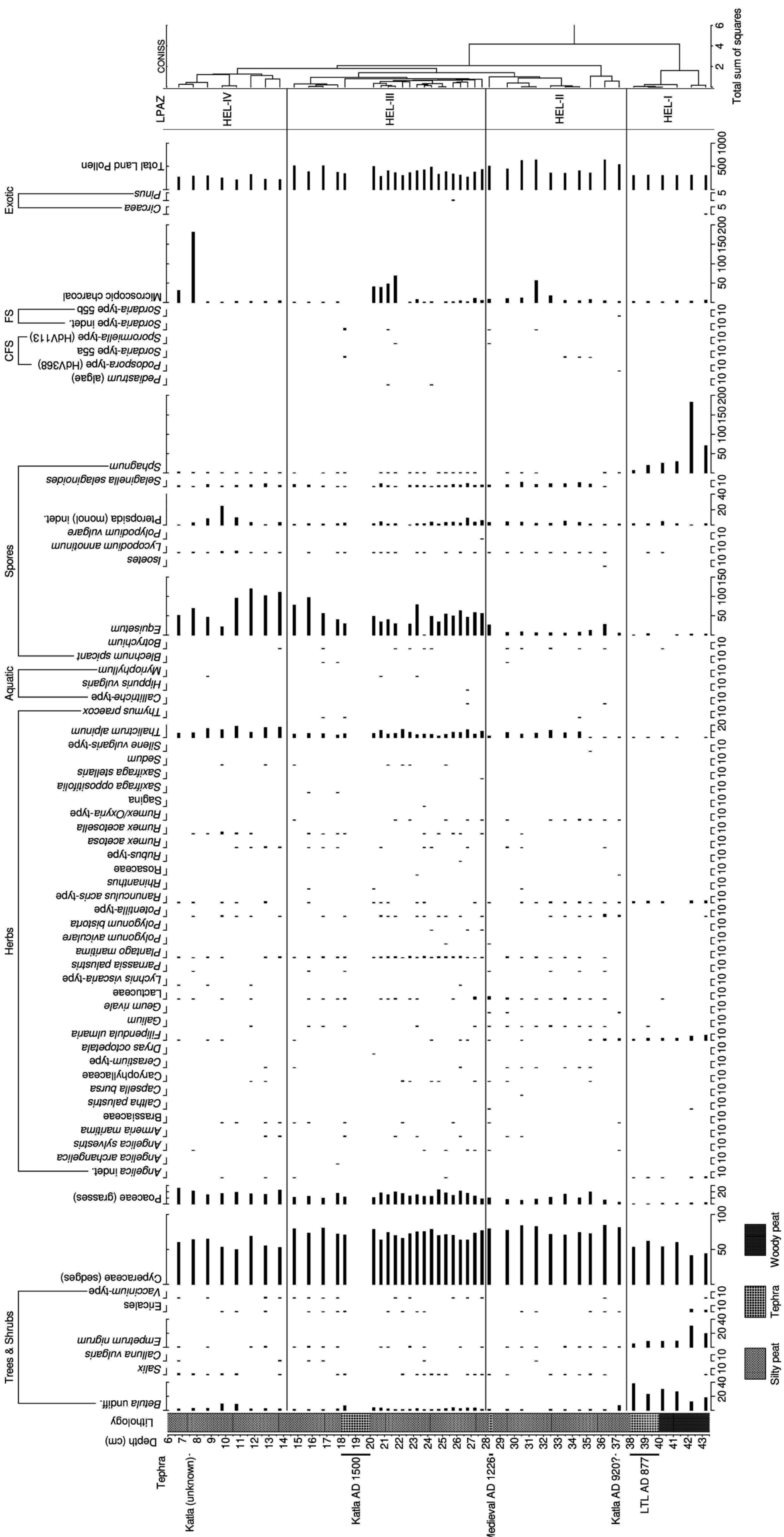


**Fig. 3** Pollen percentage diagram for HEL and LPAZ

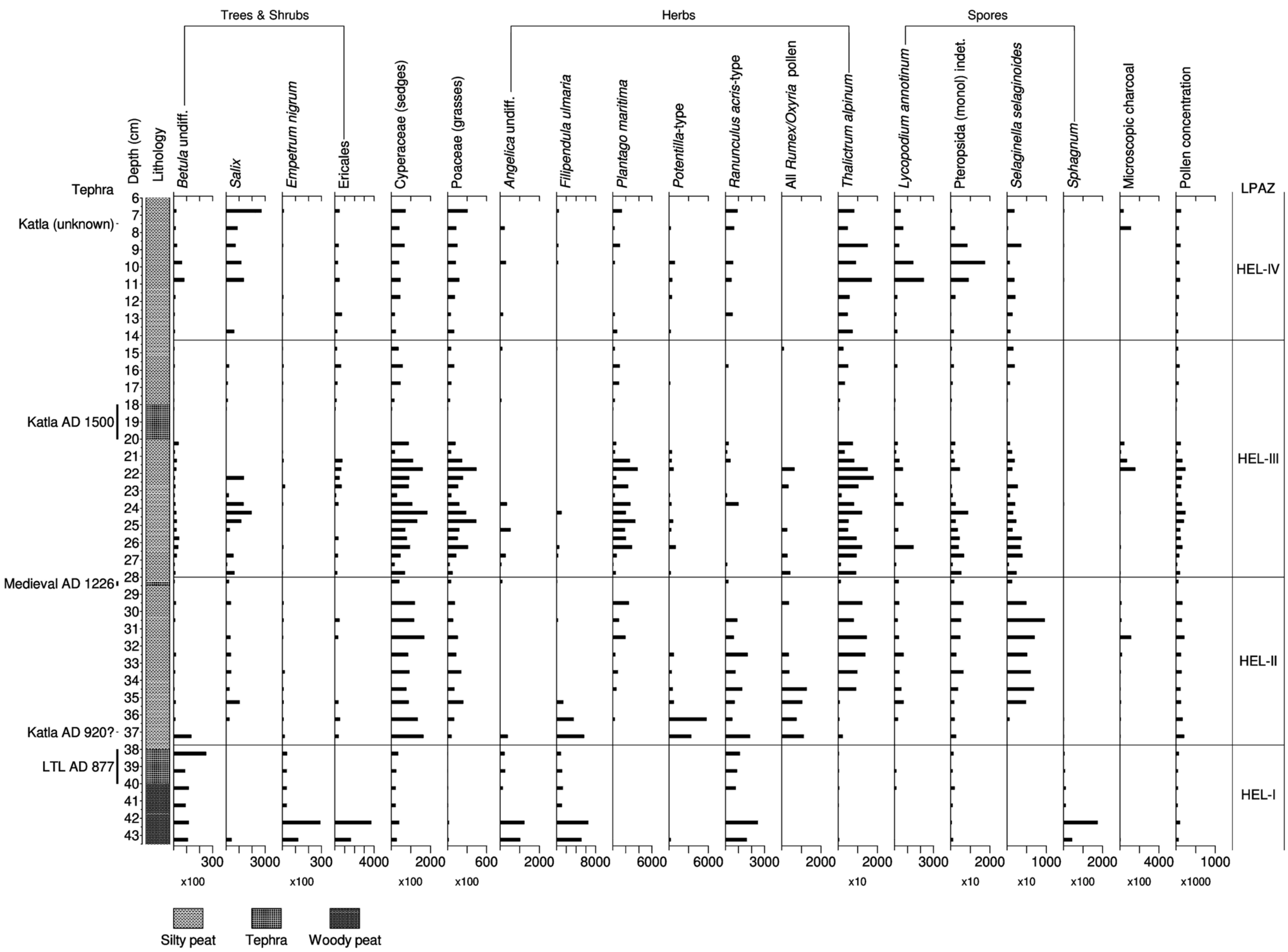


**Fig. 4** Pollen concentration diagram for HEL, selected taxa and species ≥ 1% TLP

Poaceae values rise and fluctuate between 6.1% (36.25) and 19.5% (35.25). Concentration data for HEL II (Fig. 4) suggest that variation between Cyperaceae and Poaceae values correspond. Some pollen and spore taxa occur for the first time e.g. *Plantago maritima*, *Potentilla*-type, *Rumex*/*Oxyria* undiff. and *Selaginella selaginoides,* and are accompanied by CFS (*Podospora*-type and *Sordaria*-type 55a). *Thalictrum alpinum* values increase noticeably (5.6% to 11.6%, 34.5–29.5 cm, AD 1050–1186). Notably, from 37.25 cm (ca. AD 906), values for *Sphagnum* and *Angelica* spp. collapse (≤ 1%), *E. nigrum* values drop to ≤ 1.4%, a pattern also followed by *Betula* (< 1%, 36.25 cm, ca. AD 947). PCA (Fig. 8a) presents a stark contrast to the previous LPAZ (HEL I) with an open landscape dominated by Cyperaceae.

### HEL III (Fig. 3, 28–14.25 cm, ca. AD 1235–1614)

The sedimentary context continues to be defined by silty peat with the only disruption to the strata occurring with a tephra deposit at 20 cm (Katla AD 1500). This relative stability is also evident with regard to MS and DBD (Fig. 7a) while, as with HEL II, OM recovers to 60.7% (23.50 cm) between the tephra deposits of AD 1226 and 1500. Following AD 1500, OM rises to 53.5% (15.50 cm). Cyperaceae continues to dominate (range 63.2% to 80.3%) but Poaceae values are now consistently above 10, and can be as high as 23% (24.75, ca. AD 1360). The increasing presence of Poaceae is reflected in the PCA (Fig. 8a) and suggests a strong relationship between Poaceae, *Th. alpinum*, *P. maritima* and *S. selaginoides;* all of which also present persistent and/or high pollen concentration values (Fig. 4). *Angelica sylvestris* (< 1%) and *F. ulmaria* (< 1%) make a tentative reappearance as does *Betula* (≤ 6.1%). There is a spike in microscopic charcoal values (56.1%) at 31.5 cm (ca. AD 1119), although high values (38.2% to 68.1%) are more consistent between 21.75–20.25 cm (ca. AD 1442–1500).

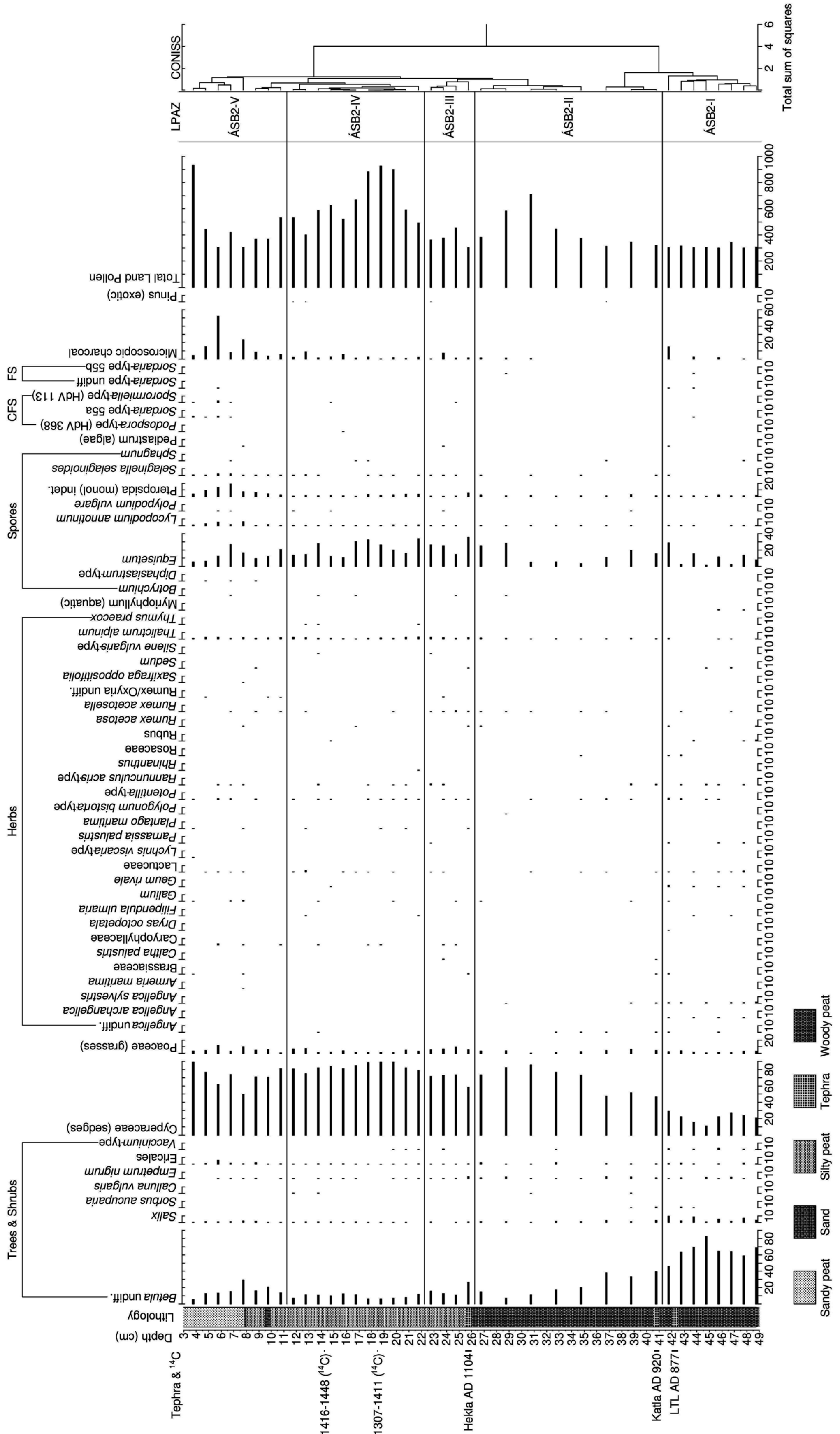


**Fig. 5** Pollen percentage diagram for ÁSB2 and LPAZ

(28.75 cm, ca. AD 1075) with a declining trend matched also by *Salix* (≤ 3%). *Empetrum nigrum* and Ericales values increase (≤ 3.2% and ≤ 2.3% respectively). *Vaccinium*-type virtually disappears. Cyperaceae values increase considerably (≤ 85.7%). The values of Poaceae vary with an initial increase to 6.1% (38.75 cm, ca. AD 968), a decline to pre-AD 877 levels, before rising again to 4% (26.75 cm, ca. AD 1091). *Th. alpinum* and *S. selaginoides* are more persistent than previously, trends in their values following those of Poaceae. Grazing sensitive taxa such as *Angelica* spp. gradually disappear or are absent e.g. *F. ulmaria*. These trends in percentage values also appear in pollen concentrations (Fig. 6) and a shift toward a more open landscape is indicated in the PCA (Fig. 8b). CFS and microscopic charcoal barely register.

#### ÁSB2 III (Fig. 5, 26.25–22.25 cm, AD 1101–1205)

Peat sediments become more minerogenic following the deposition of the Hekla AD 1104 tephra (26 cm) with the impact of the eruption most readily observed at 24.5 cm with regard to DBD and OM (Fig. 7b). However, a later peak in MS (23 cm, ca. AD 1183) marks the beginning of a longer term, more persistent, increase in MS values. There is a recovery in *Betula* values (26.4%, 25.75 cm, ca. AD 1111) which persist at levels between 10.8% (24.75 cm, ca. AD 1134) and 15.7% (22.75 cm, ca. AD 1190). Cyperaceae values fall to 58.4% (25.75 cm, ca. AD 1111) and remain lower than those of LPAZ II. Poaceae values rise to 9.7% (24.75 cm, ca. AD 1134) and remain above 5.2% from 22.75 cm (ca. AD 1190), this increase more obvious in the pollen concentration data (Fig. 6). More generally, new apophytic taxa and species appear e.g. Caryophyllaceae, *P. maritima*, while in other instances, values increase, especially for *Rumex acetosella* (≤ 2.2%) and *Th. alpinum* (≤ 3%). CFS (*Sporormiella*-type HdV 113) values are low (< 1%) in contrast to microscopic charcoal which retains a presence and rises to 7.2% (23.75 cm, ca. AD 1161).

#### ÁSB2 IV (Fig. 5, 22.25–11.25 cm, AD 1205–1541)

There is greater fluctuation in MS, DBD and OM values with an overall increase in minerogenic inputs (Fig. 7b). Cyperaceae is dominant (≤ 89.1%, 18.75 cm, ca. AD 1313), readily observed in the PCA (Fig. 8b). Although Poaceae values increase (7.7%, 12.75 cm, ca. AD 1489), Cyperaceae values never fall below 74.8% (12.75 cm, ca. AD 1489), a pattern echoed in the pollen concentration data (Fig. 6). The decline of *Betula* continues but it remains above 6.2% and even recovers to 12.3% (15.75 cm, ca. AD 1398). The signals for *Salix*, Ericales and *E. nigrum* are low (< 1%) but persist. There is a general increase in microscopic charcoal with a peak of 8.7% (12.75 cm, ca. AD 1489). The CFS (*Podospora*- and *Sporormiella*-type HdV 113) signal is relatively mute.

#### ÁSB2 V (Fig. 5, 11.25–3 cm, AD 1541–1882)

The sedimentary strata are significantly altered with bands of sand truncating the peat sequence at 10 cm (ca. AD 1587) and 8 cm (ca. AD 1666) and with an increased minerogenic input from 7.8 cm (ca. 1676). This disturbance is equally apparent with regard to MS, DBD and OM (Fig. 7b). Trees and shrub values increase, *Betula* (≤ 29.3%), *Salix* (≤ 2.3%), Ericales (≤ 5.9%) and *E. nigrum* (≤ 1%). Conversely, Cyperaceae values fall to 49.7% (7.75 cm, ca. AD 1676), also obvious in the pollen concentration data (Fig. 6), to recover at 3.75 cm (89.1%, ca. AD 1848) with a corresponding drop in *Betula* (5.3%), *Salix* (0.2%) and Ericales (0.4%). Poaceae experiences an initial decline (0.8%, 10.75 cm, ca. AD 1559) but increases to values spanning 3.1% (6.75 cm, ca. AD 1718) to 11.8% (5.75 cm, ca. AD 1760), visible in the PCA (Fig. 8b). *Equisetum* increases to 26.8% (6.75 cm, ca. AD 1718) while *Lycopodium annotinum* (≤ 5.9%, 7.75 cm, ca. AD 1676) and Pteropsida (monolete) indet. (≤ 19.1%, 6.75 cm, ca. AD 1718) reach peak values, and according to the PCA (Fig. 8b), are associated with Poaceae. With regard to CFS, the signal becomes much stronger i.e. a consistent signal for *Sordaria*-type HdV 55a from 7 cm (AD 1707) with *Sporormiella*-type HdV 113 attaining values of 3% (6 cm, ca. AD 1750). Similarly, an ongoing increase in microscopic charcoal becomes more marked, peaking at 52.3% (5.75 cm, ca. AD 1760).

## Discussion

### Landnám at Helgadalur (ca. ad 723–1235)

The earliest samples from HEL (Fig. 3, from 43.25 cm, ca. AD 723) suggest a Cyperaceae dominated wetland incorporating other species and taxa such as *Betula*, *E. nigrum*, *Angelica* indet., *F. ulmaria* and *Sphagnum*. However, while Cyperaceae remains dominant, *Betula* displaces *E. nigrum*, *Angelica* indet. and *F. ulmaria* (41.25 cm, ca. AD 819) to become sub-dominant until Landnám (ca. AD 877). This may be linked to climate amelioration, the expansion of *Betula* dominated habitats a recognised feature of south west Iceland at this time (Erlendsson and Edwards 2009). Warmer summer temperatures may have lowered, or given rise to fluctuations in the water table due to lower precipitation and increased evaporation (Charman 2002). Such conditions could have been sufficient to encourage colonisation by *Betula*, which in itself would contribute further (through evapotranspiration) to the drying out of the mire (Berglund 1985). A notable reduction in *Sphagnum* values (Fig. 3,

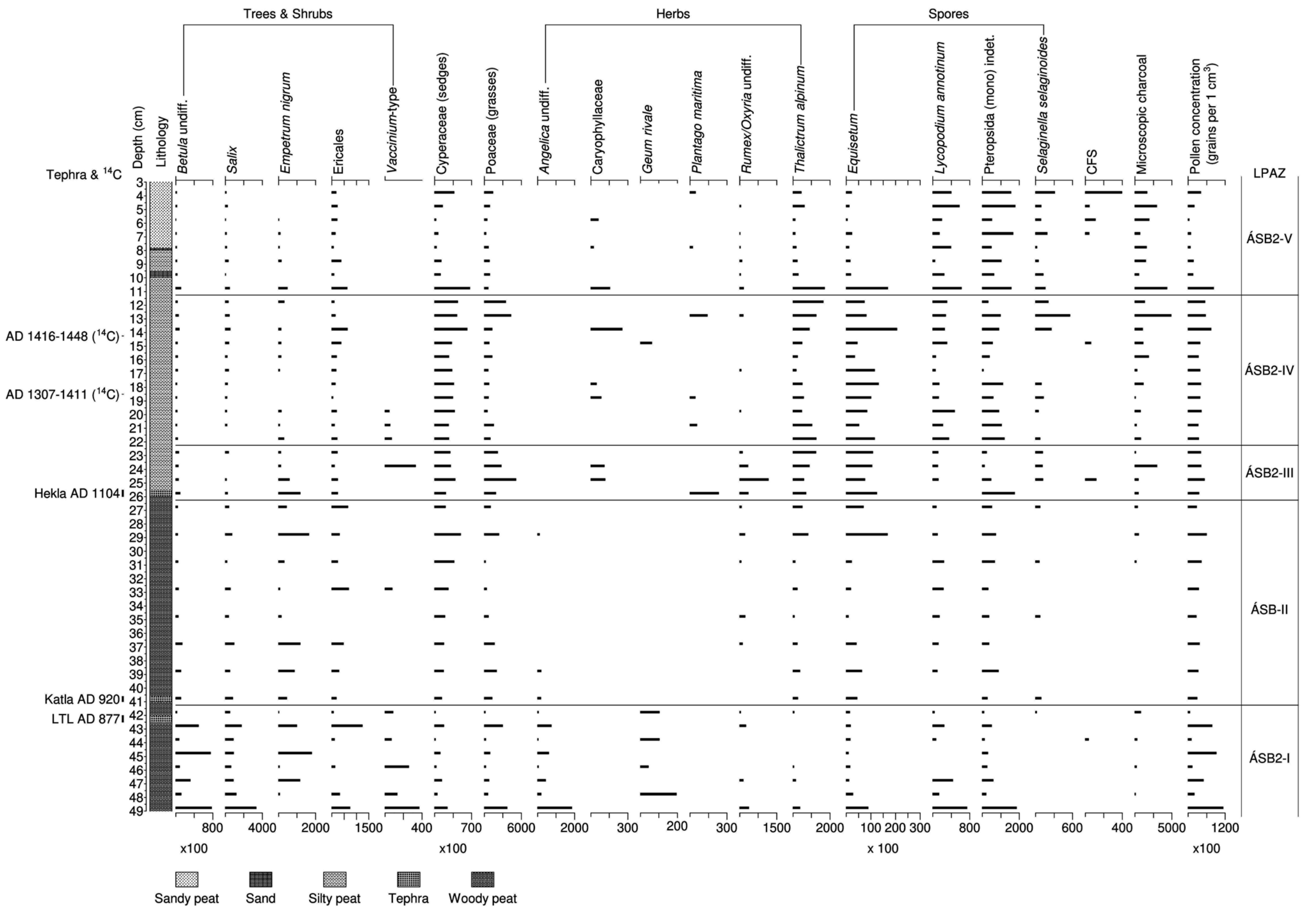

**Fig. 6** Pollen concentration diagram for ÁSB2, selected taxa and species ≥ 1% TLP

41.25 cm, ca. AD 819) reinforces the perception of a reduction in moisture in the mire. Nonetheless, the sedimentary context remains stable and organically rich (Fig. 7a, OM 72.5%, 42.50 cm, ca. AD 761). There are traces of microscopic charcoal (≤ 5%) present within the profile prior to the deposition of the LTL ca. AD 877 (Fig. 3). In the absence of other anthropogenic indicators, charcoal may be derived as windblown material from Europe (Duncan and Bey 2004) or, closer to home, residual charcoal arising from vegetation burnt during volcanic eruptions (Buckland et al. 1995).

From ca. AD 877, a Cyperaceae dominated wetland persists. However, species and taxa (Fig. 3) sensitive to grazing by livestock (as represented by *Sordaria*-type 55a CFS) e.g. *Betula*, *Salix*, *Angelica* and *F. ulmaria*, go into decline while values for Poaceae increase and the landscape is occupied by a new suite of plants that favour open terrain e.g. *P. maritima, Potentilla*-type, *Rumex/Oxyria*-type, *S. selaginoides* and Lycopodiaceae (Edwards et al. 2011). In hand with a drop in peak OM (Fig. 7a) values (independent of tephra deposition) between HEL I (72.4%) and HEL II (60.2%), the changes in the vegetation are indicative of a human presence within the landscape of Helgadalur (Hallsdóttir 1987; Erlendsson 2007; Edwards et al. 2021). In particular, raised values for *Th. alpinum* could indicate that land in the vicinity of HEL was being utilised as a wetland hay meadow (Fjordheim et al. 2018), an important feature of subsistence farming in medieval Iceland (Vésteinsson 1998–2001). The peak in microscopic charcoal ca. AD 1119 (Fig. 3, 56.1%, 31.50 cm) is probably associated with household activity (Buckland et al. 1995), a smokehouse, smithing/smelting (Eyþórsson et al. 2018), household waste dumped or spread as fertiliser (Riddell et al. 2018a), charcoal production (Church et al. 2007), or *sinubruni* (a tradition of burning plant litter in the spring, aimed at returning nutrients to the soil, thought to have begun in Iceland in the 20th century, but which may have arisen earlier).

## Transhumance or abandonment at Helgadalur … or just making hay? (ad 1235–1550)

There is now a more persistent signal for grassland (Poaceae) at Helgadalur (Fig. 3, HEL III and HEL IV) with levels remaining above 10% beyond AD 1500 (20–18 cm). This comes at the expense of Cyperaceae although it remains

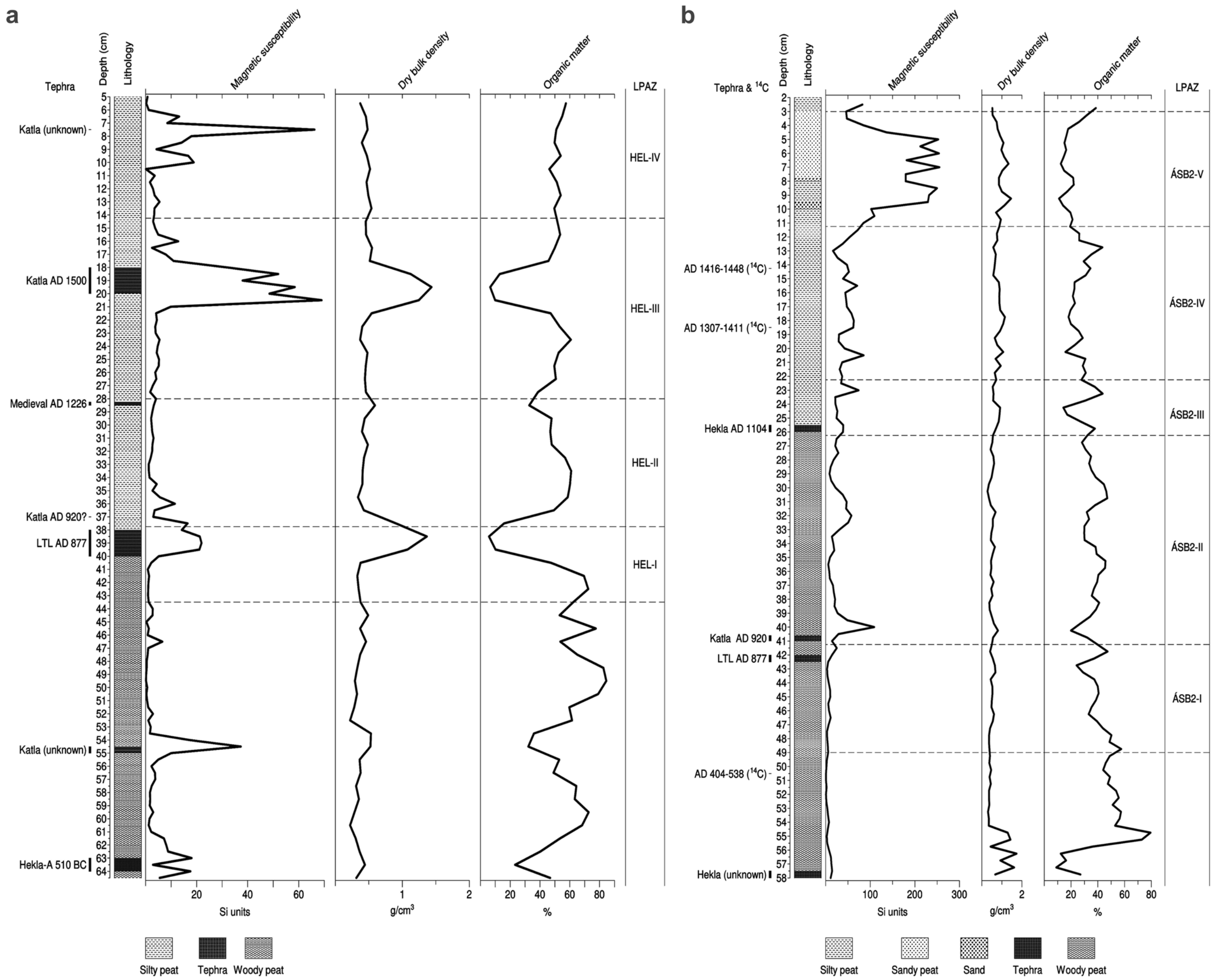


**Fig. 7** Sedimentary properties for HEL (**a**) and ÁSB2 (**b**)

the dominant vegetation. Though not entirely within the scope of this study, the pollen profile would suggest that the ongoing development of grassland is a primary feature of Helgadalur into the modern period (Fig. 3, HEL IV, 14.25–6 cm, AD 1616–1850). This would imply that land use is exclusively directed toward livestock grazing but sensitive species such as *Betula* and *Salix* persist along with phases of recovery in *Angelica* and *F. ulmaria*, while CFS values are low. The latter in particular might suggest periods of abandonment, seasonal grazing, or grazing at low livestock densities (Davies 2019). That microscopic charcoal is present (often at relatively high values) throughout the HEL (Fig. 3) sequence from Landnám runs counter to any interpretation concerning abandonment (Edwards et al. 2011). Therefore, one possibility is that Helgadalur periodically functioned as a *sel* (a shieling), a feature of seasonal transhumance (Lucas 2008; Kupiec et al. 2016). However, the CFS record for Helgadalur is rather poor throughout the sediment stratigraphy even though historical records identify animals there in the early 16th (DI-XII 1857–1986) and early 18th century (Magnússon and Vídalín 1926), while numbers were presumably even higher in the 19th and 20th centuries (Ross et al. 2016; Júlíusson 2020). CFS are extremely localised in terms of their dispersal, abundance bound by factors such as the duration of time livestock occupy an area as well as the size of the livestock population (Davies 2019). Perhaps the intermittent CFS record at Helgadalur is a consequence of the coring site being remote from the farmstead. Even so, it does suggest that the area within the landholding in which the HEL core lies was subject only to low density livestock grazing or periodic utilisation. This therefore reinforces the impression that HEL is situated within a wetland pasture reserved for haymaking, coincident with a persistent, post-Landnám, signal for *Th. alpinum* (Fig. 3, ≤ 13.1%,

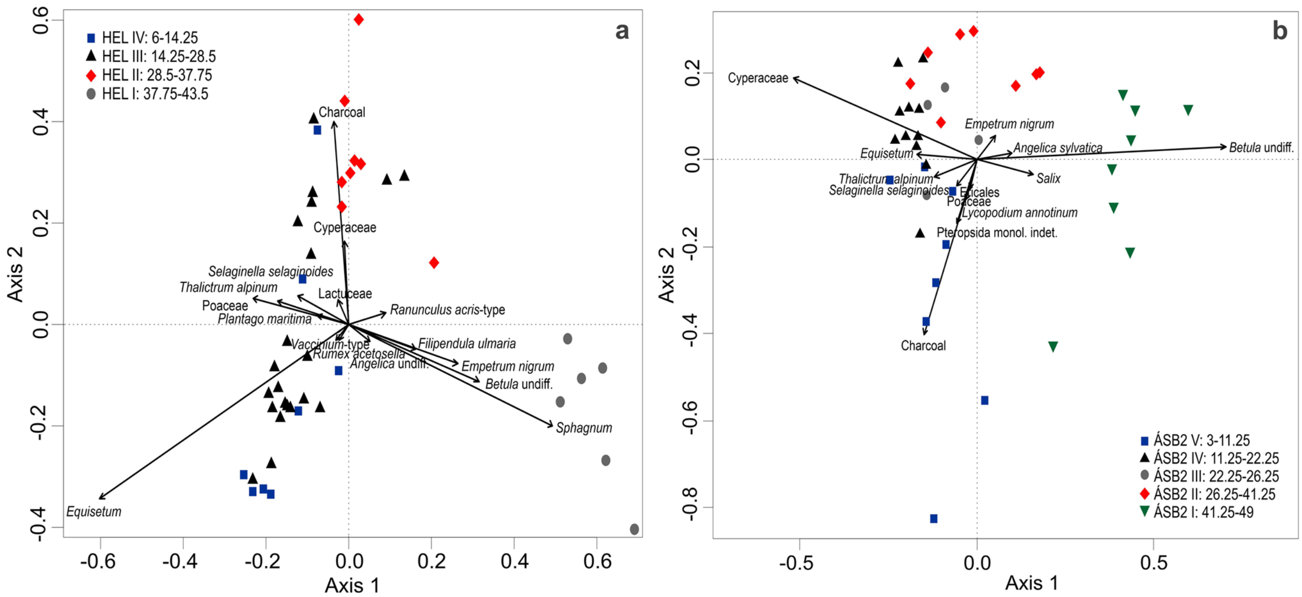


**Fig. 8** Principal Component Analysis (PCA) for HEL (**a**) and ÁSB2 (**b**)

27.75–20 cm, ca. AD 1243–1500), and explains the presence of grazing sensitive taxa and species like *Angelica* and *F. ulmaria*. The isolated peak in CFS (Fig. 3, 1.8%, 18.25 cm) associated with the Katla AD 1500 tephra layer might represent a temporary corralling of animals near HEL in response to the eruption (Edwards et al. 2004).

## Landnám at Ásbjarnarnes (ca. AD 877–1370)

Prior to Landnám (42.50–42 cm), vegetation cover at Ásbjarnarnes (Fig. 5) was dominated by *Betula* (between 59 and 82.6%) with Cyperaceae sub-dominant (between 11.2% and 28.8%). Sediments (Fig. 7b) remain unaltered following the deposition of the LTL (except for the AD 920 tephra layer, 41–40.60 cm) and while *Betula* (Fig. 5) values drop, this is gradual, and they remain above 7% through the 10th and into the 11th century. A brief pulse in microscopic charcoal values ca. AD 899 (Fig. 5, 14.9%, 41.75 cm) may represent an initial phase of human occupation but it is striking that microscopic charcoal is absent from the record from the early 10th century until the late 11th century, possibly allied with the albeit declining, but prevailing, presence of *Betula* in this period. The CFS signal is also very weak or non-existent for the medieval period as a whole and, as with Helgadalur, values may be subdued due to variables related to livestock abundance and/or distribution within the landholding (Davies 2019). That said, declines in grazing sensitive species and taxa e.g. *A. archangelica*, *A. sylvestris*, *F. ulmaria*, *Geum rivale*, *Parnassia palustris* and *Vaccinium*-type (Edwards et al. 2011) do occur following AD 920 (Fig. 5). Concurrently, we see an increase in values for Cyperaceae and Poaceae while the *Th. alpinum* signal is more consistent, implying the opening of a scrub/woodland canopy. With specific reference to the MS, DBD and OM data (Fig. 7b), following the deposition of the AD 1104 tephra (26 cm), a minerogenic element is introduced to a hitherto, exclusively (bar tephra deposits), peat dominated sequence. This is coincident with increased pollen values indicative of anthropogenic activity (Fig. 5) i.e. the stronger presence of apophytic taxa (Caryophyllaceae, *P. maritima*, *Rumex acetosa* and *R. acetosella*) microscopic charcoal, and CFS (especially after ca. AD 1370, 16.75 cm). Sedimentary changes occurring in the early 12th century may therefore relate to the inception of erosion on the higher ground of Ásbjarnarnes in the vicinity of ÁSB2, perhaps a consequence of livestock grazing cf. Dugmore et al. (2009) and Gísladóttir et al. (2010); it is too early to attribute this to the onset of the LIA (Ogilvie and Jónsson 2001).

Overall, despite references to Ásbjarnarnes in the quasi-historical texts (Friðriksson and Vésteinsson 2003; Woolf 2007) of Landnámabók (Pálsson and Edwards 1972) and Laxdæla saga (Sveinsson 1934), ostensibly accounts of the Icelandic settlement, it would appear that the arrival of humankind at Ásbjarnarnes in the late 9th century was somewhat muted; a feature comparable with other sites in northern Iceland (Lawson et al. 2007; Riddell et al. 2018b; Roy et al. 2018; Tisdall et al. 2018). It has been mooted that active scrub/woodland clearance was deliberately avoided by early settlers as too labour intensive (Vickers et al. 2011), while it has also been suggested that early settlers utilised coastal sites like Ásbjarnarnes only as a beachhead before moving inland to settle permanently (Smith 1995), which may explain the limited palaeoecological indication of human settlement there. Perhaps, if saga narratives are to be believed, Ásbjarnarnes was inhabited but the initial focus during this period was predicated upon shore rights and access to driftwood, sealing, whale wrecks and fishing as testified to by later 14th (DI-II 1857–1986; DI-III 1857–1986) and 15th (DI-V 1857–1986) century documents. This would not preclude the exploitation of terrestrial resources, but subsistence might not have been entirely dependent upon them. Therefore, based on the close proximity between ÁSB2 and the farmstead (and the premise that ÁSB2 is capturing a local palynomorph signal), from Landnám until the early 12th century, Ásbjarnarnes seems to have been largely uninhabited or utilised only for low-density livestock grazing, perhaps seasonally e.g. winter grazing and shelter (Hejcman et al. 2016). Indeed, it is only from the early 13th century (Fig. 5, 22.25 cm, ca. AD 1205) that the series of anthropogenic proxies intimating tree and shrub clearance become contemporaneous i.e. Cyperaceae has finally become consistently dominant, apophytes persist, and the charcoal signal is increasingly constant and stronger (although the CFS signal remains sparse).

## Woodland, coppice and charcoal at Ásbjarnarnes (AD 1361–1600)

In AD 1361, the deed pertaining to the sale of Ásbjarnarnes to Þingeyraklaustur describes an extensive area of "*skog*" (woodland) in the list of resources attached to the farm (DI-III 1857–1986). The description is not entirely clear with regard to area but states that this woodland extended from Hóp westwards across Bjargaás (ca. 2 km; Fig. 1). A later document from AD 1669 identifies the woodland at Ásbjarnarnes as "Nesskógur", the only record of its name, with its exact location and extent unknown (Þorsteinsson 1922–1932). In AD 1705, statements in Jarðabók (Magnússon and Vídalín 1926), clearly distinguishing between woodland, trees and shrubs, also convey that a woodland existed at Ásbjarnarnes down to the mid-17th century. Based upon these historical references to woodland, it may be inferred that a proportion of the *Betula* pollen grains present in the palynological record for ÁSB2 (Fig. 5) is comprised of *B. pubescens*. Woodland in Iceland was seen as an important source of timber (rafters), wood fuel, charcoal (iron smelting and smithing), leaf fodder, winter grazing and shelter for livestock (Magnússon and Vídalín 1926; Vésteinsson and Simpson 2001; Church et al. 2007; Hejcman et al. 2016); clear incentives to nurture woodlands.

*Betula* values increase slightly from ca. AD 1370 (Fig. 5, 2%, 16.75 cm) and stabilise (around 10%) in the late 15th century (12.75 cm, ca. AD 1489), the period within which Ásbjarnarnes was subject to Þingeyrarklaustur. This might infer greater rigour imposed by the monastery with regard to managing woodland more sustainably. However, Þingeyrarklaustur did suffer from the depredations of Plague (Riddell et al. 2018b), especially during the earlier outbreak of AD 1402, perhaps allowing scrub there to recover as observed elsewhere in Europe (van Hoof et al. 2006; Yeloff and van Geel 2007; Jónsson 2009). The same may apply at Ásbjarnarnes, although coincident increases in microscopic charcoal values suggest that people remained there. Some Icelandic farms were untouched by plague (Karlsson 1996; Júlíusson 1997) and *Betula* recovery in the 15th century could actually represent altered land management practices in response to plague and human demographics rather than outright abandonment (Streeter et al. 2012).

In a 16th century inventory (DI-XII 1857–1986), Ásbjarnarnes is conspicuous in that it is the only tenant farm of 62 that pays a portion of its rent to Þingeyraklaustur with charcoal (Júlíusson 2014). Charcoal production was also a feature of Ásbjarnarnes in the late 17th century (Magnússon and Vídalín 1926). Given that a charcoal signal at Ásbjarnarnes is consistent from the late 11th century (26.75 cm, ca. AD 1091), in hand with a persistent *Betula* signal, it is possible that charcoal production was an established practice there (bearing in mind that microscopic charcoal as a palynomorph can be derived from other sources in Iceland e.g. volcanism, household smoke, household waste and *sinubruni*). If so, this implies that charcoal production was simply a matter of continuity following the acquisition of Ásbjarnarnes by Þingeyraklaustur although, tentatively, charcoal production may have increased (≤ 8.7%) in terms of output ca. AD 1398–1523 (Fig. 5, 15.75–11.75 cm). Some impact upon *Betula* values would perhaps be expected in relation to the charcoal signal. However, there is none. It has been speculated that some form of coppicing may have been practiced in Iceland in the medieval period (Church et al. 2007); *Betula pubescens* in Iceland is capable of sprouting new shoots from cut stumps which could sustain *Betula* pollen values. It is conjecture, but this may not have necessarily occurred as a conventional coppice rotation (Rackham 1980); coppicing may have been ad hoc at Ásbjarnarnes, with individual trees rather than swathes selected for felling, stool regeneration occurring by default rather than by design, with intervals between harvests longer. This could shroud the removal of trees in terms of *Betula* pollen values and the expected oscillation of said values between the coppice cut and regrowth. That said, the impact of coppicing on *B. pubescens* pollen production in Iceland is unknown, and is poorly understood elsewhere (Bunting et al. 2016). Whatever the case, the fact is that *Betula* persisted at Ásbjarnarnes despite the production of charcoal there, either through limited harvesting, natural regeneration, or coppice stool regrowth. Combined with the limited evidence for the presence of domestic livestock, woodland at Ásbjarnarnes was likely a valued natural resource in the medieval period, as is intimated by the historical archive for AD 1361 (DI-III 1857–1986) and AD 1552 (DI-XII 1857–1986). As an aside, given historical references to it at Ásbjarnarnes (DI-III 1857–1986), driftwood was rarely used as a source of fuel in medieval Iceland and was valued more as a source of timber (Mooney 2018). Beyond the period and context under scrutiny, the survival of woodland at Ásbjarnarnes (Fig. 5, ÁSB2 V, 11.25–3 cm, AD 1541–1882) into the modern period is notable, as is the later disturbance (minerogenic input) manifest in the sediments (Fig. 7b).

### Pollen sources for HEL and ÁSB2

It is possible to be reasonably confident that the pre-Landnám pollen assemblages of HEL (Fig. 3) and ÁSB2 (Fig. 5) reflect the local vegetation within (and surrounding) the wetlands sampled. Pollen dispersal over large distances at this time would have been inhibited by greater woodland cover (Berglund 1985; Caseldine 2001; Edwards et al. 2021) and source areas for reworked pollen grains were likely restricted to the active volcanic zone (Möckel et al. 2017) and glacial outwash plains (both some distance from HEL and ÁSB2). Following Landnám, the development of a more open landscape enhances the capacity for pollen to arrive at HEL and ÁSB2 from farther afield (Berglund 1985); not least with regard to *Betula* (Rymer 1973; Eddudóttir et al. 2016). Furthermore, high values for *Betula* pollen grains and Pteropsida (monolete) indet. spores in pollen stratigraphies in Iceland have been associated with the aeolian reworking of sediments (Gathorne-Hardy et al. 2009) disturbed by anthropogenic activity. This may apply to both HEL and ÁSB2. However, there is nothing in the sedimentary record to suggest any significant influx of eroded materials at HEL (Fig. 7a) outwith volcanic ash deposits, while at ÁSB2 (with regard to *Betula*), woodland is a persistent feature of the historical archive (DI-III 1857–1986; Magnússon and Vídalín 1926; Þorsteinsson 1922–1932) between the 14th and 17th century. While it is feasible that pollen originating from overseas can arrive in Iceland (Duncan and Bey 2004; Varga et al. 2021), this is not thought to be significant with regard to interpreting Icelandic pollen profiles (Hättestrand et al. 2008), borne out here by the very limited presence of exotic taxa at HEL and ÁSB2 (Figs. 3 and 5).

## Conclusions

The early phases of both HEL and ÁSB2 provide insights into what is effectively a prehistoric period in Iceland (Friðriksson and Vésteinsson 2003). Landnám is visible palaeoecologically at both locations but there is variation in the magnitude of anthropogenic impact, consistent with palynological findings from elsewhere in Iceland as shown by e.g. Riddell et al. (2018a) and Streeter et al. (2015). At HEL, we see a pre-Landnám transition from wetland to woodland to post-Landnám pasture. This hysteresis (Hallsdóttir 1987) is apparent in the sediment stratigraphy (OM), the decline in grazing sensitive plant species, the increase in apophytic plant species, and the presence of CFS. Overall, the medieval period for HEL was focussed upon the development of a hayfield, although some of the palynological attributes attached to the latter could be a consequence of low density and/or seasonal grazing. Significantly, there is no evidence that Viðeyjarklaustur was exerting any direct influence over land management practices at Helgadalur.

The pre-Landnám context at ÁSB2 is of a *Betula* dominated scrub/woodland. The arrival of people at Ásbjarnarnes ca. AD 877 is quite muted in comparison with HEL with no change in sediments and only a gradual decline in *Betula* cover. In fact, it is not until ca. AD 920 that we start to see any real decline in grazing sensitive species and taxa, and although apophytes are present, there is no increase in their range or values until ca. AD 1104 (also in association with sedimentary changes). Overall, human occupation and exploitation of resources at Ásbjarnarnes is gradual; while the environmental proxies for human activity are always present, it is only in the early 13th century that they represent a coherent signal. Analysis of palaeoecological data, in hand with historical documents, suggests that a *B. pubescens* woodland survived at Ábjarnarnes more or less throughout the medieval period and that this may have been linked to charcoal production. There is a very slight possibility that woodland was conserved at Ásbjarnarnes, (with a concomitant increase in charcoal production) once it fell under the aegis of Þingeyraklaustur, but this is inconclusive.

The simplest interpretation of the palaeoecological datasets presented here is that medieval tenancies in Iceland were largely unaffected ecologically by absorption into a manorial system overseen by monasticism. There is neither conclusive evidence of alteration and/or intensification of resource exploitation or grazing, nor is there any evidence of new plant species being introduced at the behest of a monastery (e.g. no Poaceae pollen grains characteristic of cereal-type were identified at either site). These findings might suggest that the respective monastic houses oversaw their tenants' activities with a minimum of investment beyond ensuring rents and tithes were met and that the agricultural innovations of European monasticism were perhaps only restricted to the immediate vicinity of the cloister. However, it is important to bear in mind that opportunities for diversification or alternative agricultural strategies at Helgadalur were limited by daily and seasonal daylight hours. At Ásbjarnarnes the resource focus may have been directed more toward the ocean. Perhaps neither Helgadalur nor Ásbjarnarnes are necessarily representative of monastic tenancies, they are but two properties of the ca. 120 tenancies shared between the monasteries of Viðeyjarklaustur and Þingeyraklaustur. It is however important to bear in mind that nuance concerning phyto-social contexts may be obscured due to the low values for non-Cyperaceae pollen types (Caseldine and Hatton 1994) in the pollen samples. Furthermore, with regard to Helgadalur in particular, the coring site is relatively distant from the farmstead, the centre of human activity within that landholding. Therefore, further palaeoecological evaluation of tenant farms may be required in order to consider more conclusively the influence of both ecclesiastical (and secular) manorial systems on land ownership and land use in medieval Iceland.

**Supplementary Information** The online version contains supplementary material available at https://doi.org/10.1007/s00334-021-00861-y.

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