1 **A hut on the hill: a multi-proxy microbotanical and micro-algae approach to a Pictish roundhouse**
2 **floor at Cairnmore, Aberdeenshire.**
3
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11
12 <u>**Abstract**</u>
13 *Early medieval architecture is notably difficult to trace in northern Britain. The fortuitous survival of an*
14 *intact floor of a building located just outside a ringfort at Cairnmore, a high-status early medieval*
15 *ringfort enclosure in Aberdeenshire, Northeast Scotland, allowed the targeted deployment of a*
16 *paleoethnobotanical approach that utilized microbotanical (i.e., phytoliths) and micro-algae residues*
17 *(e.g., diatom frustules) to illuminate the character of the unusual survival of an early medieval building in*
18 *Scotland. This research revealed novel data on the architecture of the early medieval roundhouse floor in*
19 *this poorly documented region and era for settlement remains, securely identifying the use of turf for*
20 *walling in an early medieval lowland building. Evidence for roofing material was also preserved in the*
21 *phytolith signature. Moreover, the microbotanical assemblage from Cairnmore was found to represent a*
22 *use of a variety of ecological niches providing important evidence for landscape use. The presence (and*
23 *absence) of particular microbotanical indicators also allowed interpretation of the possible uses of the*
24 *structure. The results from this research demonstrate that microbotanical approaches can be critical in*
25 *understanding architecture in regions where settlement survival is poor, highlighting the merits of*
26 *microbotanical and micro-algae analyses in northern environments. The article concludes by advocating*
27 *for the in-tandem assessment of these proxies in archaeological investigations where macrobotanical and*
28 *other organic residues are poorly preserved.*
29
30 <u>**Keywords**</u>: paleoethnobotany, phytolith, floor layer, Pictland, diatom
31
32 <u>**Introduction**</u>
33 Paleoethnobotanical approaches to archaeological deposits have provided valuable insights into how
34 people in the past interacted with plant communities. Several recent studies have demonstrated the value
35 of these approaches to illuminate past landscapes, foodways, and spatial activities (e.g., Borderie et al.
36 2020; Dal Corso et al. 2017; Juhola et al. 2019; Wade et al. 2021). Within northern British archaeological
37 contexts, highly acidic soil conditions along with later land use (Ralston 1997; Hunter 2007:48–50; Noble
38 et al. 2019ba; Noble et al. 2020:328) often inhibit the preservation of macrobotanical residues, floors,
39 artifacts and structural remains, leading to poor understanding of settlement and early landscape use.
40 These limitations are particularly evident for early medieval Scotland where our knowledge of
41 architectural traditions is notably limited (Ralston 1997:24; Noble et al. 2020:320, 327–328). While in
42 Scotland handfuls of early medieval structures are known in lowland contexts, in neighbouring areas such
43 as early medieval Ireland or England, tens of thousands of sites are known (e.g., Hamerow 1993, 2012;
44 O'Sullivan 2008, O'Sullivan et al. 2014:47–138; Carver 2019:139–303). Thus, in areas where settlement
45 remains are sparse, such as Scotland, our knowledge of architecture is notably deficient compared to that
46 of contemporary nearby cultural groups. For early medieval Scotland, the dearth in settlement architecture
47 may have partly been due to a shift towards using material such as turf, and architectural traditions where
48 earth-fast structural elements were less common in the late and post-Roman era, though these
49 assumptions are often based on absence of evidence rather than direct attestation (Ralston 1997:24; Noble
50 et al. 2020:320, 327–328).

51   Where preservation is poor, microbotanical methods can provide crucial insights into settlement
52 traditions where other evidence is lacking. Microbotanical analyses target more durable residues such as
53 phytoliths (plant microfossils), and such analyses are often effective where macrobotanical remains (such
54 as seeds) are limited in the archaeological record (Pearsall 2015:253; Piperno 2006:1; Shillito 2013:72).
55 This study shows the efficacy of procuring phytoliths and other durable microstructures (e.g., diatom
56 frustules) from archaeological deposits in challenging preservation contexts – such as within a floor layer
57 from an early medieval site in northeast Scotland.
58   Phytoliths and diatom frustules are microfossils composed of biogenic silica, and the morphology
59 of these silicious cell walls can be taxonomically diagnostic (Pearsall 2015:253; Piperno 2006; Smol and
60 Stoermer 2010; Stone and Yost 2020). Microscopic algae are often present in archaeological samples that
61 target phytoliths and other microbotanical structures; however, these microscopic residues are rarely
62 examined together in archaeological investigations (e.g., Vuorela et al. 1996). Other types of multi-proxy
63 archaeological approaches, often termed "piggy-back" approaches, have targeted phytoliths, starch grains,
64 calcareous spherulites and other microscopic residues together (Canti and Nicosia 2018:32; Portillo and
65 Albert 2011), but diatoms and other micro-algae are rarely incorporated into these studies beyond a count
66 of specimens present in archaeological samples (Stone and Yost 2020:23). This hesitancy toward
67 targeting diatoms and other micro-algae specimens in archaeological investigations is presumably a
68 response to the skill required for accurate identification of these silicious microstructures as diatom
69 species are incredibly diverse (Battarbee 1988; Stone and Yost 2020:23). However, like phytoliths,
70 diatoms can provide detailed information about their environmental contexts when retrieved from *in situ*
71 archaeological deposits (Juggins and Cameron 2010; Mannion 1987; Smol and Stoermer 2010:3). The
72 presence of diatom residues (i.e., frustules) allows archaeologists to investigate the aquatic and semi-
73 aquatic components of human-environment relationships, such as the collection and movement of aquatic
74 and semi-aquatic resources (e.g., turf, drinking water, clay, etc.) (Beneš et al. 2022; Flower 2006; Hill et
75 al. 2019; Juggins and Cameron 2010; Rippon 2000).
76
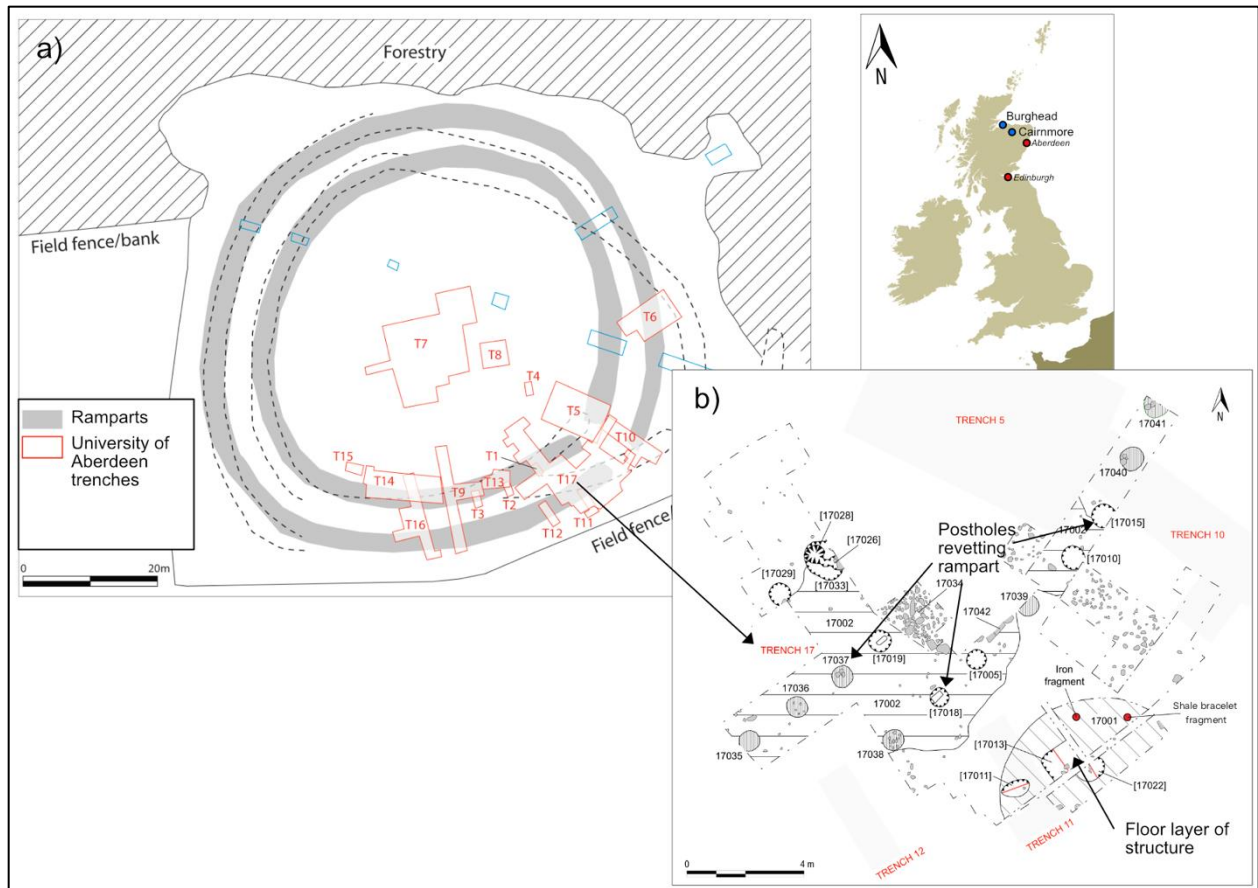
Figure 1. Location of Cairnmore (Aberdeenshire, Scotland) and contemporaneous site Burghead, both located to the west of the city of Aberdeen; a) plan of the double-walled ringfort at Cairnmore with b) small roundhouse structure located just outside the outermost rampart (the structure is the subject of analysis of this article).

Cairnmore, Scotland

In this article we assess phytoliths, diatom frustules, and chrysophycean cysts procured from a single roundhouse floor layer within the complex at Cairnmore (Aberdeenshire, Scotland). Cairnmore is an unusual and rare complex bivallate fort that overlooks the Upper Strathbogie Valley, where at Rhynie, a high status early medieval settlement enclosure, metalworking area, and cemetery have been found over the course of six seasons of excavation (Noble et al. 2019b). Cairnmore sits on the shoulder of a hill and comprises two rubble rampart walls that were strengthened by a complex post revetment (Noble et al. 2019c; Noble et al. 2019c). At both Rhynie and Cairnmore, settlement remains were poorly represented in the centre of the settlements where later cultivation had removed the majority of floor layers. These later agricultural activities left behind only fragmentary postholes and other architectural features, as is the case with nearly all lowland early medieval settlements in eastern Scotland (Ralston 1997). However, at Cairnmore the collapse of the outer ramparts had fortuitously preserved the floor layer of a better preserved structure, located beside the outermost enclosure wall (Fig. 1). This building survived under extensive stone spread from rampart decay and was located abutting the outermost rampart wall.

The floor layer for the structure comprised a deposit over 6 m in diameter and up to 0.12 m thick (Fig.1 & 2) and consisted of a dark brown clayey silt with burnt bone and charcoal incorporated throughout the deposit (Noble et al. 2022). The floor layer appeared to form part of a circular roundhouse structure, though only one part of the floor was excavated as the rest underlay or was truncated by a later

102 stone boundary wall. A small number of artifacts were recovered from the floor layer, including a
103 fragment of a shale bracelet and a small iron object (Fig. 1). Three pit features were present within the
104 floor layer, potentially representing hearths (Noble et al. 2022). Macrobotanical remains included
105 charcoal fragments of oak (*Quercus* sp.) and birch (*Betula* sp.), along with charred plant seeds from black
106 mustard (*Brassica nigra*), ribwort plantain (*Plantago lanceolata*) and sedges (*Carex* sp.) (Niehaus 2021).
107 No structural features such as postholes or evidence of roofing were preserved to give any indication of
108 the appearance or form of the building. Radiocarbon dating suggests the floor layer is of 5th – 6th century
109 AD date, and was therefore contemporary with the ringfort settlement, the dates for which span the 5th to
110 7th centuries AD.
111   The objectives of this paleoethnobotanical study were to 1) evaluate the effectiveness of
112 microbotanical analysis for archaeological investigations in areas where these techniques have rarely been
113 attempted such as Scotland, 2) assess if this microbotanical assemblage could address the nature of the
114 Cairnmore structure and illuminate the architectural details of a rare roundhouse building in a region with
115 a very limited settlement record, and 3) assess the spatialization of activities within the building and wider
116 landscape use (both terrestrial and aquatic environments).
117
118 **<u>Material and methods</u>**
119 The paleoethnobotanical approach for this study was oriented to address the often shallow (e.g., < 0.3 m)
120 archaeological deposits at Pictish sites and to interpret the spatial deposition of microarchaeological
121 residues from the roundhouse. The sampling and laboratory procedures outlined below follow standard
122 protocols for phytolith analysis and were successful in isolating microbotanical and micro-algae
123 specimens.
124
125 *Sampling*
126 Twenty-one samples were taken from the floor layer using a horizontal sampling technique and "pinch"
127 sampling method (Fig. 2 & 3). Horizontal sampling allows for variation in plant taxa to be seen more
128 clearly and can be used to identify activity areas and assess architectural features (Lennstrom and Hastorf
129 1992; Pearsall 2015:275). The floor area was sampled by establishing a 1 m x 1 m sampling grid and the
130 "pinch" sampling method was employed for each unit within the grid. Several pinches of sediment (~ 1
131 Tbsp each) were taken within and across each unit which created a composite sample that amounted to
132 approximately 200 grams from each unit. Two samples were procured from areas believed to be outside
133 the floor layer context (samples 18 and 21) to examine 'natural' signatures of microbotanical and
134 microalgae residues for comparison with the floor layer.
135
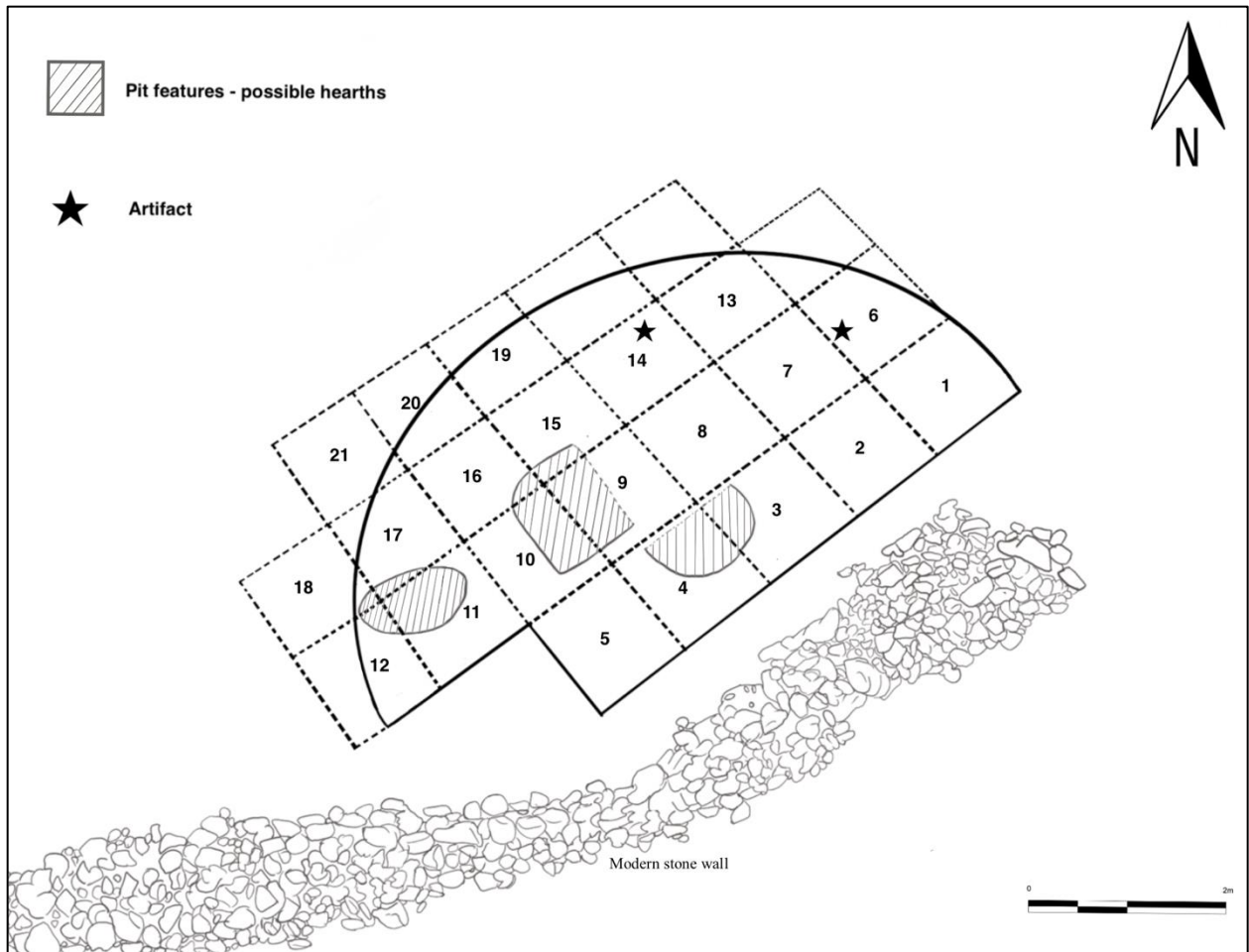
136
137 Figure 2. Pinch sampling grid and sample numbers of the roundhouse floor context
138
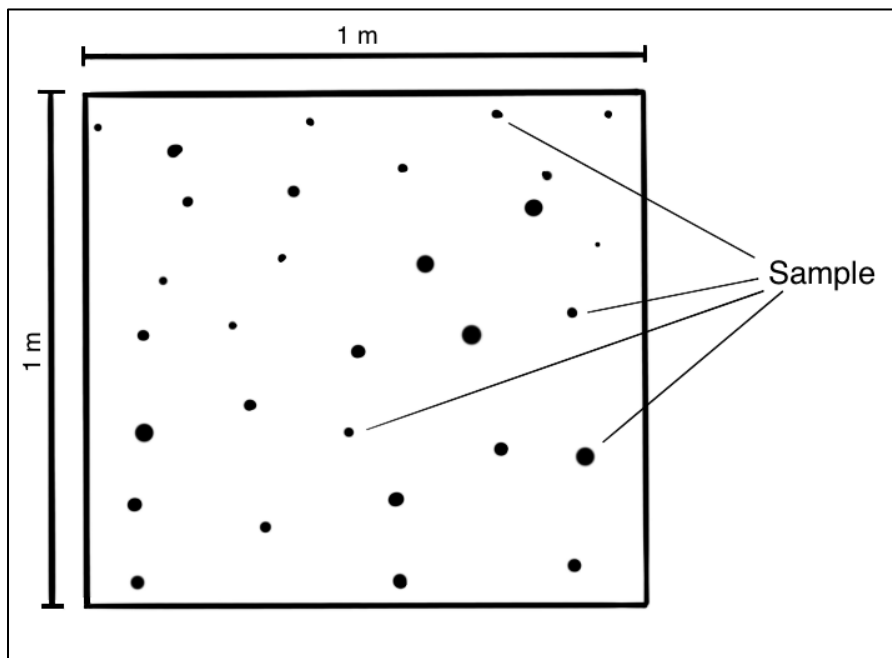
139
140 Figure 3. Pinch sampling diagram

141
142 *Laboratory Processing*
143 Samples were sent to the McMaster Paleoethnobotanical Research Facility (MPERF) where they were
144 processed following MPERF protocols for extracting phytoliths from sediments (Piperno 2006; Morell-
145 Hart 2018). This process involves soil sterilization, deflocculating samples in water, dividing soils into
146 A/B and S fractions, clay removal, microwave chemical digestion and flotation of phytoliths. For the
147 Cairnmore context, processing took twenty-six days for the batch of 21 samples.
148   As the samples were processed outside of Scotland, soils were first sterilized in a muffle furnace
149 at 200 degrees Celsius for six hours to remove the risk of soil borne-contamination. The samples were
150 then transferred to 1000mL beakers, and 2 Tbsp of sodium bicarbonate was added, then beakers were
151 filled with hot water and stirred every 15 minutes to break up clumps of soil. Next, the samples were
152 divided into sand (S), larger sediments (D) and fine/coarse sediments (A/B) using U.S.A. Standard
153 Testing sieves No. 35, No. 60, No. 270, and base pan. S fractions were collected from sieve No. 270 into
154 50mL centrifuge tubes, and A/B fractions from the base pan were each transferred to a 1000mL beaker.
155 These A/B fractions required a clay removal step and so the samples were stirred, allowed to sit for one
156 hour, slowly poured off the upper 400mL, re-added hot water, then repeated until the water was clear of
157 suspended clay for all samples. Once clear, the A/B samples were transferred to 50mL centrifuge tubes.
158   Samples were centrifuged for 5 minutes at 1000rpm to concentrate the sample at the base of the
159 centrifuge tube, and excess water was poured off, leaving a damp sediment plug in the tube. Ten grams of
160 each sediment plug was weighed into 600mL beakers for the chemical digestion process, using 3mL of
161 hydrochloric acid (10% aqueous solution), 5mL of nitric acid (68 –70% aqueous solution) and 1mL of
162 hydrogen peroxide (30% aqueous solution). Once all three chemicals were added, samples were
163 transferred to microwave vessel tubes and heated in the MARS 6 microwave digestion system for 130
164 minutes. Samples were allowed to sit in the microwave overnight after processing, then transferred from
165 microwave tubes into 50mL centrifuge tubes and centrifuged at 3000rpm for 5 minutes. The chemical
166 supernatant from each tube was poured off, then samples were subject to two rinses using ultra-pure
167 water.
168   Following chemical digestion and rinsing, the samples were floated using heavy liquid (sodium
169 polytungstate solution). This solution was added to each 50mL centrifuge tube sample, agitated, then
170 centrifuged for 5 minutes at 1000rpm to allow phytoliths to rise to the surface of the tube. Phytoliths were
171 extracted using a pipet to skim the surface of each sample and transferred to a 15mL centrifuge tube. This
172 process was repeated for two extractions total from each sample. The samples were then isolated by
173 removing the heavy liquid by filling the 15mL tube with ultra-pure water, centrifuged for 10 minutes at
174 1000 rpm and poured off. This process was repeated for a total of three washes until the sample was clear.
175 After the final pour off, approximately 3mL of acetone was added to the sample, centrifuged for 10
176 minutes at 1500rpm and poured off. Samples were uncapped, covered with parafilm, and placed under a
177 fume hood for one week to dry completely. Once dry, the samples were mounted onto glass microscope
178 slides using a pipet, covered with 1–3 drops of immersion oil and a glass coverslip.
179
180 *Analyses*
181 Tabulation and analysis were conducted at the MPERF using a Zeiss microscope for transmitted light
182 microscopy (200x, 400x and 630x magnifications). Primary analysis involved identifying and tabulating
183 diagnostic phytolith morphotypes to a minimum of 200 counts per sample (A/B and S fractions)
184 following recommended practice (Albert et al. 1999; Albert and Weiner 2001; Pearsall 2015).
185 Morphotypes were identified using the International Code for Phytolith Nomenclature (ICPN) 1.0 and 2.0
186 when possible (Madella et al. 2005; Neumann et al. 2019). Micro-algae such as diatoms and chrysophytes
187 were counted separately (although synchronously) from the phytoliths, and were tentatively identified
188 using ICPN 2.0, Jüttner et al. (2022), Spaulding et al. (2022) and Stone and Yost (2020).
189   Secondary analyses included calculating 1) the relative prominence of ecological indicators (e.g.,
190 wetland taxa), 2) the relative prominence of human activities (e.g., grain processing), 3) the ubiquity of

191 major plant groups (e.g., monocots and dicots) and micro-algae, and 4) the richness of plant taxa within
192 the roundhouse floor layer. All secondary analyses were carried out using Excel pivot tables.
193
194 **Results**
195 *Microbotanical results*
196
197 The procedure for extracting phytoliths from archaeological soil samples successfully isolated phytoliths,
198 diatoms, chrysophycean cysts, and microcharcoal from the Cairnmore roundhouse. Some phytoliths
199 appeared partially dissolved or weathered which likely reflects the acidic soil conditions. Degraded
200 phytoliths were not counted, but many were of the elongate entire and scutiform morphotypes.
201 Monocotyledonous plant taxa, which germinate with a single embryonic leaf (typical of grasses), were the
202 most commonly represented in all of the samples and phytoliths from the grass family (Poaceae) had the
203 highest total counts for this assemblage. This is unsurprising as the grass family is known as one of the
204 highest producers of phytoliths (Delhon 2010; Delhon et al. 2020:231; Morell-Hart 2019:236; Twiss
205 1992). Within this sampling context the Panicoideae (characteristically xerophytic – thriving in dry
206 environments) (Morell-Hart 2019:236) and Pooideae (characteristically temperate – consisting of pasture
207 and cereal grasses) subfamilies of the grass family are the most prominent, with rarer occurrences of
208 likely Arundinoideae (as evidenced by the bulliform morphotype). The Chlorideae subfamily may also be
209 represented by these bulliform specimens; however, Arundinoideae is more likely given the climate and
210 plant communities known for this region. Overall, the grass family is represented at Cairnmore through
211 bilobate, polylobate, trapeziform, and elongate morphotypes (Fig. 4). Phytoliths representative of cereal
212 inflorescence bracts (i.e., elongate dendritic and papillae phytoliths) were also recovered in trace
213 quantities (see discussion). Sedge family (Cyperaceae) cones were occasionally identified, indicating the
214 presence of sedges (Carnelli et al. 2004: 51; Morris et al. 2009; Ollendorf 1992) and occasional acicular
215 morphotypes appear very similar to those present in common club-rush (*Schoenoplectus lacustris*) (Fig.
216 5). The presence of sedges can be used to infer resource procurement from wetland ecological niche
217 zones as these plants thrive in areas with wet and inundated soils.
218   Dicotyledonous morphotypes (representing plants that germinate with two embryonic leaves)
219 such as opaque perforated plates were also frequent within the roundhouse floor context, and likely
220 indicated the aster family (Asteraceae) (Fig. 4 G-H). However, several perforated plate morphotypes also
221 resemble the heather family (Ericaceae) forms identified by Carnelli et al. (2004) and others appear
222 similar to vascular tissues, potentially from tubers (Fig. 4I). Research on phytolith production in the
223 Ericaceae family is limited (e.g., Bujan 2013; Thorn 2006), and further investigations should focus on
224 identifying diagnostic morphotypes for this family of plants. This would be especially useful for northern
225 European phytolith research as this family of plants is well represented in temperate European
226 environments and within Scotland specifically (e.g., *Calluna vulgaris*). Lastly, tabular and spheroid
227 morphotypes were also present in the floor layer and these morphotypes were counted as dicot specimens
228 (Albert et al. 1999; Danu et al. 2020:7; Delhon et al. 2020:232). Overall, dicotyledonous morphotypes
229 were less represented in the floor layer than monocotyledonous morphotypes; however, this follows the
230 general pattern observed in archaeological investigations (Carnelli et al. 2004; Dal Corso et al. 2017:15;
231 Tsartsidou et al. 2007).
232

Sample / Unit	Fraction	Floor Context	Identified morphotypes	Phytolith count	Diatom count	Chrysophyte count
1	A/B	north east wall edge	11	102	15	142
1	S	north east wall edge	7	200	2	31
2	A/B	north east floor area	7	100	10	160

Sample / Unit	Fraction	Floor Context	Identified morphotypes	Phytolith count	Diatom count	Chrysophyte count
2	S	north east floor area	12	108	7	60
3	A/B	central floor area & hearth/pit feature	8	169	3	0
3	S	central floor area & hearth/pit feature	9	100	5	48
4	A/B	central floor area & hearth/pit feature	9	136	5	22
4	S	central floor area & hearth/pit feature	7	142	3	25
5	A/B	central floor area	6	182	8	49
5	S	central floor area	9	107	3	41
6	A/B	north east wall edge	12	102	0	199
6	S	north east wall edge	9	102	0	26
7	A/B	north east floor area	6	100	2	90
7	S	north east floor area	6	104	2	62
8	A/B	central floor area	10	100	12	89
8	S	central floor area	11	101	3	19
9	A/B	central floor area & hearth/pit feature	5	134	3	70
9	S	central floor area & hearth/pit feature	8	104	8	85
10	A/B	central floor area & hearth/pit feature	8	100	12	163
10	S	central floor area & hearth/pit feature	12	108	4	194
11	A/B	western floor area & hearth/pit feature	8	115	0	92
11	S	western floor area & hearth/pit feature	8	102	11	137
12	A/B	western wall edge	10	128	8	69
12	S	western wall edge	9	102	3	152
13	A/B	north wall edge	9	162	14	37

Sample / Unit	Fraction	Floor Context	Identified morphotypes	Phytolith count	Diatom count	Chrysophyte count
13	S	north wall edge	10	104	4	75
14	A/B	north floor area	8	140	8	70
14	S	north floor area	10	102	4	16
15	A/B	north floor area	8	109	3	93
15	S	north floor area	10	105	3	54
16	A/B	north west floor area	9	180	2	19
16	S	north west floor area	11	103	5	87
17	A/B	north west wall edge	8	107	10	20
17	S	north west wall edge	8	101	12	52
18	A/B	western wall edge	6	138	3	73
18	S	western wall edge	12	104	2	61
19	A/B	north west wall edge	8	102	9	65
19	S	north west wall edge	8	107	3	101
20	A/B	north west wall edge	8	110	6	61
20	S	north west wall edge	9	105	3	96
21	A/B	presumed 'natural' outside floor layer feature	7	100	4	411
21	S	presumed 'natural' outside floor layer feature	9	102	3	169

233   Table 1. Results of microbotanical and micro-algae residues from roundhouse floor samples
234
235   *Micro-algae: diatoms and chrysophycean cysts*
236   Diatom frustules and chrysophycean cysts were present throughout the roundhouse floor samples and
237   were counted synchronously alongside the phytoliths in each sample. These aquatic microstructures are
238   essential for illuminating the presence of semi-aquatic and aquatic environments. Accurate identification
239   of diatom frustules can be challenging as diatoms are the most diverse protists (Spaulding et al. 2022;
240   Stone and Yost 2020:23); however, this presents interdisciplinary opportunities for paleoethnobotanists
241   and microbiologists (among other specialists) to work together on environmental archaeology research to
242   aid future identification. Within the context of the floor samples, tentative identifications were assigned
243   for several complete diatoms with redundant morphotypes (Fig. 6). All diatoms were pennate in form, and
244   included araphid pennate and raphid pennate examples. The provisional identifications include the genera
245   *Achnanthidium, Hantzschia, Pinnularia, Eunotia* and *Navicula.* Following Jüttner et al. (2022), Spaulding
246   et al. (2022), Stone and Yost (2020) and Denys (1991) it appears that most of these diatoms are

247 freshwater species and lived within subaerial and terrestrial environments. Chrysophytes largely consisted
248 of small spherical forms (Fig. 6G) and stomatocysts with smooth and rugose ornamentation (Fig. 6H & I).
249 The round chrysophyte specimens appear similar to the *C. pseudodiachloros* and *C. elegans* forms
250 recovered from peat bogs by Cambra (2010) in Spain. However, verification from diatomists is needed to
251 fully confirm these identifications.
252
253 *Contexts*
254 Overall, the counts of diatoms and chrysophycean cysts were often higher around the edge of the floor
255 layer, within the assumed 'natural' units (18 and 21), and within units with pit/hearth features. Although
256 the taxonomic identification of these specimens is unverified, their presence indicates concentrations of
257 damp or inundated deposits where these micro-algae were present.
258
259 **Discussion**
260 This multiproxy study provides robust data to interpret the architectural features of the Cairnmore
261 roundhouse such as the wall and roof materials. This data also contributes to our knowledge of the use of
262 space within the roundhouse and activities associated with the Cairnmore complex more broadly.
263
264 *Architecture – walls and roof*
265 Intact floor layers uncovered during excavation allow archaeologists to examine the use of space,
266 architectural details, activities and site formation processes (Borderie et al. 2020:151; Macphail et al.
267 2004; Milek 2012; Robertson and Roy 2019). However, *in situ* floor deposits are rare for lowland
268 structures within Britain (e.g., for prehistoric roundhouses see Ghey et al. 2007; Webley 2007) and
269 exceptionally uncommon in early medieval eastern Scotland (Ralston 1997; Noble et al. 2020:320). Initial
270 observations by the excavators noted that this structure was potentially constructed of turf or other earthen
271 materials (Noble et al. 2022), as has been suggested for other early medieval lowland structures (e.g.,
272 Ralston 1997:24; Noble et al. 2020:320), and this hypothesis is supported by the absence of postholes and
273 stakeholes surrounding the floor layer which could have supported an earthfast timber structure to brace
274 the walls and roof. One of the aims of this study was to test the hypothesis for turf walling by examining

275   the microbotanical and micro-algae assemblages present in and around the floor of this structure that lay
276   just outside the ringfort.
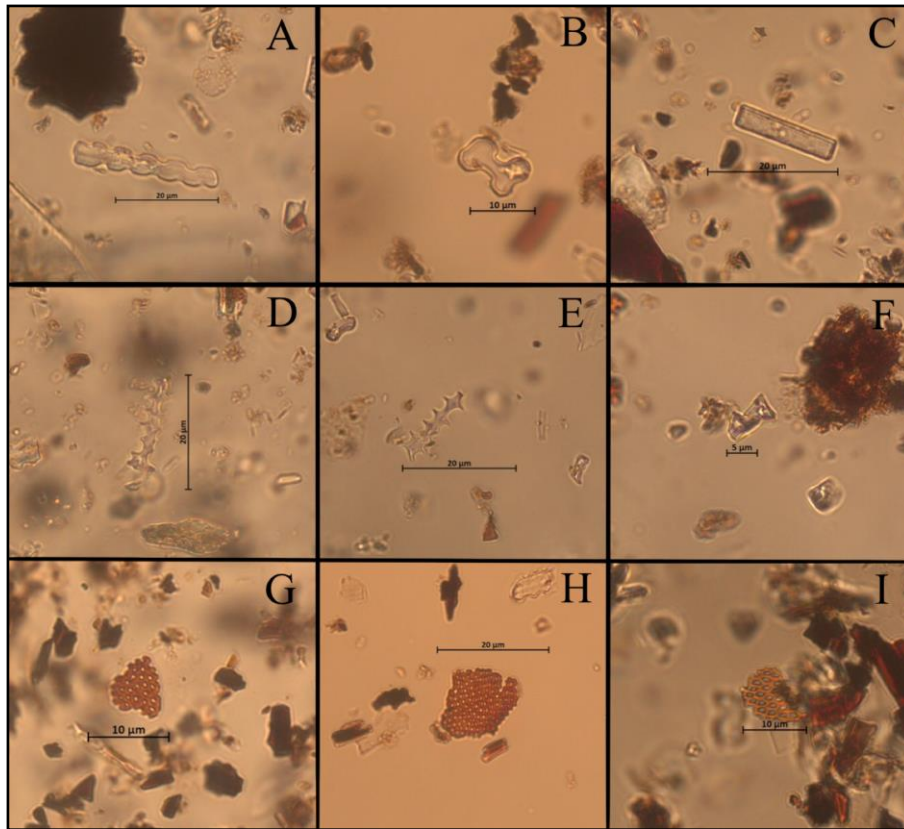
277   Figure 4. Common phytolith morphotypes from roundhouse floor samples (viewed at 400x). (A)
278   cylindrical polylobate – Poaceae, (B) bilobate – Poaceae, (C) elongate entire – Poaceae (D – E) elongate
279   dendritic [inflorescence bract] – Poaceae, (F) Cyperaceae cones, (G – H) Asteraceae or possibly Ericaceae
280   opaque perforated plates, (I) Vascular tissue, possibly from a tuber.
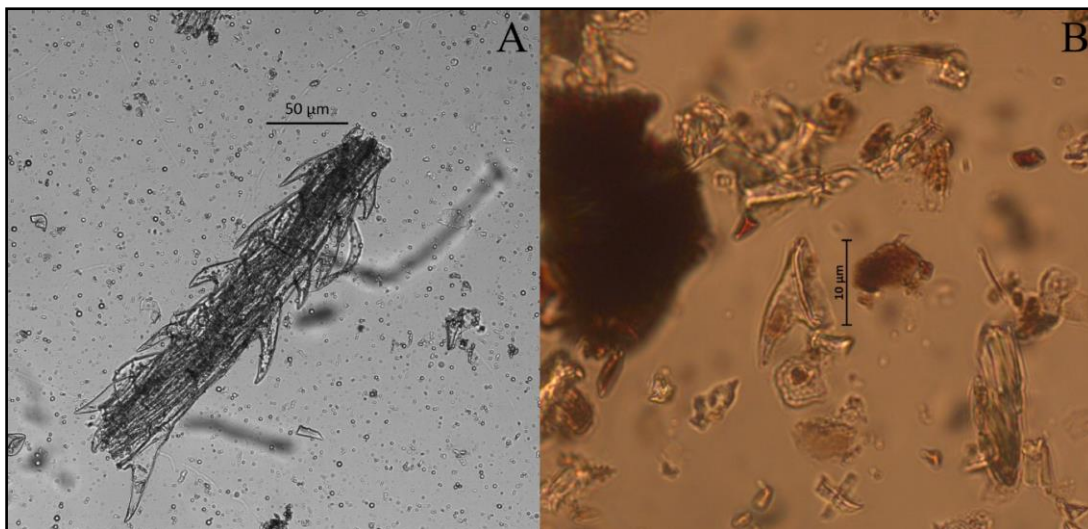
281   Figure 5. (A) Acicular hair morphotype from modern *Schoenoplectus lacustris* viewed at 100x (Prado
282   2022) and (B) acicular hair from roundhouse floor, viewed at 400x.
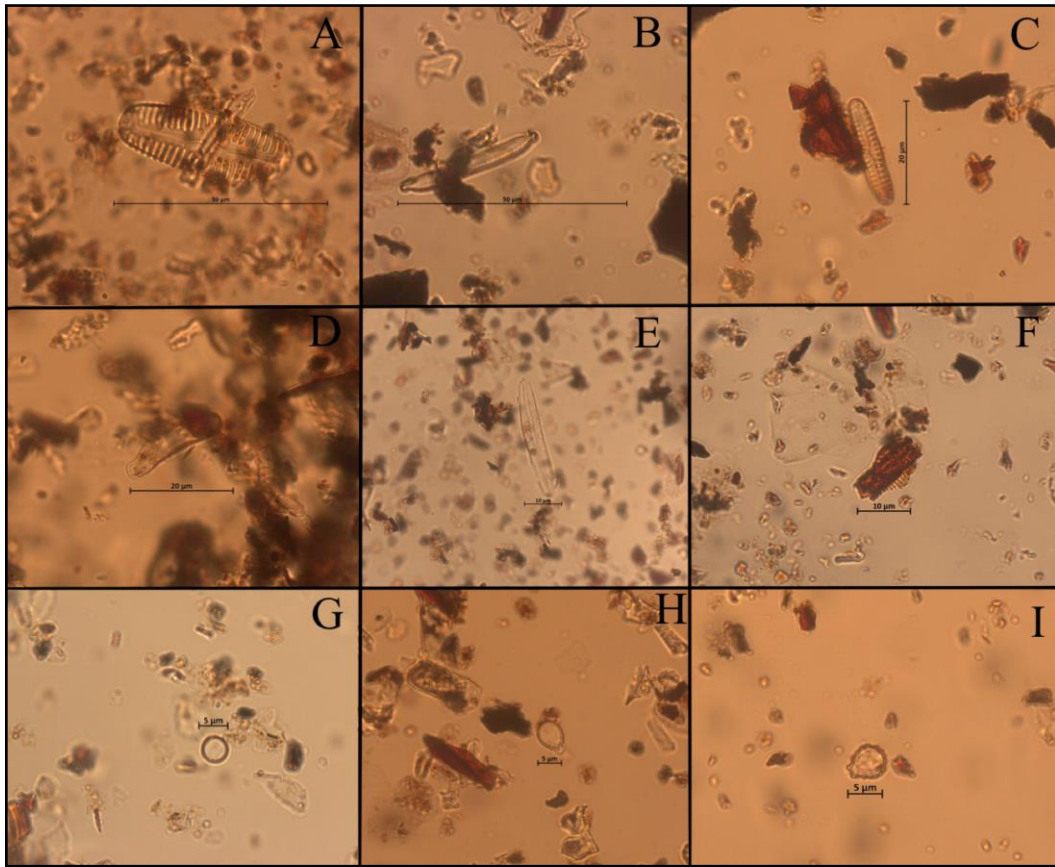
283   Figure 6. Diatoms and chrysophycean cysts extracted from roundhouse floor (viewed at 400x). All
284   identifications are unverified by a diatomist (A) cf. *Achnanthidium* sp., (B) cf. *Hanzschia* sp., (C) cf.
285   *Pinnularia* sp., (D) cf. *Eunotia* sp., (E) cf. *Pinnularia* sp., (F) possible burnt fragment of *Navicula* sp., (G
286   – I) chrysophycean cysts.
287
288   The phytolith evidence indicates a consistent presence of wetland plant taxa (e.g., Cyperaceae sp.) in the
289   Cairnmore floor deposit. Although present in lower quantities than Poaceae morphotypes, above average
290   counts of Cyperaceae cones were retrieved from 54% of the outer floor units where the wall of a
291   superstructure may be expected. This is a remarkable finding as Cyperaceae phytoliths are considered to
292   have relatively low visibility (Dal Corso et al. 2017:16; Novello and Barboni 2015; Ollendorf 1992). The
293   micro-algae assemblage, consisting of diatoms and chrysophycean cysts, was also ubiquitous across the
294   floor, often in similar counts and concentrations to the Cyperaceae cones. Although these microfossils
295   were retrieved from 90% of the sampling area (each present in 20 out of 21 units), elevated counts around
296   the edge of the floor deposit and from supposed 'natural' units (18 and 21) indicate wetland plants and
297   algae were concentrated around the edge of the structure.
298   The most likely explanation of this pattern is that the wetland indicator species come from a
299   turf/peat wall, with turfs cut from a wetland context the likely source. Analogous construction techniques
300   are also known from Viking Age and later historical turf structures in Iceland, where turf was typically
301   cut from lowland bogs and transported to the uplands for house construction (Bathurst et al. 2010; van
302   Hoof and van Dijken 2008). Several diatom genera from the roundhouse floor at Cairnmore appear to
303   overlap with the findings of Bathurst et al. (e.g., *Achnanthes, Eunotia, Navicula* and *Pinnularia*) and these

304 taxa are notably often found in peat-bogs (Bathurst et al. 2010:2925). The study by Bathurst et al. is an
305 excellent example of the advantages of targeting micro-algae residues in archaeological research;
306 however, this is a rare case as most archaeological approaches to past environments, especially in
307 northern regions, do not prioritize the recovery of diatom frustules. Within northern environments there
308 are very few studies that analyze microbotanical and micro-algae residues in-tandem (e.g., Vuorela et al.
309 1996) and to our knowledge, no archaeological studies have targeted chrysophycean cysts for analysis.
310 Wetland turf has often been a preferred material over grassland turf because of its denser root mat
311 which makes it better suited to absorbing water; therefore, making it more suitable for insulation in cool
312 and wet climates (Milek 2012:120–122; van Hoof and van Dijken 2008:1026). The practice of targeting
313 wet environments for turf extraction has been attributed to areas across the northern hemisphere including
314 Scotland, Iceland, Greenland, the Faroe Islands, Germany, Ireland, the Netherlands, and Norway
315 (Huisman and Milek 2017: 113). Within Scotland, turf was often procured from wet environments such as
316 sedge marshes, peat bogs, and heathlands (Huisman and Milek 2017:113; Walker 2006:7–8) as these
317 environments yield turf with deep root systems which results in a robust building material. Within
318 Scotland, Cyperaceae plants are mostly found in wet environments including fen, heathland, and marsh
319 environments. The phytolith signature in the Cairnmore floor deposit containing Cyperaceae and
320 Asteraceae (possibly Ericaceae) forms could therefore reflect turfs procured from a variety of wet
321 environments. Few Cyperaceae plant species grow in drier locales within Scotland as most sedges thrive
322 in wet and inundated soils (Preston et al. 2002). Coupled with the micro-algae evidence, we suggest that
323 the sedges in this floor deposit are unlikely to originate from dry environments. Overall, the phytoliths,
324 diatom frustules, and chrysophycean cysts retrieved from the Cairnmore floor signature suggest that the
325 turfs procured for this structure came from wet environments, likely peat bogs and other wet locales (e.g.,
326 heathland and fens).
327 Wetland areas still exist close to Cairnmore today and turf could have been sourced nearby for the
328 walls of the Cairnmore structure. The ubiquitous nature of wetland taxa across the roundhouse floor may
329 have resulted from the redeposition and movement of wall detritus across the floor (e.g., through
330 sweeping) and through decay from weathering and decomposition of the turf walls over time. The
331 presence of elevated counts of chrysophycean cysts and diatom frustules in units 18 and 21, which were
332 believed to be outside of the floor layer (and therefore were assumed to be 'natural' contexts), likely
333 suggests the context of these units relates to the inner fabric of the turf wall. Therefore, it is recommended
334 that sampling of 'natural' contexts should be targeted at a greater distance from an intact floor deposit to
335 avoid sampling other unseen structural elements such as turf walling. Shovel test pits at a greater distance
336 from excavated areas could potentially be useful for sampling 'natural' contexts. Although the samples
337 from units 18 and 21 do not appear to be wholly 'natural' in derivation they were still useful for
338 comparison with the floor layer as these signatures strongly contrasted with the floor signature (i.e.,
339 elevated counts of chrysophycean cysts and diatom frustules). This contrast also suggests that the
340 signatures from the floor are not representative of 'natural' growth on the floor after the structure was
341 abandoned.
342 In historical contexts turf walls could be reasonably thick, often comprising two 'faces' and a
343 core, similar in form to our modern cavity walls, with turf constructed in two parallel lines with earth
344 between (van Hoof and van Dijken 2008:1026–1027). Turf structures are thought to be relatively efficient
345 in terms of time and labour investment required for their construction and upkeep (Loveday 2007) and are
346 also excellent structures to use in areas where wood for building is scarce. Turf structures are also
347 particularly valued in cold and wet regions as these structures have excellent insulation properties
348 (Bathurst et al. 2010:2920; Milek 2012:120), a pertinent observation for the northern environments of
349 northeast Scotland. The hillslope setting of Cairnmore would have been an exposed location and warmth
350 and insulation would have been particularly valued in this context.
351 Interpreting the roof material of this turf walled structure is complicated as the samples in this
352 study were procured from what may be a mixed context of floor and roof material. It is difficult to
353 differentiate collapsed roof material from floor deposits in this context; therefore, to understand the
354 character of the roof we compared the microbotanical signature with broader archaeological and

355 ethnographic evidence. Overall, we did not differentiate between floor materials and collapsed roof
356 materials as this context was likely a mix of both; however, we have provided tentative interpretations for
357 the roof structure below.
358   The low counts of reed type phytoliths (e.g., bulliform morphotypes) across the floor layer
359 suggests that the roof, and the roundhouse structure broadly, did not significantly rely on these wetland
360 plants, as has been argued for some prehistoric roundhouse structures in Britain (Ghey et al. 2007; Pope
361 2008:17). Instead, the high degree of grass family (Poaceae) and aster family (Asteraceae) phytoliths
362 potentially suggest the roof was thatched using dried grasses and other wild plants (Morell-Hart
363 2019:236; Portillo and Albert 2011:3232). Aster family phytoliths and other dicot morphotypes were
364 recovered across most of the floor layer, and prominent deposits of dicot residues were identified within
365 several units (Fig. 7). Within the contemporary environment, aster family species include (but are not
366 limited to) hawkweed, daisy, yarrow, knapweed and coltsfoot. However, further research is needed on
367 Asteraceae phytoliths within northern Europe as some phytoliths recovered within this context were semi-
368 translucent and resembled heather family (Ericaceae) microstructures identified by Carnelli et al.
369 (2004:56). Ethnographic and historic research on Scottish shielings and other types of upland dwellings
370 reference the use of heather (*Calluna vulgaris*) for thatched roofs (e.g., the blackhouses from the outer
371 Hebrides and The Black Barn in Northumberland) (Dower 2015; Scott 2007; Walker 2006), and this
372 could potentially explain the representation of Asteraceae and possible Ericaceae morphotypes recovered
373 from this context.
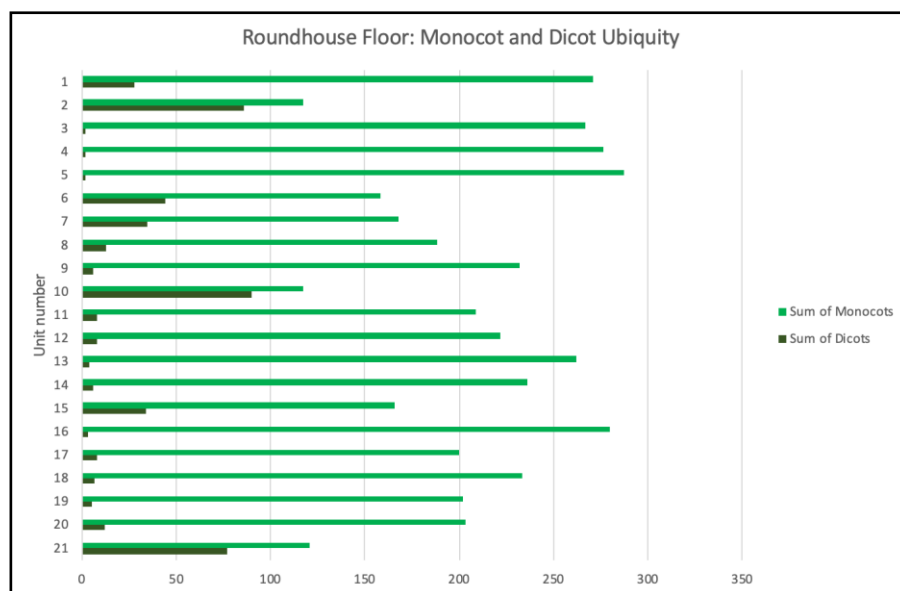
374 Figure 7. Monocotyledon and dicotyledon ubiquity within the roundhouse floor
375
376 *Spatial analysis*
377 The microbotanical assemblage does not strongly indicate the division of space for specific activities,
378 such as cooking, crop processing, or sleeping, though only part of the structure was revealed in
379 excavation (Fig. 9). However, small concentrations of specific morphotypes were present. For example,
380 dicot phytoliths and chrysophytes show a similar spatial pattern across the roundhouse floor with higher
381 counts around the edges of the roundhouse and in the central units near the probable hearth features (i.e.,
382 units 9, 10, 11 & 15). Cabanes et al. (2010) discusses a similar pattern within late Mousterian cave
383 occupations in Cantabria, Spain, where dicotyledonous residues were largely recovered from hearth
384 deposits whereas monocotyledon residues surrounding hearth features were interpreted as bedding areas.
385 The concentrations of chrysophytes related to probable hearth features may indicate that peat was also

386   being used for fuel within the roundhouse, a known practice from historical and ethnographic examples
387   (Loveday 2007:87). Alternatively, perhaps some material from the wall and floor detritus was used to fill
388   and close the hearths when abandoned or infiltrated what may have been sunken bowl-shaped hearths,
389   through later processes of decay and dissolution of the turf superstructure.
390   Food processing may have been carried out in or in the vicinity of the building. Trace
391   macrobotanical evidence from Cairnmore recovered granary weevils (*Sitophilus granarius*) from the
392   roundhouse floor (Niehaus 2021:43), possibly indicating a crop processing area or storage facility located
393   within or near the Cairnmore roundhouse. The microbotanical residues add more potential evidence for
394   this. A small number of inflorescence bract phytoliths were retrieved, with the highest counts reaching 5
395   elongate dendritic forms in units 14 and 16 (Fig. 8). Grass inflorescences are typically formed in the later
396   summer or early autumn and robust phytolith evidence of these foodstuffs is usually represented through
397   articulated multicellular structures of elongate dendritic and papillae phytoliths (Delhon et al. 2020).
398   Without multicellular forms or the use of morphometric analysis (Ball et al. 1996; Ball et al. 2009; Ball et
399   al. 2016; Portillo, Ball and Manwaring 2006; Rosen 1992) it is challenging to interpret the taxa
400   represented through these morphotypes. Many of these phytoliths were fragmented and were difficult to
401   confidently match with reference examples in the *McMaster Microbotanical Research Database* (Prado
402   2022). However, the most likely identification is barley (*Hordeum vulgare*), the dominant crop type for
403   the region in this period (Jones et al. 2021).
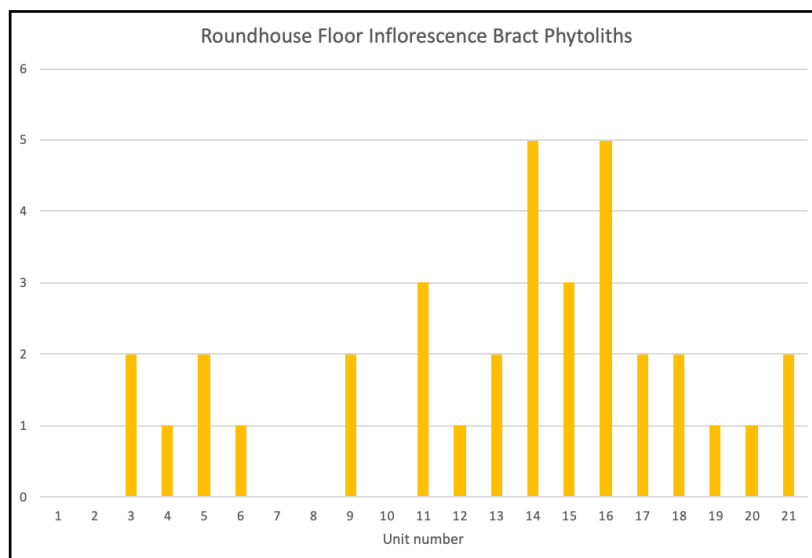
404   Figure 8. Counts of inflorescence bract phytoliths within the roundhouse floor
405
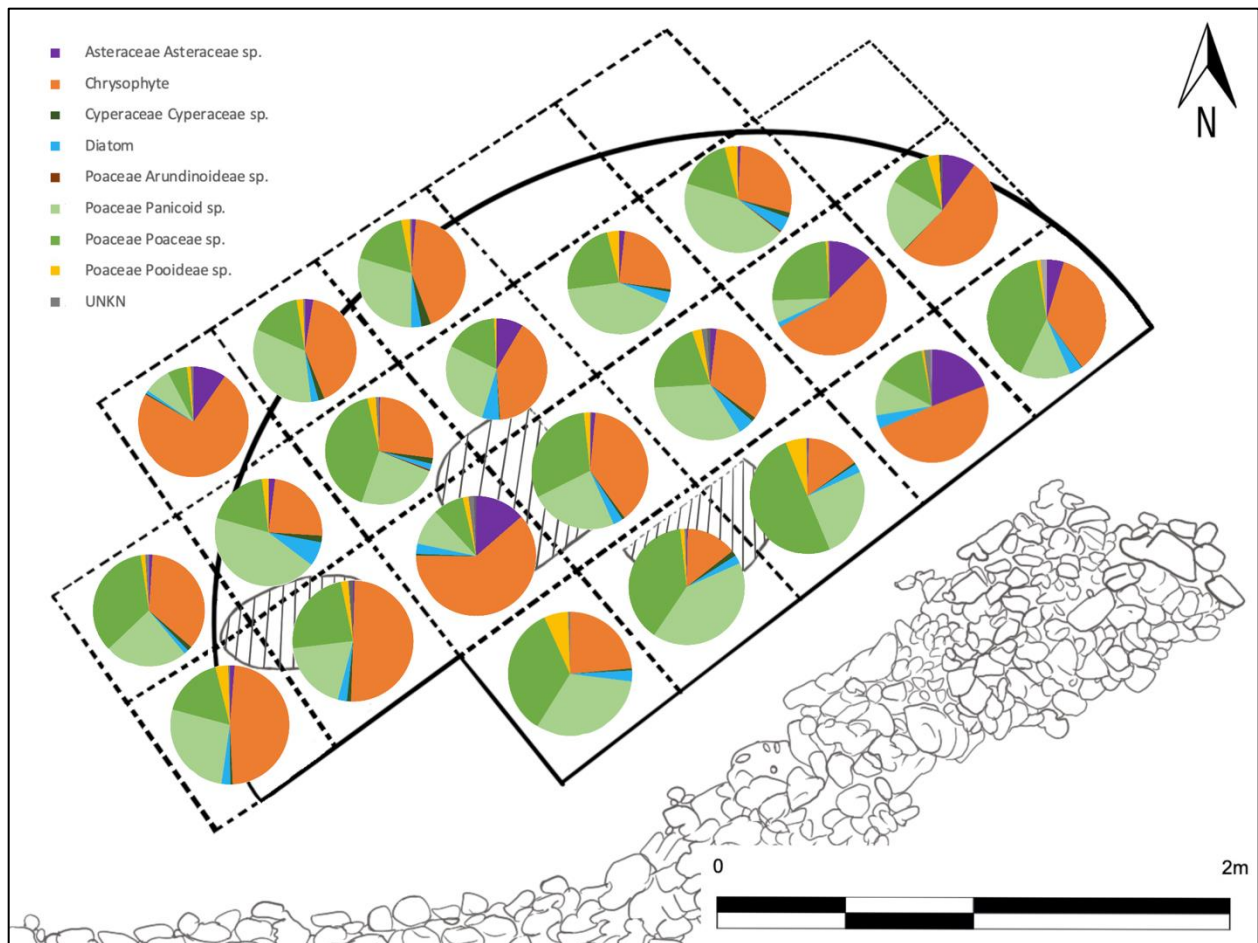
Figure 9. Spatial representation of microbotanical and micro-algae residues across the roundhouse floor

In regard to function, the presence of a rare intact floor layer suggests that this structure was repeatedly used; however, the activities within the structure are challenging to interpret. As already discussed, only weak signatures indicating food processing or bedding areas were recovered from this context. Given the relative lack of such indicators it is possible the building was mainly an auxiliary vernacular structure such as a workshop or agricultural building, an interpretation that may chime with the presence of the structure outside of the ringfort. The use of this building as a domestic space cannot be fully dismissed however, as trace residues of food processing were recovered (e.g., elongate dendritic phytoliths) and the floor layer suggests some level of repeated use of the structure. Lastly, other forms of domestic evidence could have lain elsewhere in the building outside of the accessible sampling area.

Family	Number of units where present (max 21)	Frequency (%)
Poaceae	21	100
Asteraceae	20	95
Cyperaceae	20	95
Poaceae (inflor. bracts)	16	76

Family	Number of units where present (max 21)	Frequency (%)
Arundinoideae	3	14

419 Table 2. Ubiquity of plant families represented by phytoliths in roundhouse floor
420
421 **Conclusions**
422 This article has addressed microbotanical and micro-algae assemblages within a floor context from a
423 building located outside of an early medieval ringfort in eastern Scotland – a rare survival of a settlement
424 context from a region that has a relative dearth of settlement evidence. The findings suggest
425 microbotanical analysis is a very useful technique for archaeological sites and contexts where settlement
426 remains are sparse and difficult to interpret, as is the case for early medieval Scotland.
427 Microbotanical residues can be used to interpret architectural details otherwise lacking direct
428 evidence such as the character of the materials used for flooring or roofing. At Cairnmore, the ubiquity of
429 chrysophytes, diatom frustules, and sedge family (Cyperaceae) phytoliths throughout the floor layer and
430 the concentrations of these microalgae and wetland phytoliths around the perimeter of the floor suggest
431 the use of nearby wetlands for turf which was utilised to build the outer walls of the roundhouse. More
432 tentatively, the presence of semi-opaque perforated plate phytoliths, suggests the presence of aster and
433 potentially heather thatch. The microbotanical assemblage from Cairnmore was also found to represent a
434 use of a variety of ecological niche zones providing important evidence for landscape use. Grasslands,
435 wetlands (e.g., bogs, marshes, and fens), and likely heathlands were represented through grass, sedge and
436 aster phytolith morphotypes. Semi-aquatic and aquatic environments were represented through diatom
437 frustules and chrysophycean cysts that likely originated from subaerial and terrestrial inundated
438 environments such as peat bogs. The presence (and absence) of particular microbotanical indicators also
439 allowed interpretation of the possible uses of the structure, with evidence for potential crop processing in
440 the structure or nearby, while the lack of multicellular phytoliths possibly suggests the building may not
441 have been a primary occupation space but could have been a secondary structure such as an agricultural
442 building, which may fit with its location outside the ramparts of the ringfort. However, more excavation
443 would be needed to clarify this.
444 Microbotanical assessments of floor layers have been proven to be useful for the identification of
445 plant resources from storage areas, ovens, hearths, and sleeping areas (Rosen 2005) and this study has
446 contributed to our understanding of floor deposits in a northern European region and era where our
447 knowledge and understanding of settlement traditions is very limited. The recovery of phytoliths from
448 intact floor layers is not always straightforward, as taphonomic processes are not always clear and
449 contamination during excavation can complicate these assemblages (Shillito 2013:76). However, the
450 distinct signatures from Cairnmore suggest that this floor layer was not significantly disturbed post-
451 abandonment nor during the excavation process. Microbotanical analysis successfully retrieved desired
452 counts of phytoliths across the sampling area and this methodology was effective in providing new data,
453 which also incorporated micro-algae residues, to interpret this roundhouse and the activities that may
454 have been carried out inside the structure, nearby and in the wider landscape. Such microbotanical and
455 micro-algae approaches should be encouraged in northern environments where organic preservation has
456 limited our knowledge of past settlement traditions.
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