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ABSTRACT
Glastonbury Lake Village is one of the most iconic late prehistoric wetland settlements in Europe. A new excavation in the core of Glastonbury Lake Village, for the first time since 1907, provided the opportunity for sampling of deposits associated with occupation of the site and for reconstructing the environmental conditions before the settlement was constructed. The results of a detailed multiproxy study are presented, including palaeoecological proxies (Coleoptera, plant macrofossils, diatoms, pollen, non-pollen palynomorphs), geoarchaeological methods (soil micromorphology), supported by new radiocarbon determinations. The results highlight how the difficult process of creating a settlement in a wetland was achieved, both within structures and in the spaces around them. Evidence for grain storage within the macrofossil assemblages, and the presence of animals on the settlement reflected in coleopteran assemblages and non-pollen palynomorphs has refined our understanding of the interaction between the settlement and the neighbouring dryland.

KEYWORDS
Palaeoenvironment; Iron Age; multi-proxy; pollen; wetland; Coleoptera; plant macrofossil; anthropogenic

Introduction

Glastonbury Lake Village is one of the most iconic and well-known late prehistoric wetland settlements in Europe. The waterlogged setting has preserved a unique corpus of organic material culture relating to the construction and occupation of the Iron Age site (Bulleid and Gray 1911, 1917). Discovered in 1892 by Arthur Bulleid, a local antiquarian, it was excavated by him and a small team of labourers until 1898. Between 1904 and 1907 Bulleid excavated in partnership with Harold St George Gray, the curator of the Somerset Archaeology and Natural History Society Museum in

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Taunton and a former assistant to Pitt-Rivers. The excavations covered the whole of the settlement and were published in two volumes (Bulleid and Gray 1911, 1917). However, not all roundhouses were fully excavated. Subsequent excavations have consisted of small-scale interventions, on the periphery of the site undertaken by Michael Avery in 1969 (unpublished), the Somerset Levels Project in 1984 (Coles, Coles, and Morgan 1988), and as part of the Monuments at Risk in the Somerset Peatlands (MARISP) project in 2003 (Brunning 2013) (Figure 1). The excavations undertaken in 2014, the first since 1907 in the core of the occupied area, provided the opportunity to obtain palaeoenvironmental information directly relating to on-site activities and the environment prior to (and during) settlement construction.

Previous Palaeoecological Research

Bulleid and Gray (1911, 1917) made useful observations on the environmental remains on the site and had the significant benefit of being able to view the deposits across the entirety of the settlement. They recorded that the village had been built on an area of wet woodland shown by the presence of numerous tree stumps and a leafy peat, readily distinguished from a reed/rush peat outside the village perimeter. The leafy peat contained numerous woodchips and

> … became less marked as a layer the nearer the Village margin was approached … The superficial layers near the palisades consisted of a heterogeneous mass of vegetable debris, containing bones, pottery, and other evidences of human occupation: the quantity varying according to the particular area under examination, and diminishing in direct proportion to the distance at which the peat was explored from the palisading (Bulleid and Gray 1911, 47).

Fragments of pottery were found 18 m from the palisades and sling shots even further out. Fresh water shells and river-weed were plentiful on the east side of the village and decreased towards the west, while fresh water mussels and water-lily roots were common on the east and north-east sides, suggesting an open freshwater setting prevailed to the north and east of the Village. The palisading was also less robust in structure on the western side.

There have been several palaeoenvironmental investigations of the wetlands surrounding the settlement (Housley 1988, 1995; Aalbersberg 1999; Housley, Straker, and Cope 2000; Brown 2006; Aalbersberg and Brown 2011; Housley et al. 2007) but the peat underneath the village has only been studied once, from an undated core extracted through Mound 5 (Figure 1) by Godwin and Macfadyen (1955). His interpretation supported Bulleid's observations, concluding that the village had been built on a 'floating fen carr' with open water beside it, although Housley (1995) suggests that at least the initial 60 cm of sediment in Godwin's column was disturbed backfill associated with original excavations at the site.

The most recent, well dated, reassessment (Tinsley and Jones 2013) was from outside the southern palisade (Figure 1), roughly 40 m south of Mound 9. That sequence showed evidence for the presence of an alder-willow-birch fen wood in the late Bronze Age and early Iron Age with a rich swamp community of reeds and sedge. In the later Iron Age an organic mud formed, representing deeper water conditions and a decline in willow pollen is suggested as representing the clearance of these trees

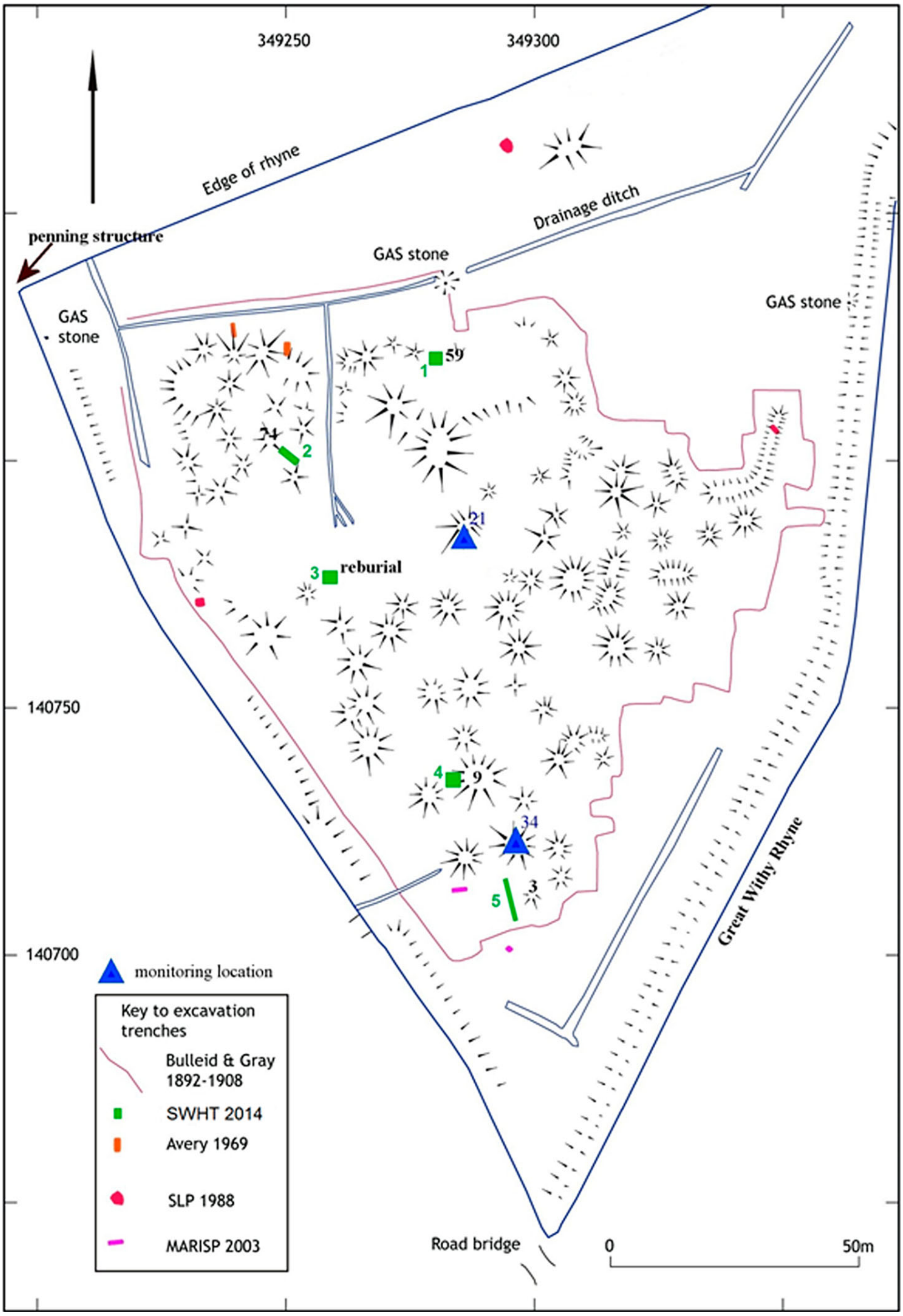

Figure 1. Site map, showing Mound 9 location and position of Trench (4) relative to the Mound, within GLV plan, in addition to the location of excavation sites associated with the 2014 work and previous GLV studies.

for the creation of the settlement. The presence of worked wood and sling shots in the early Iron Age peat deposits was taken as evidence that they had sunk down into the soft peat from higher levels. Wider landscape studies highlighted the diversity of wetland habitats in the first millennium BC, with raised bog to the west, estuarine conditions to the north and around the settlement shallow open water with extensive reedswamp, sedge fen and fen carr, cut through by deeper water channels (Housley 1988, 1995; Housley, Straker, and Cope 2000; Housley et al. 2007). The early medieval course of the River Brue runs along the eastern edge of the field containing the settlement, its course downstream surviving as a roddon. Analysis of that roddon has shown that it represents an open large tidal channel in the late Iron Age (Aalbersberg 1999; Aalbersberg and Brown 2011).

2014 Excavations and Sampling Methodology

Five small trenches excavated in 2014 (Figure 1) targeted *in situ* archaeological remains with the intention of assessing their extent and condition and to acquire samples for scientific dating (Marshall et al. submitted). Samples were also obtained from a sequence of deposits to reconstruct the environment immediately preceding mound construction and to better understand the character of activities taking place during the settlement's occupation.

Trench 4 provided the opportunity to investigate the western edge of Mound 9 and its sequence of structures (Figure 2). Mound 9 was originally excavated by Bulleid in 1896 and was the most prominent on the site, with a series of nine superimposed clay floors (floor 9 being the earliest) forming deposits 1.8 m thick at the centre (Figure 3).

Re-excavation of Bulleid's backfill in Trench 4 revealed that only the lowest levels of the settlement mound had been left *in situ* and that in places Bulleid had excavated deeper, either to remove interesting timbers or to examine the substructure (Figures 4 and 5).

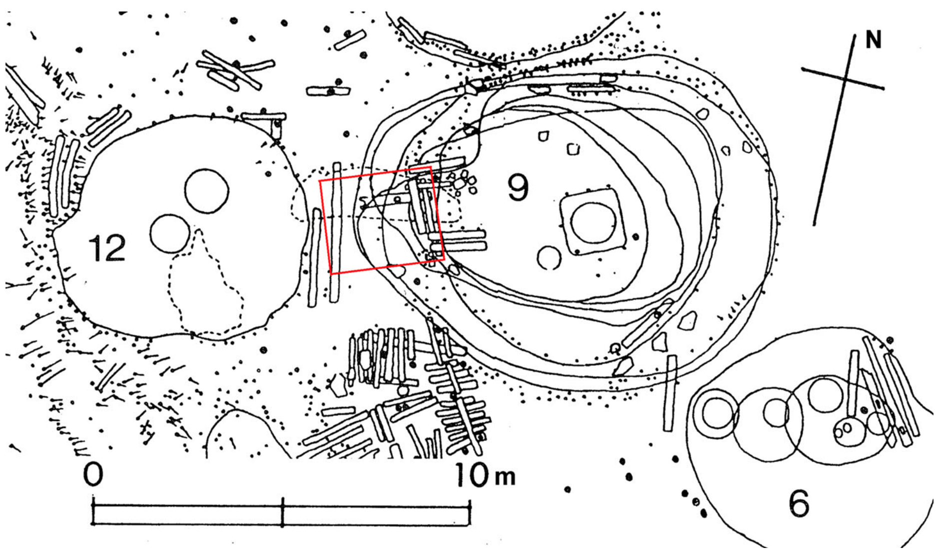

Figure 2. Site map showing trench 4 relative to Mound 9.

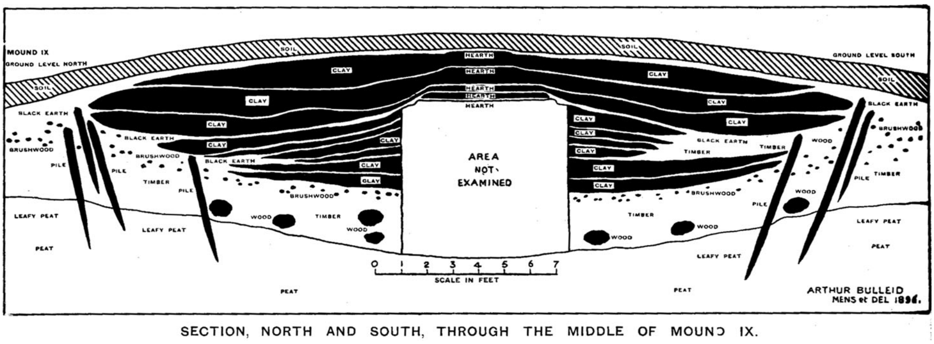

Figure 3. Section through Mound 9, from Bulleid and Gray (1911). Please note the section runs N-S, whereas this study's section ran broadly E-W. In addition, the weight of the mound has caused compaction, which has resulted in the top of the 'leafy peat' layer being lowered. It would originally have been level.

Stake lines, representing the walls of sequential roundhouses, provided numerous samples for scientific dating (Marshall et al submitted). In one place (Area 1 of this study; Figure 4), Bulleid had removed the lowest flooring timbers, thus providing a location where sampling could take place with minimal damage to the *in situ* archaeology. This provided the opportunity to obtain sediments from immediately underneath the doorway porch of the earliest roundhouse (associated with floor 9), which would have been covered by subsequent floor layers.

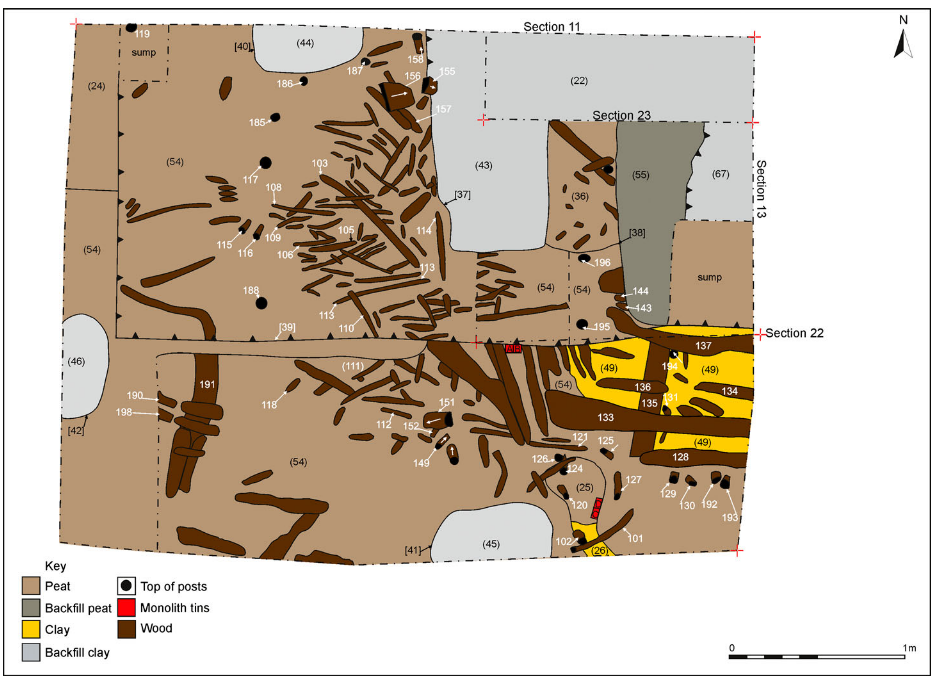

Figure 4. Plan of Trench 4 showing sample areas 1 (monolith tins A + B), 2 (tins C + D) and 3 (context 24 top left corner).

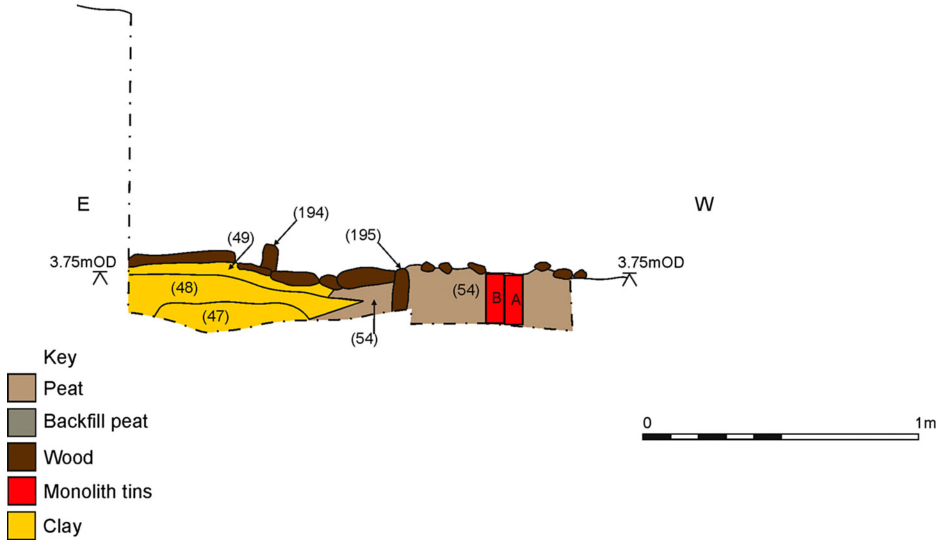

Figure 5. Trench 4 section Illustration showing Tins A and B relative to stratigraphy.

Duplicate monolith tins (A and B, top at 3.71 m OD) and a series of bulk samples were therefore taken from the peat underlying the earliest floor (Figure 5). Tins A and B were used for pollen, non-pollen palynomorph (NPP), micromorphological and diatom analyses, while the bulk samples were used for Coleoptera and plant macrofossil analyses. Radiocarbon determinations were obtained from five bulk peat samples (c. 300 g; radiometric measurements) from the section in Trench 4 and two samples of bulked waterlogged plant macrofossils (AMS measurements) from Tin B. Radiocarbon methods and results are provided in Table 1 and the Supplementary Information.

Samples were also obtained from the south-western corner of the trench (Area 2) where a small patch of *in situ* floor deposit had survived (Figure 4). The lowest deposit here was a peat overlain by a thin clay layer (context 26) that appeared to respect a line of small posts to the west. These are believed to represent the walls and clay floors of one of the first roundhouses (floors 8 or 9). Another line of wall posts existed to the east, one of which had been pushed over onto the top of the clay floor. This was thought to represent a rebuilt wall line. Overlying the posts was a wood-rich peaty layer (context 25) interpreted as a deliberately lain surface associated with one of the later rebuilds. Two kubiena tins (C and D) were taken vertically through contexts 25 and 26 and the underlying peat (Figure 4) for pollen, NPP and soil micromorphological analyses. Diatom analysis was undertaken on the clay layer (context 26).

Area 3 was located at the western edge of the trench equidistant between the entrances to Mound 9 and Mound 12 (Figure 4). A single bulk sample for coleopteran and macrofossil analysis was taken from context 24, thought to represent the remnant of an undisturbed occupation layer stratigraphically later than the deposits sampled in Area 1.

Details relating to the methodologies for palaeoenvironmental analyses, in addition to the associated raw results, are provided in the Supplementary Information. The stratigraphy and associated proxy sampling strategies applied to Area 1, are provided in Table 2.

Table 1. Glastonbury Lake Village radiocarbon results (GLV 71/2014 – Area 1, Trench 4).

Laboratory number	Sample reference	Material & context	$\delta^{13}C$ (‰)	Radiocarbon Age (BP)	Calibrated Date (95% confidence)
Wk-41234	10–20 mm	Peat, humic fraction from 10–20 mm at the western side of Mound 9	−29.1 ± 0.2	2216 ± 23	
Wk-41229	10–20 mm	Peat, humin fraction from 10–20 mm at the western side of Mound 9	−28.5 ± 0.2	2193 ± 23	
Weighted mean	10–20 mm	$T' = 0.5$; $T'(5\%) = 3.8$; $v = 1$		2205 ± 17	365–195 cal BC
Wk-41235	40–50 mm	Peat, humic fraction from 40–50 mm at the western side of Mound 9	−30.8 ± 0.2	2392 ± 29	
Wk-41230	40–50 mm	Peat, humin fraction from 40–50 mm at the western side of Mound 9	−30.1 ± 0.2	2401 ± 24	
Weighted mean	40–50 mm	$T' = 0.1$; $T'(5\%) = 3.8$; $v = 1$		2397 ± 19	540–400 cal BC
UBA-28844	40–50 mm	Waterlogged plant remains, *Cladium mariscus* nutlets x2, *Hydrocotyle vulgaris* x 3 (J Jones) from 40 to 50 mm at the western side of Mound 9	–	2133 ± 29	350–50 cal BC
Wk-41236	80–90 mm	Peat, humic fraction from 80 to 90 mm at the western side of Mound 9	−31.5 ± 0.2	2332 ± 21	
Wk-41231	80–90 mm	Peat, humin fraction from 80 to 90 mm at the western side of Mound 9	−29.7 ± 0.2	2413 ± 24	
Weighted mean	80–90 mm	$T' = 6.5$; $T'(5\%) = 3.8$; $v = 1$		2367 ± 16	415–395 cal BC
Wk-41237	120–130 mm	Peat, humic fraction from 120 to 130 mm at the western side of Mound 9	−30.8 ± 0.2	2216 ± 29	
Wk-41232	120–130 mm	Peat, humin fraction from 120 to 130 mm at the western side of Mound 9	−28.0 ± 0.2	2260 ± 33	
Weighted mean	120–130 mm	$T' = 1.0$; $T'(5\%) = 3.8$; $v = 1$		2235 ± 22	385–200 cal BC
UBA-28845	120–130 mm	Waterlogged plant remains, *Solanum dulcamara x 1, Eleocharis palustris/ uniglumis x 1 + 3 halves, Ranunculus lingua x 1, Potentilla anserina ½, Stellaria media x 1, Carex x 1, Urtica dioica x 5, Rubus Glandulosus 1 fragment* (J Jones) from 120–130 mm at the western side of Mound 9		2211 ± 35	390–170 cal BC
Wk-41238	160–170 mm	Peat, humic fraction from 160 to 170 mm at the western side of Mound 9	−29.1 ± 0.2	2297 ± 26	
Wk-41233	160–170 mm	Peat, humin fraction from 160 to 170 mm at the western side of Mound 9	−29.3 ± 0.2	2268 ± 31	
Weighted mean	160–170 mm	$T' = 0.5$; $T'(5\%) = 3.8$; $v = 1$		2285 ± 20	400–260 cal BC

Results

Sample Area 1 – Below the Roundhouse

The radiocarbon results (Table 1; Figure 6) are conventional radiocarbon ages (Stuiver and Polach 1977), and are quoted in accordance with the international standard known as the Trondheim convention (Stuiver and Kra 1986). Full technical details relating to radiocarbon laboratory methods and calibration are given in the Supplementary information. Four of the five sets of replicate measurements on the humic/humin of bulk peat samples are statistically consistent at 95% confidence (Table 1) with the other consistent at 99% confidence. These individual results are thus just out of line with statistical expectation, but are statistically consistent enough to allow a weighted mean to be calculated to provide the best estimate for the age of peat formation in each case (Table 1).

Table 2. Overview of palaeoecological changes in Area 1 (Tins A and B, bulk samples).

Depth (mm)	Stratigraphy & Micromorphology	Beetles	Pollen	NPP	Plant Macro	Diatom
00–10	**Natural peat** 90% organic matter. Vughy and spongy microstructure. Organic matter aligned linear and parallel orientated to basal boundary forming microlaminations 'Unit 1' Fig. 7	Aquatics + Wetland taxa avg. 55% MNI S.V. avg. 59 Foul Material taxa avg. 46% tMNI Dung taxa avg. 7% tMNI Woodland taxa avg. 8% tMNI	Cyperaceae 10–15% *Alnus* up to 18% *C. avellana* type up to 25%, *Salix* c. 5% Charcoal in abundance	Contains evidence of dung/human disturbance (55A, 113) and 30% of settlement indicator *Chaetomium* (Type 7A) towards top of profile	50% assoc. with waste/ disturbed ground. Pale persicaria at 38%. Woody fragments abundant	Freshwater benthic epiphytes dominate (>90% TDV). Most species pH > 7. Typified by an abundance of *Epithemia sp. Eunotia sp.* and *Synedra sp., Cocconeis placentula*
*10–20						
20–30					Aquatic and bankside/marsh species dominate (c. 90%). 10% disturbed ground.	
30–40						
*40–50						
50–60						
60–70						
70–80						
*80–90			Cyperaceae 40%, *Alnus* & *C. avellana* type c. 10%	Type 729 (27.5%), Type 12 (16%), Type 10 (12%)	Aquatic and bankside/marsh taxa dominate, Disturbed ground species at 4% + less woody fragments than in uppermost samples	As 00–10 mm
90–100						
100–110	Brushwood layer					
110–120	**Anthropogenic peat** High organic content, similar to natural peat but organic settlement materials accumulated rapidly in high groundwater table. Anthropogenic residues include large fragments of angular charred wood, bone and herbivore coprolites. Aligned linear and parallel, strongly orientated to basal boundary forming microlaminations. 'Unit 2' Fig. 7	Aquatics + Wetland taxa avg. 65% MNI S.V. avg. 45 Foul Material taxa avg. 35% tMNI Dung taxa avg. 8% tMNI Woodland taxa avg. 6% tMNI	Cyperaceae 30–40% *Alnus* & *C. avellana* type c. 10% Salix 5–10%	Chlamydospores (Type 10 & 12) encountered throughout profile but most abundant towards the base. Found in the leaves of heathers (*Calluna* and *Erica*). Dung indicators *Sordaria* (Types 55A) and Type 206 also present		
*120–130					Aquatic and bankside/marsh taxa dominate (c. 85%). Occasional woody fragments	
130–140						
140–150						
150–160						
*160–170						
170–180						
180–190					Aquatic and bankside/marsh taxa dominate (c. 80%)	
190–200						Sparse remains & poor preservation. Freshwater.

*Indicates depths at which radiocarbon dating samples were extracted (please refer to Table 1 and Figure 6).

Only one of the two samples of bulked plant material (dated by AMS) is statistically consistent with the radiometric dated humic/humin fraction measurements (120–130 mm; T' = 1.3; $T'(5\%) = 6.0$; $v = 2$; Ward and Wilson 1978). The plant material (dated by AMS) and humic/humin fractions (radiometrically dated) from 40 to 50 mm are of significantly different ages ($T' = 49.3$; $T'(5\%) = 6.0$; $v = 2$), with the macrofossil measurement some c. 250 years younger than that of the fraction measurement. Given these differences, an age-depth model that combines the radiocarbon dates and their stratigraphic relationships has poor overall agreement and therefore a robust chronology for the palaeoenvironmental work cannot be provided (discussed further later).

Palaeoenvironmental proxy results are summarized in Table 2. A thin layer of small 'brushwood' was recorded in the trench and palaeoenvironmental analyses at a depth of approximately 100–110 mm. Differences above and below the brushwood are noted in the pollen, coleopteran and micromorphology results, and (to a lesser extent) in the plant macrofossil evidence (Figures 7–9). In the pollen analysis (Figure 7) the lower levels of the sequence are characterized by wet or waterlogged conditions, with abundant Cyperaceae (sedge) pollen and a range of herbs that are associated with fen conditions, for example *Filipendula* (meadowsweet), *Galium* type (bedstraw) and *Hypericum* (St Johns Wort). The micromorphology assessment indicates that the peat towards the base of the sequence also accumulated in a high groundwater table (Figure 8). In addition, the micromorphology revealed anthropogenic residues within the peat, including large fragments of angular charred wood, (within Unit 2, Figure 8). The coleopteran assemblages contain a greater relative abundance of aquatic and wetland taxa throughout the lower section (Table 2, Figure 9). The plant macrofossil assemblages contain more taxa representative of marshland and aquatic plants below the brushwood layer when compared to those from above it.

Above the brushwood layer, a change in the process of the peat accumulation and associated palaeohydrology is recorded in the micromorphology with a transition from a peat unit deposited under high water table to one under a lower water table. Interestingly, the micromorphology suggests the upper peat is 'natural' in origin (Figure 8, Unit 1), in marked contrast to the underlying peat unit, which is full of anthropogenic residues (Table 2). This is due to the vughy structure (the presence of irregularly shaped voids) and spongey microstructure of the peat and the very high (>90%) organic

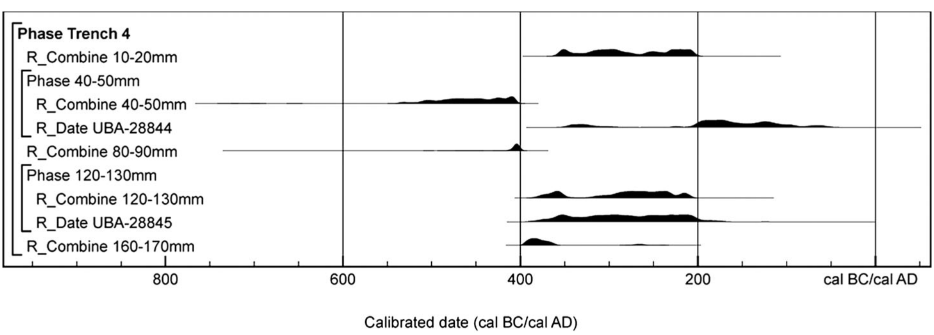

Figure 6. Probability distributions of dates from Glastonbury Lake Village – Area 1, Trench 4. The distributions are the result of simple radiocarbon calibration (Stuiver and Reimer 1993).

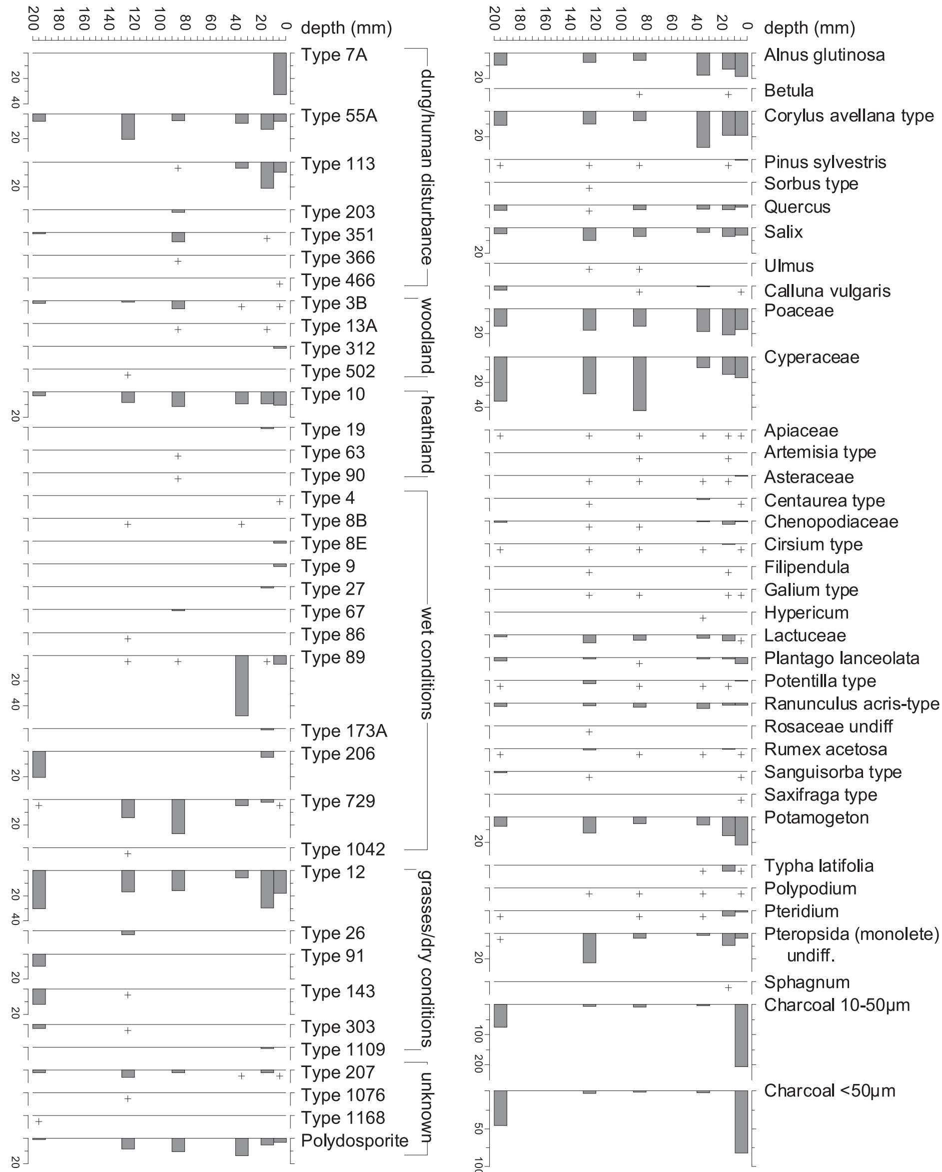

Figure 7. Results of pollen and charcoal (left) and non-pollen palynomorph (right) analysis from Monolith Tin A, Area1.

matter content. Within the pollen assemblages Cyperaceae proportions decline and trees/shrubs indicative of drier conditions, particularly *Corylus avellana* type (hazel) increase, notably towards the upper levels (Figure 7). This may be indicative of a drying phase within the local environment. This trend is reflected in the Coleoptera, in which wetland and aquatic taxa are found in lower abundances, c. 10% on average, while exhibiting increased synanthropy (Table 2, Figure 9). The sustained presence of Chlamydospores (Type 12) which are found in leaves of Heathers (such as *Calluna* and *Erica* sp.),throughout the NPP profile is also noted, and suggest dry

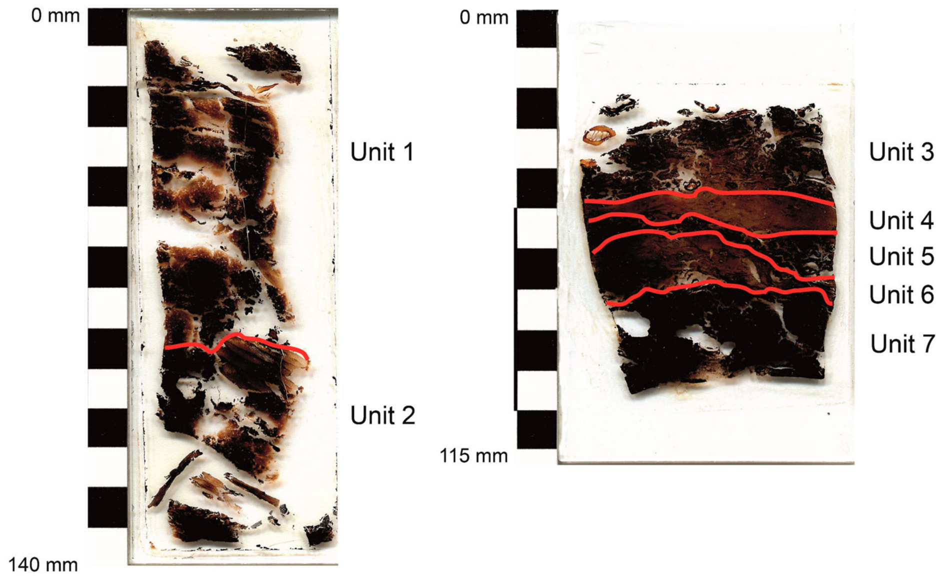

Figure 8. Scanned image of the thin-section for Monolith Tin A from Area 1 (left) and of the thin-section for Kubinea Tin C from Area 2 (right). Please note, approximately 5 cm of shrinkage affected Tin A and 2.5 cm of shrinkage affected Tin C during drying and resin impregnation. The scale bars provided therefore reflect the size of the thin sections *after* shrinkage, but the impact of this shrinkage has been accounted for in subsequent analyses and interpretations.

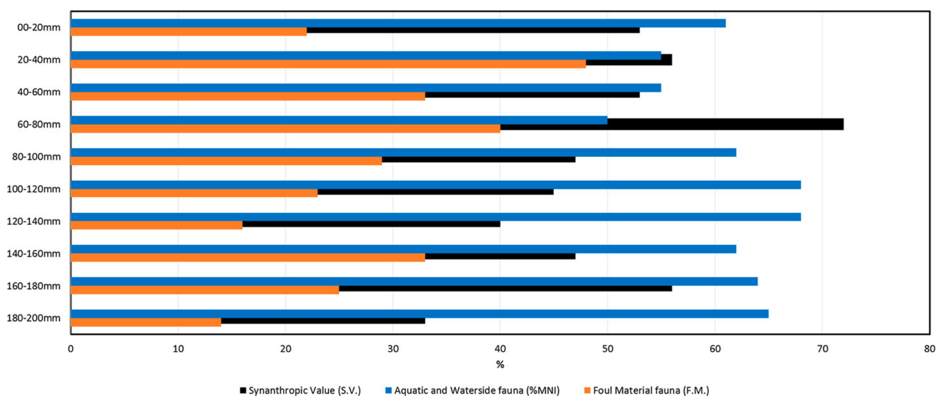

Figure 9. Relative proportions (%) of key coleopteran functional groups encountered in samples from the Area 1. Aquatic fauna have been calculated as percentage of the total faunal assemblage, whereas Foul Material fauna have been calculated as % of terrestrial only assemblage. The Synanthropic Value (S.V.) for each coleopteran assemblage is also displayed.

conditions (Van Geel 1978). Charred wood fragments are rare, but those present were well rounded, which suggests the transportation by fluvial processes of charred remains to the site from sources further afield. Plant macrofossil assemblages display an increase in the frequency of woody fragments (woodchip, twigs and bark) and a significant increase in disturbed ground taxa (e.g. pale persicaria) in the uppermost deposits. Diatoms were most abundant in the uppermost sample (00–10 mm) and were

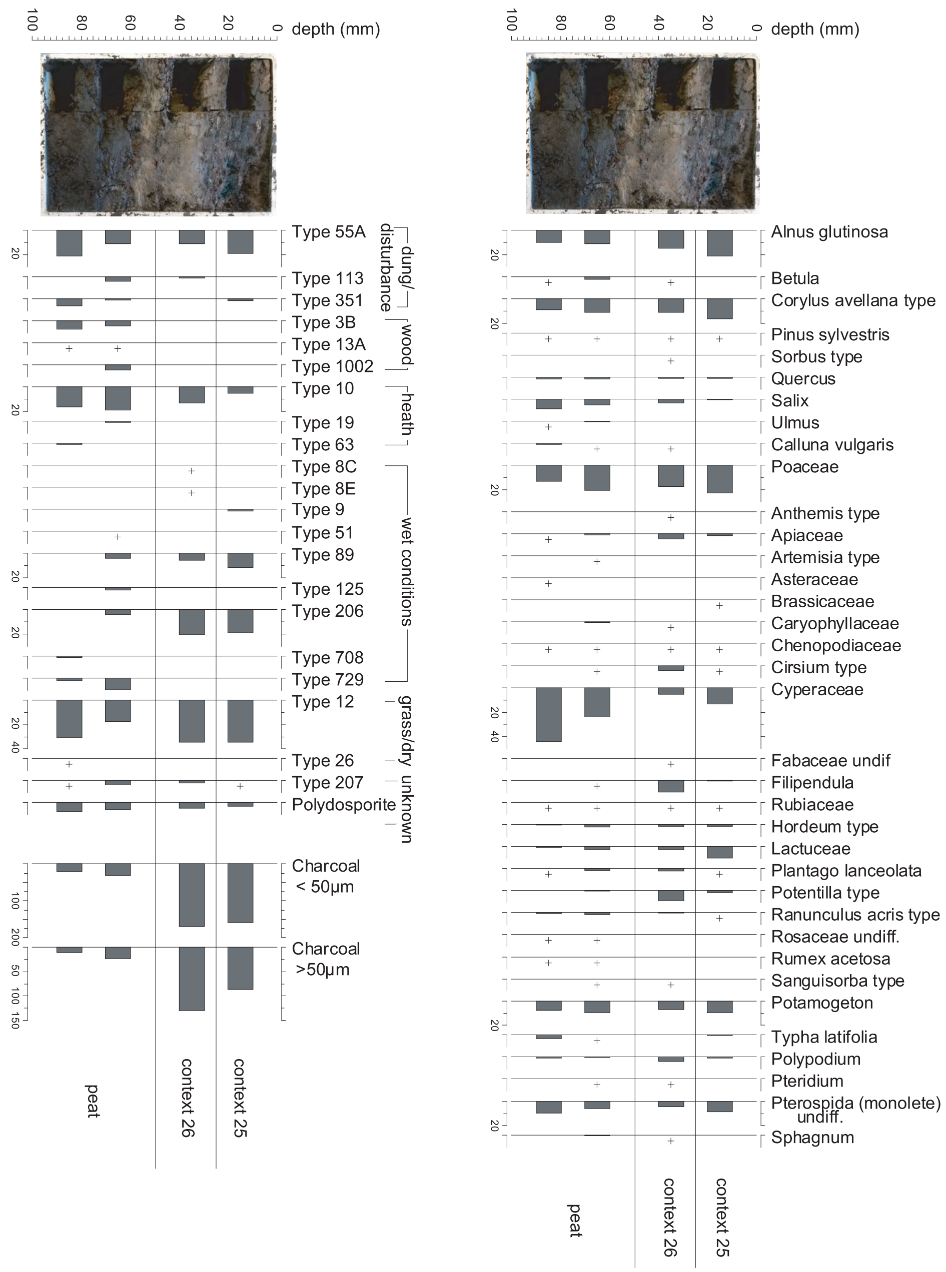

Figure 10. Results of pollen and charcoal (left) and non-pollen palynomorph (right) analysis from Tin D, Area 2. An image of the sample Tin is included, and horizontal lines across the panels indicate the different contexts sampled.

dominated by freshwater and benthic epiphytes (Table 2). Many of the diatom genera encountered, in particular species of *Gomphonema*, *Synedra* and *Eunotia*, are typically epiphytic species, found attached to plant debris in marginal depositional environments. However, in contrast to other proxy interpretations suggesting dryer conditions within the upper section of the sequence, many of these diatoms are found to prefer depositional settings that remain flooded by groundwater for much of the year (Gaiser, Taylor, and Brooks 2001).

Sample Area 2 – Roundhouse Floors

Area 2 contained a basal peat overlain by a clay unit (context 26) which, in turn, was overlain by an upper layer of woodchips in a peaty matrix (context 25). Micromorphological analysis classified the base of the peat deposit (Unit 7, Figure 8) as a 'natural' peat containing similar microstructure to that described in Unit 1 (Area 1). The pollen assemblages associated with the basal unit are dominated by Cyperaceae, Poaceae (wild grasses), *Salix* (willow), *Alnus* (alder) and *C. avellana* type (Figure 10).

Overlying the natural peat was a trampled possible floor surface (Unit 6) characterized by compacted microlaminations where finer sediment is mixed with organic material, with quartz as the dominant inclusion. Above this surface were a series of embedded microlaminations of silt loam, silty clay loam and sandy silty loam, with lenticular platey bed formation, phytoliths of grass leaves and stems (Unit 5). This is interpreted as a trampled occupation surface.

This was covered by a well sorted loam (Unit 4 = Context 26) with no microlaminations or anthropogenic inclusions, suggesting a floor surface deliberately laid in one event. This context (26) has a diverse pollen assemblage which includes several herbaceous taxa recorded at levels between 3 and 8% TLP. Notable are Apiaceae (Carrot family), *Cirsium* type (thistles), *Filipendula*, Lactuceae undiff. (dandelion family) and *Potentilla* type (cinquefoil). Diatom analysis of the clay floor reveals a freshwater source for this deliberately laid clay surface, with a suite of epiphytic and aerophilous taxa (including, but not restricted to, *Epithemia turgida*, *E. adnata*, *Synedra ulna*, *Pinnularia viridis* and *Hantzschia amphioxys*) suggesting the clay was sourced from a shallow lake or floodplain setting.

Above the unit 4 floor was an anthropogenic peat (Unit3 = Context 25) containing large amounts of bark, leaves, seeds, twigs and wood, some of which was charred, phytoliths, bone and herbivore coprolites. Microlaminations show formation through the accumulation of organic material and sediment. A dense layer of woodchips was excavated at the top of this layer.

Sample Area 3 – Outside the Roundhouse

The bulk samples excavated from Area 3 were assessed for plant macrofossil and Coleoptera; however, the latter were found to be absent. Plant macrofossil analysis revealed an abundance of charred cereal. Some cultural material was retrieved from the bulk sample including pottery, and small bone fragments, some of which were burnt. Fragments of hard yellow clay were interpreted as daub, with one blackened piece showing Poaceae stem fragments embedded into the matrix. Charcoal fragments were abundant, estimated to account for 50% of the 2 mm fraction. Charred cereal grain included several hulled wheat (*Triticum* sp.) and barley (*Hordeum* sp.) grains, with 68 wheat glume bases well enough preserved to be identified as spelt (*Triticum spelta*). There were also wheat/barley awns, oat (*Avena*) grains and soft/rye brome (*Bromus* c.f. *hordaceus* ssp. *hordaceus/secalinus*). Despite the abundance of cultural material, much of the plant macrofossil assemblage largely reflects the natural environment with 60% bankside/marsh taxa, c. 30% aquatics, but only 6% species typical of disturbed habitats.

Discussion

The three sample areas under investigation have all revealed considerable evidence of anthropogenic influence within deposits i) underlying, ii) within and iii) adjacent to, the occupation layers of Mound 9. The basal peat deposits sampled in Areas 1 and 2 were originally assumed to have been 'natural' and hence were believed to also predate the start human occupation of Glastonbury Lake Village. This multiproxy study has however confirmed that most (if not all) of the deposits investigated have been substantially impacted by human activity prior to the construction of the roundhouse that was present at Mound 9. This is primarily supported by the suite of anthropogenic indicators revealed through the micromorphology, coleopteran and plant macrofossil results, but is further reinforced by the contradicting palaeoenvironmental signals that are encountered when comparing and contrasting proxy evidence *within* samples. The peat above the brushwood layer in Area 1 is now interpreted as part of the construction of the mound, as is a corresponding peat in Area 2 (Unit 7). Analysis of the upper material in Area 2 has provided evidence of the construction of the first roundhouse floors and Area 3 has enabled the characterization of an open area immediately outside the roundhouses of Mound 9.

The Chronology of Glastonbury Lake Village and Mound 9

The radiocarbon determinations obtained as part of this project and presented here, have been further modelled and are presented in full in Marshall et al. (submitted). The chronological modelling provides an estimate for the establishment of Glastonbury Lake Village of *210–150 cal BC* (*95% probability*; *first_build_GLV*; ibid, fig 6), probably in *190–160 cal BC* (*68% probability*), with the last construction event taking place *80–20 cal BC* (*95% probability*; *last_build_GLV*; ibid, fig 6), probably in *75–45 cal BC* (*68% probability*). The initial construction (walls and floors 8–9), subsequent rebuilding (walls and floors 7–6–5), and final builds (walls and floors 1–2) of structures on Mound 9 took place over a period of *35–120 years* (*95% probability*; *use_Mound_9*; ibid, fig 6) and probably only *60–100 years* (*68% probability*). This suggests that most structures on Mound 9 were probably in use for no more than a decade or two.

The relative chronology of the settlement developed by Coles and Minnitt (1995) suggested that Mound 9 was built later than the earliest roundhouses to the north and south (Figure 11(A)) although there was no definitive stratigraphic proof of this. The substrate upon which Mound 9 was built could therefore have been exposed to anthropogenic influences prior to construction.

As previously noted, a robust chronology could not be established for the sample column in Area 1. This is due to the discrepancy between macrofossil and humic-humin measurements at 40–50 mm depth and the age inversion at 80–90 mm, but the anomalous results need to be explained within their stratigraphic and palaeoenvironmental context. The brushwood layer at 100–110 mm depth is of anthropogenic origin, and has been interpreted as part of the foundations under the mound. Micromorphology suggests the peat overlying it is 'natural', yet the coleopteran, plant macrofossil and NPP signatures within the same upper unit reveal considerable anthropogenic influences, whilst the radiocarbon dating anomalies are reserved to within this upper unit. A stratigraphic boundary was identified by micromorphology at c. 90 mm, proximal to the brushwood layer (Figure 8), and at the same depth the age inversion was encountered, inferring that the organic material at 80–90 mm depth is older than that underlying it. In addition, further up the stratigraphic column at 40–50 mm depth, but still within the theorized 'natural' peat, a c. 250 year age difference between humic-humin and plant macrofossil measurements from the same depth is encountered. It is suggested that such age anomalies and contradictory palaeoenvironmental signatures were achieved through the artificial introduction of a layer of redeposited peat on top of the brushwood in advance of laying the first floor. In addition, the much dryer nature of this overlying 'natural' peat, as suggested by the proxy evidence, may have resulted in cracking that allowed younger macrofossils to move down the profile. Howard et al. (2009) suggest that, in fluvial context at least, younger ages achieved through plant macrofossil measurements are the result of *Phragmites* (reed) roots pushing plant macrossils down through the sedimentary sequence, or opening up voids for material to fall through. Irrespective, the interpretation that the overlying 'natural' peat was redeposited is consistent with Bulleid's description of the foundations consisting of 30 cm of brushwood below 60 cm of redeposited peat at the centre of the mound 9 (Bulleid and Gray 1911, 80) . Below the brushwood layer, scientific dating obtained from samples at 120–130 mm and 160–170 mm can be used to provide a robust chronology suggesting deposits forming over roughly 200 years prior to the beginning of the settlement (Figure 6).

As anthropogenic influences have been identified throughout all sequences under investigation, it is important to clarify the chronological relationship of the three areas

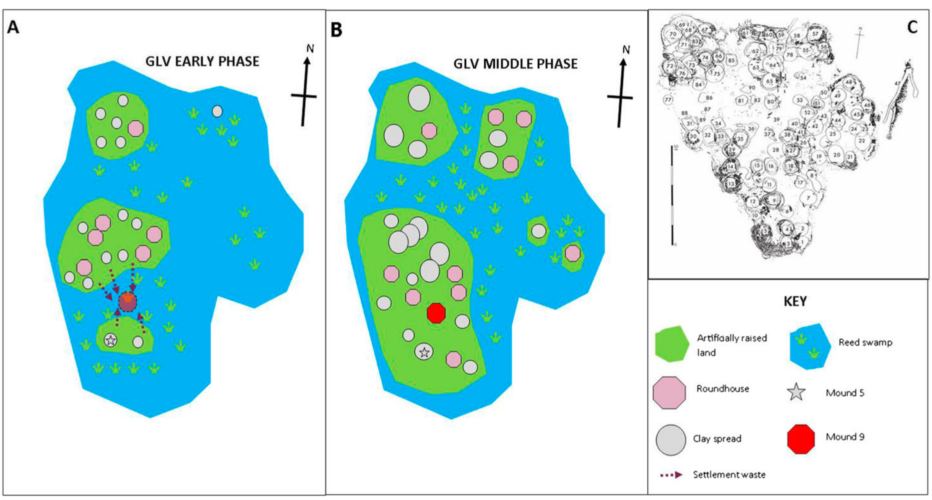

Figure 11. Schematic reconstruction of the environmental setting at Glastonbury Lake Village during its initial establishment at a time when the site of Mound 9 was under water (A) and the subsequent construction of Mound 9 (B). Please note that the positioning of specific roundhouses and clay spreads in A and B are to provide a general understanding of Lake Village layout and hence not accurate. Please refer to (C) for a summary of mound locations within the Lake Village (from Coles and Minnitt 1995).

under assessment relative to one another. Area 1 is located at the entrance to Mound 9 and was capped by the first (and hence earliest) floor layer (Bulleid's floor 9). Area 2 was located proximal to a line of small posts and flooring also associated with one of the earliest phases of mound occupation (floors 9 or 8), preserving a sequence of deposits before during and after the formation of those earliest floors. Area 3 (context 24) is outside Mound 9 and is believed to represent the external ground surface at a point in the occupation before a rubble path was built between mounds 9 and 12 at some point after the creation of floor 8 (and before floors 1–3).

The Environment Prior to Mound 9 Construction

As discussed above, the lower half of the sample column in Area 1 represents the accumulation of organic layers over roughly 200 years *prior* to the known beginning of the settlement. The palaeoenvironmental evidence confirms the presence of pools, or channels, of freshwater of variable depth up to 2–3 m, of generally still-to-slow-flowing waters. Aquatic Coleoptera such as *Limnebius aluta*, *Hydrophilus piceus* and *Dyops luridus* are particularly associated with freshwater in fen and marsh land and are still found in the Somerset Levels. While a wood carr was present locally, it did not form a dense canopy. The range and quantity of marsh plants encountered via the plant and beetle macrofossil analyses instead highlights a diverse and open, freshwater wetland habitat. Alongside rushes, sedges, pondweed and sweetgrasses, marsh spike rush, water mint, arrowhead, branched bur-reed, lesser water-parsnip gypsywort, common reed, white water lily, six-stamen waterwort, great fen-sedge and bulrush are present. We can, therefore, picture such a freshwater setting existing in the local area, prior to the construction of Mound 9.

Micromorphology has characterized the deposit below the brushwood as an anthropogenic peat in accordance with a formation process that has also been observed in lakeshore settlements from the Neolithic in Switzerland (Ismail-Meyer, Rentzel, and Wiemann 2013), and the late Bronze-early Iron Age in Lithuania (Ismail-Meyer 2014). This shows similar characteristics to natural peat forming processes, but where organic materials from around the settlement have rapidly accumulated where there is a high groundwater table, which has preserved the organic matter (Ismail-Meyer, Rentzel, and Wiemann 2013, 331). Whilst aquatic taxa dominate within this anthropogenic peat, the ecological group 'Foul Material', incorporating those taxa living upon varying types of decaying organic material (although not obligate dung beetles), contributed some 35% tMNI, increasing to 46% tMNI near the top of the sequence (Figure 9). While this group is not exclusively synanthropic, their presence in such proportions is typical of occupation sites (Hill 2015; Smith, Hill, and Kenward 2018). The presence of charred wood in the micromorphology samples, NPP taxa associated with dung and charcoal in the basal pollen/NPP sample, all give credence to an anthropogenic influence on this deposit.

It remains unclear as to whether the anthropogenic signal preserved below the brushwood layer within Area 1 either (i) relates to an earlier phase of human activity in the vicinity prior to the construction of the settlement remains associated with the Glastonbury Lake Village (as recorded by Bulleid and Gray), or alternatively, (ii) records the earliest occupation activities of the Glastonbury Lake Village, preserving an anthropogenic signal associated with construction and subsequent occupation of the first mounds (and prior to Mound 9 construction). Bulleid's excavations largely stopped at the mound foundations so it is unknown if any evidence of earlier human activity may exist underneath. In the MARISP Trench 2, worked wood and sling shots were found up in layers dated to the early Iron Age and were suggested to have sunk down into soft sediment (Brunning 2013, 185–191) but an alternative is that they were a product of an earlier phase of activity on the site. The preferred explanation is that the anthropogenic signal beneath the brushwood layer was due to some of the mounds being in use before Mound 9, as suggested in the Coles and Minnitt (1995) model. Waste material from the surrounding occupation could have entered the area later to be occupied by mound 9 (Figure 11).

The Construction and Occupation of Mound 9

The brushwood layer at c. 100 mm depth in the Area A sample column is thought to represent the lowest part of the mound 9 foundation, whilst the overlying peat represents material redeposited from nearby to help raise the ground level before the first floors were created. Unit 7 in Area 2 is thought to represent the same deposit.

Taxa associated with the ecological grouping 'Foul Material' also belong to an indicator group collectively referred to as the 'House Fauna' (Kenward and Hall 1995), which also show an increase in abundance up-column into the overlying 'natural' peat. This group comprises of a suite of beetles with a particular affinity to human habitation and settlement. Consistently present in these assemblages are *Ptinus fur*, *Latridius minutus* (grp.), *Atomaria* spp. and *Cryptophagus* spp. – all of which are particularly attracted to the dry moulding conditions of organic detritus made available within sheltered structures, including bedding, roofing and wattle and daub cavities. The furniture beetle, *Anobium punctatum* and *Lyctus linearis* are frequently found in the structural timbers and posts of wooden structures.

The presence of synanthropic indicators in a naturally accumulating a wetland peat that has been interpreted by micromorphology as being 'natural' is, on face value, incongruous. Furthermore, a general increase in the samples overall synanthropic value (S.V.) throughout the column (Figure 9) suggests that their presence increased in temporal proximity to the overlying occupation layers of mound 9. However, the presence of these 'house'/ synanthropic fauna throughout the samples demonstrates the proximity of human settlement throughout the period represented here. The pollen evidence associated with the upper peat unit also suggests a dry woodland and wood carr was expanding in the local environment. However, apart from wood fragments, which may be part of the brushwood, or other local construction, there was no evidence (seeds or fruits) for any woody fen carr species in the close proximity. Combined with the 'natural peat' characteristics identified through soil micromorphological analyses, it is suggested that the brushwood layer and overlying 'natural' peat have incorporated settlement debris from activities taking place nearby, that accumulated within overlying deposits (having either been washed in, swept or dumped, or a combination thereof), similar to that observed at Meare Lake Village where domestic waste was dumped into natural peat at the side of the settlement (Girling 1979).

In both the NPP and Coleopteran analyses, dung indicators are present throughout the samples. *Sordaria* sp. (Type 55A and 351) are present which, given their limited dispersal, would indicate that herbivores were close by and managed rather than wild, particularly above the brushwood layer where *Sporormiella* sp. are also present and abundant. Dung beetles, largely from the scarab *Aphodius* genera, were consistently present throughout the column but only c.7–8% of the terrestrial species. These proportions are considerably smaller than has been recovered from Iron Age pastoral sites across the UK, suggesting that any grazing animals were not in close proximity to the site or occurred in large numbers (Smith, Hill, and Kenward 2018).

The uppermost 10 mm of the sample column have a slightly different character. The plant macrofossil assemblage changes considerably with disturbed ground plants such as pale persicaria, fig-leaved goosefoot, common nettle and fat-hen dominating. These plants are all associated with nutrient rich disturbed soils, often near habitation, and near manure heaps where there are elevated levels of phosphate and nitrogen. The top sample is also the only one to contain *Chaetomium* sp. (Type 7 NPP) associated with human habitation, and there is also a distinct spike in the charcoal fragments recorded in the pollen analysis. The diatom assemblages from the uppermost sample is dominated by epiphytic species, which are taxa often found on wetland margins attached to living and/or decaying plant matter.

Shortly after the addition of a layer of brushwood and peat (to level the site and/or raise the surface elevation sufficiently above the water table), the first walls and clay floors would have been created. This was followed by a rebuilding sequence of eight further floors, central hearths and associated walls over the life of the building (c. *60–100years; 68% probability*). The micromorphological results from Area 2 have exposed the complex character of this deposition with a (presumably redeposited) peat (Unit 7) as the top of the foundations overlain by a trampled, possible floor surface (Unit 6) with trampled occupation material above (Unit 5). A replacement floor (Unit 4) was laid down over that, with an anthropogenic peaty matrix (Unit 3, Context 25) on top, again probably formed during occupation of the building, containing both charred wood and herbivore dung. The latter suggests that some animals may have been kept within the buildings. The overlying layer of woodchips possibly represents a deliberate consolidation of the floor and/or a product of activities within the building. The palynological investigations revealed the presence of barley pollen in all samples analysed, which is perhaps unsurprising considering the abundance of charred cereal encountered on the site in Area 3. The abundance of NPP heather indicators within the trodden anthropogenic layers also highlight the likely use of heather on site in the roundhouse possibly as flooring or bedding materials. Bulleid recorded comparable accumulations along the margins of floors 4, 5 and 6 consisting of 'a layer of fire ash, brushwood and bracken fern' (Bulleid and Gray 1911, 79–80).

Diatom analysis of one of the earliest floors (Unit 4 context 26) confirms the source of the clay, as freshwater benthic diatoms dominated the assemblage, whilst aerophilous taxa (including *P. viridis*and *H. amphioxys*) were also notable suggesting the clay unit was from a location that experienced cyclic aerial exposure, possibly in response to fluctuations in the relative water table, or flooding. The diatoms and sedimentary properties suggest the depositional setting would require very slow moving or stagnant water, to enable the deposition of such a fine grained sedimentary matrix. This would suggest that either the margins of a shallow lake or a flood plain setting are likely scenarios. The taxa were broadly similar to the assemblages encountered in the 'natural' peat underlying the floor layers in Area 1 which suggests that, despite one being minerogenic and the other organic, both these two units originated from a similar source or location. This suggests that during the construction of the foundations and floors, the builders were using the same source, likely in close proximity to the settlement, to obtain both the organic and minerogenic materials.

Outside the Mound 9 Buildings

The plant macrofossil remains encountered within Area 3, located between Mounds 9 and 12, were found to include charred cereal grain and chaff. Mound 5 (just south of Mound 9) also produced 'quantities of wheat and peas' (Coles and Minnitt 1995, 36). Although these finds are few they show the presence of both spelt wheat and barley. The oats may have been an additional crop or part of the arable weed flora along with brome, although this too may have been used at times to bulk out the diet, or to provide animal fodder. The presence of spelt glume bases, with a few awn and cereal stem fragments indicates that cereal was brought into the village as spikelets and they were probably stored in this way until ground into flour or used as a seed crop for the next year. Across Glastonbury Lake Village, structural evidence suggests 10 square structures that may have been granaries or storehouses, which would have provided excellent protection above the ground to keep the cereals dry and pest free, especially relevant in such a waterlogged setting.

Conclusions

The detailed multiproxy work presented here from the Glastonbury Lake Village has provided a wealth of valuable and new information. Interpretation of palaeoenvironmental sequences such as those presented here which, immediately underlie complex habitation sites, must account for a significant degree of disturbance and reworking of the upper deposits. The analysis has, however provided an insight into the activity associated with the establishment, construction, occupation and subsequent maintenance of Glastonbury Lake Village.

It is concluded that Mound 9 was constructed after the initial establishment of Glastonbury Lake Village, and as a result the peat positioned underneath Mound 9 was exposed to human activity for some time (perhaps a few decades). The distinct shift from wetland to dryland proxy indicators in Area 1, combined with the rise in coleopteran house fauna and other synanthropes, in addition to stratigraphic evidence derived from micromorphological studies and the presence of radiocarbon age reversals, all support the interpretation that the peat above the brushwood layer had been re-deposited from nearby to form part of the foundations, confirming the observations made by Bulleid in his original excavation. The micromorphological analysis of floor deposits in Area 2 is a reminder of the complexity of the life history of such buildings, the finer details of which were not apparent during excavation. This reinforces the significance and potential of the unexcavated column of hearths and floors in the centre of the mound which could elucidate the rapid and complex accumulation of material during the occupation of the mound.

The analysis has added significantly to our understanding of the settlement. The source of the clay for the floors has been characterized and the composition of a house floor has been studied for the first time. The analysis has also provided the clearest evidence yet for the presence of domesticated herbivores in the settlement, and even possibly within the buildings. The deposition of material in the open areas around the buildings has also been studied and has provided evidence for onsite grain storage as spikelets.

This investigation has reinforced the value of using a multiproxy approach in the analysis of highly complex sedimentary sequences where both natural and anthropogenic forces are heavily intertwined. The use of any single proxy, or maybe a combination of just two, may well have led to differing conclusions as to the nature of the depositional environment prior to the construction of Mound 9. Due consideration of all available proxy indicators is therefore needed, *in advance* of sampling, to ensure that the requirements of the differing proxy methodologies are observed during the extraction of sediments and subsequent processing.

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