University of Leicester Archaeological Services

An Archaeological Evaluation and Assessment of Waterlogged Deposits within the 'Plant Site' Area at Brooksby Quarry, Leicestershire

NGR: SK 67270 14042

James Harvey

(with major contributions by Michael Bamforth, Ian Panter, Charlotte Wilkinson and Kirsty High)

ULAS Report No. 2018-182

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Summary

In 2006 waterlogged archaeological deposits were revealed in several areas, during initial work within the ‘Plant Site’ at Brooksby Quarry, Leicestershire (SK 67270 14042). These areas included prehistoric burnt mound structures and a Late Roman/Early Saxon pit containing a wooden ladder. These features were subsequently preserved in-situ.

The results of water level monitoring at the quarry has led to concerns that recent fluctuations might be impacting on the condition of the buried waterlogged archaeology. Of the areas previously identified, the area that included the ladder structure remained potentially accessible in the Plant Site. Therefore it was required by the archaeological advisor to the planning authority that the pit containing the ladder was re-exposed, in order to establish the current condition of the waterlogged wood left in situ. The condition would be observed in situ, and samples taken for macroscopic and microscopic study.

The evaluative work was undertaken between the 8th and 10th of October 2018 by University of Leicester Archaeological Services (ULAS). The pit was re-exposed beneath c.4m of overburden and a sub-sample of one of the ladder stiles was retrieved.

The visual inspection of the ladder timbers detected no evidence of degradation since their initial exposure. Several laboratory tests were undertaken in order to compare the condition of the new timber sub-sample to an adjoining sub-sample retrieved in 2006. These showed that both samples exhibited an excellent degree of preservation, with the newer sub-sample actually showing slightly better preservation.

The work has concluded that there is no evidence to suggest that the current conditions within the quarry are not conducive to the continued in situ preservation of waterlogged organic archaeological remains.

Introduction

In accordance with National Planning Policy Framework (NPPF) Section 12 *Conserving and Enhancing the Historic Environment*, this document forms the report for the re-evaluation of the condition of waterlogged archaeological deposits located within the ‘Plant Site’ at Brooksby Quarry, Leicestershire (Figure 1 and Figure 2). It follows the strategy of work set out in the Written Scheme for Investigation (WSI; Lisboa 2018) and the Method Statement & Health and Safety Assessment (RAMS; Beamish 2018).

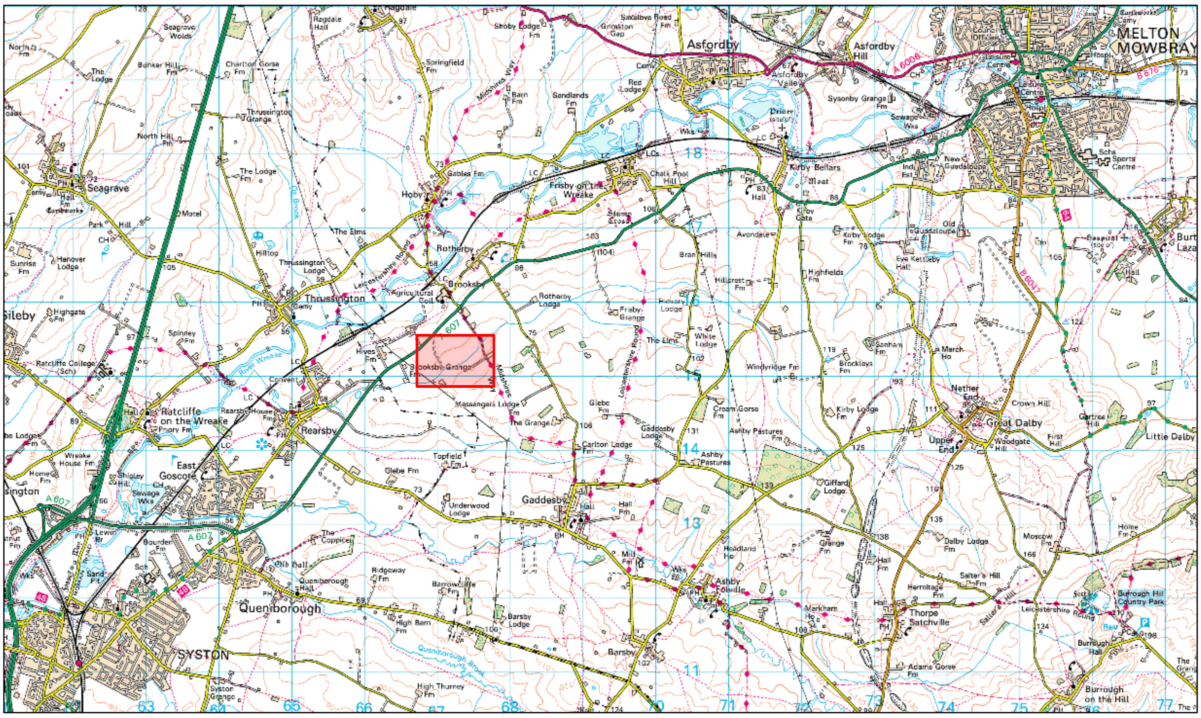

Figure 1: Site Location Plan

An archaeological watching brief has been ongoing at Brooksby Quarry since 2006. The initial work undertaken at the quarry within the 'Plant Site' involved the removal of alluvial deposits, revealing up to eight burnt mounds features and various other archaeological activity (Jarvis 2013). One of the exposed burnt mounds was evaluated. It included the excavation of an associated waterlogged trough containing lining timbers that have been dated to between the 24^{th} to 22^{nd} centuries cal BC (ibid, 53). The periphery of a separate burnt mound was partially truncated by a waterlogged pit that was also evaluated. It contained the remains of a wooden ladder, dating to the Late Roman or Early Saxon period (ibid, 54; Figure 2).

Following consultation with Leicestershire County Council and English Heritage, it was agreed that the waterlogged archaeological deposits exposed within the 'Plant Site' area would be preserved *in situ*, subject to a programme of water monitoring and the submission of proposals for excavation, if water levels dropped below the trigger level of 63.65m OD. The deposits were subsequently covered over with a protective layer alluvium clay that was overlain by a platform of sand and gravel that was used as a base to construct the quarry processing plant and compound.

Ongoing water level monitoring has showed significant fluctuations within the water table, leading to concerns over the current quality and condition of the buried archaeological deposits. Therefore is was required by Richard Clark, Senior Archaeologist, Leicestershire County Council in his capacity as archaeological advisor to the planning authority, that an area of known waterlogged structure was re-exposed and sampled, in order to undertake a comparative assessment of the state of preservation of waterlogged wood. This would provide a proxy indicator for the condition of the other buried archaeological deposits within this area of the quarry. Of the known areas of waterlogged wood, a pit containing a ladder structure remained potentially accessible within the Plant Site area, and it was agreed with Tarmac Trading Ltd, and the Archaeological Consultant for Tarmac, Dr Isabel Lisboa (Archaeologica Ltd), that this feature be the target for the assessment.

University of Leicester Archaeological Services (ULAS) were commissioned to undertake this evaluative work. It was carried out between the 8th and 10th of October 2018.

Aims and Objectives

The main aim of the investigation is to assess the current condition of waterlogged deposits within the 'Plant Site' at Brooksby Quarry.

The main objectives of the evaluation were to re-locate the Late Roman/Early Saxon pit (Pit 75) and recover a sample from one of the ladder stiles (uprights), in order to assess the current condition of the ladder and determine whether the condition of the wood had deteriorated since it was first exposed and sampled in 2006.

Excavation Methodology

Initial surveying within the 'Plant Area' was undertaken in order to re-locate the position of Pit 75, using a Topcon Hiper SR Network Rtk GPS. The RAMS suggested setting out a rectangular trench measuring *c*. 14m x 6m in order to provide enough room at the base of the trench, once the sides had been battered back.

A 36 tonne machine fitted with a flat bucket was used to remove the sand and gravel that had been laid down over the area in order to construct the plant site. This was removed under the control of a quarry supervisor until a membrane layer was reached. The trench was then battered at this level and a ramp was constructed on the eastern side of the trench to provide safe access into the trench. The underlying deposit of backfilled alluvium (used to protect the underlying archaeological deposits) was subsequently excavated in spits under the control of an experienced archaeologist until the top of undisturbed ground was reached.

The base of the trench was inspected in order to re-locate Pit 75. Any features observed were hand cleaned in order to define their edges and the back-filled deposits within the previously excavated section of the pit were removed using hand tools. A sub-sample of timber was then sawn from one of the ladder styles by an archaeological wood specialist.

The trench and any archaeological deposits were then surveyed and located on the OS grid and photographs was taken, as appropriate. Once sampling had been completed, the ladder stiles were recovered with plastic bags and the pit feature soaked in water. The feature was backfilled with silty clay and covered in 'terram' fabric. More silty clay was subsequently backfilled into the trench to a height of some 700mm and another layer of terram laid over the deposits. The trench was then backfilled with sands and gravels, and returned into operational use within the quarry.

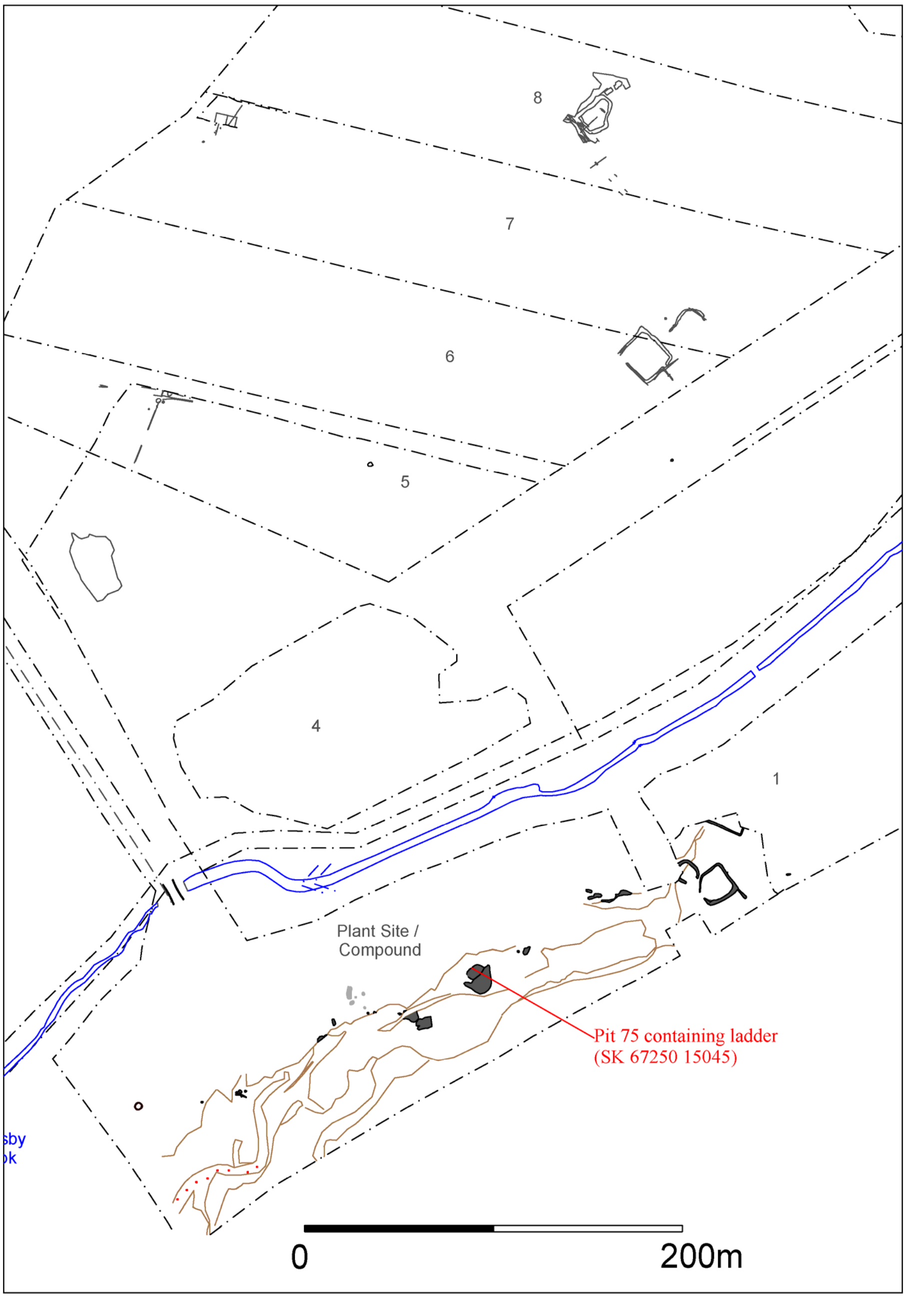

Figure 2: Location plan showing quarry areas, recorded archaeology and the location of Pit 75 (containing the wooden ladder) recorded in 2006

Excavation Results

The actual shape of the trench was modified due to its overall depth and the site constraints. These constraints consisted of the haul road located to the west, a sand stock pile to the south-east and the operational plant to the north. The resultant trench was slightly shorter and contained a ramped entrance, centrally located on its eastern side (Figure 3).

The upper overburden consisted of *c*. 1.1m of compacted sand and gravel (build up from the processing plant) that overlaid a further *c*.2.4m of unprocessed sand and gravel. A layer of terram fabric membrane was encountered at the base of the sand and gravel. Beneath the membrane a further *c*. 0.7m layer of backfilled alluvial clay was removed, revealing the stripped level that was first exposed during 2006. This level consisted of a dark yellowish-brown alluvial gravel containing small quantities of heat-cracked stones (HCS), relating to the burnt mound located immediately south of the trench (Figure 3). The conditions of the exposed level (at *c*.64.6m aOD) were damp, but not saturated.

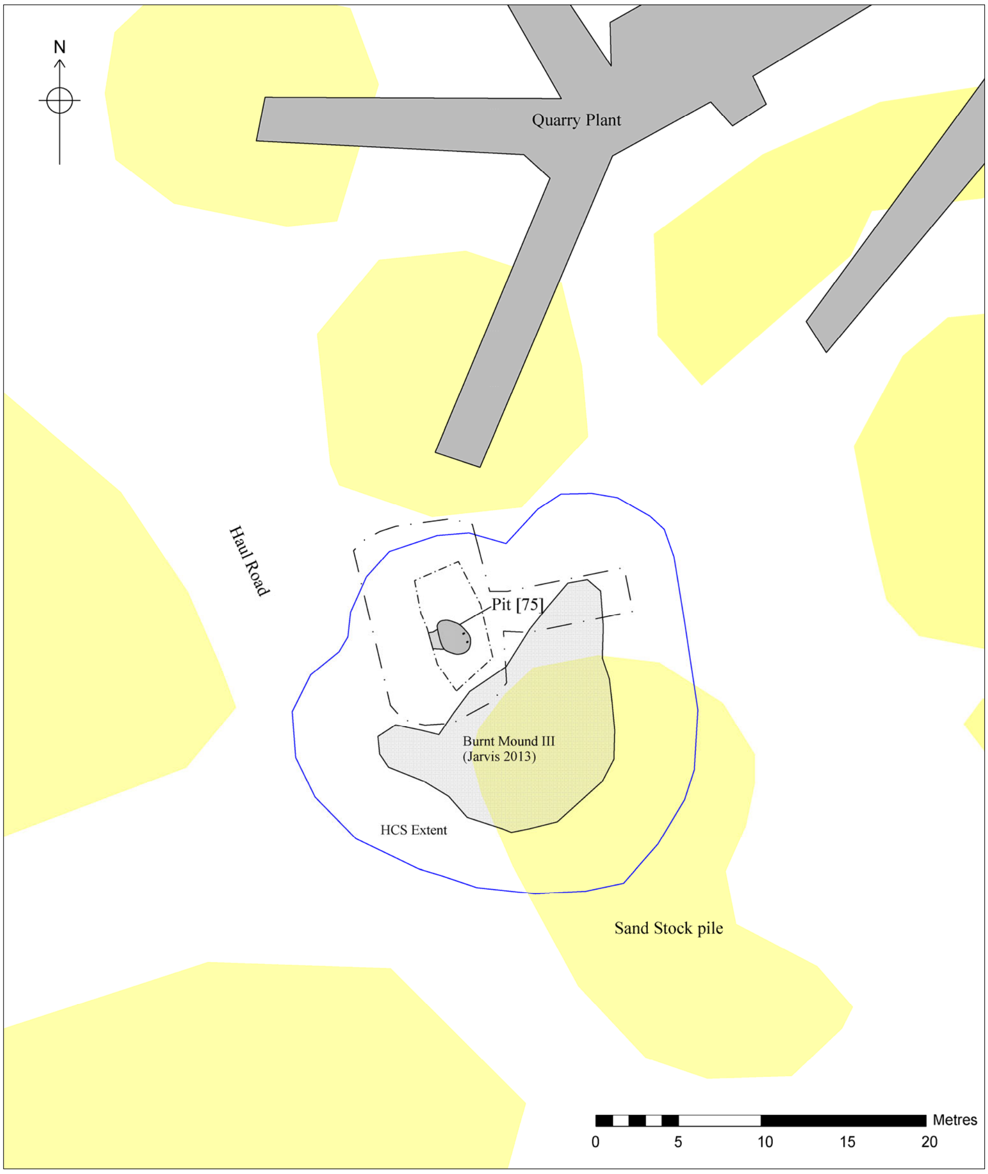

Figure 3: Location of trench in relation to current quarry and archaeological deposits as recorded in 2006.

A sub-oval feature was located towards the centre of trench, closely corresponding to the location and dimensions of Pit [75] recorded in 2006. It measured 2.4m long, a maximum of 1.8m wide and was north-west to south-east orientated. Cleaning confirmed its identification and the backfill of the original section was removed against its eastern edge (Figure 4). This revealed the upper ends of the two wooden ladder stiles (T17 and T18) close to the eastern edge of the pit. The sawn ends of the timbers were sealed beneath two plastic sample bags (Figure 5 and Figure 6). The depth to the base of the excavated section suggested that the feature had suffered a small amount of truncation (*c*. 0.2 m), presumably during the subsequent re-excavation of the feature.

Pit 75 partially truncated another feature that extended beyond the western side of the trench. This feature measured >1m long, 1.1m wide and appeared to be linear in form. The feature was filled with a mid-grey alluvial clay. No excavation of this feature was undertaken and its actual nature (archaeological or otherwise) remains uncertain (Figure 5).

Figure 4: Pit [75] after cleaning and removal of section backfill, looking west

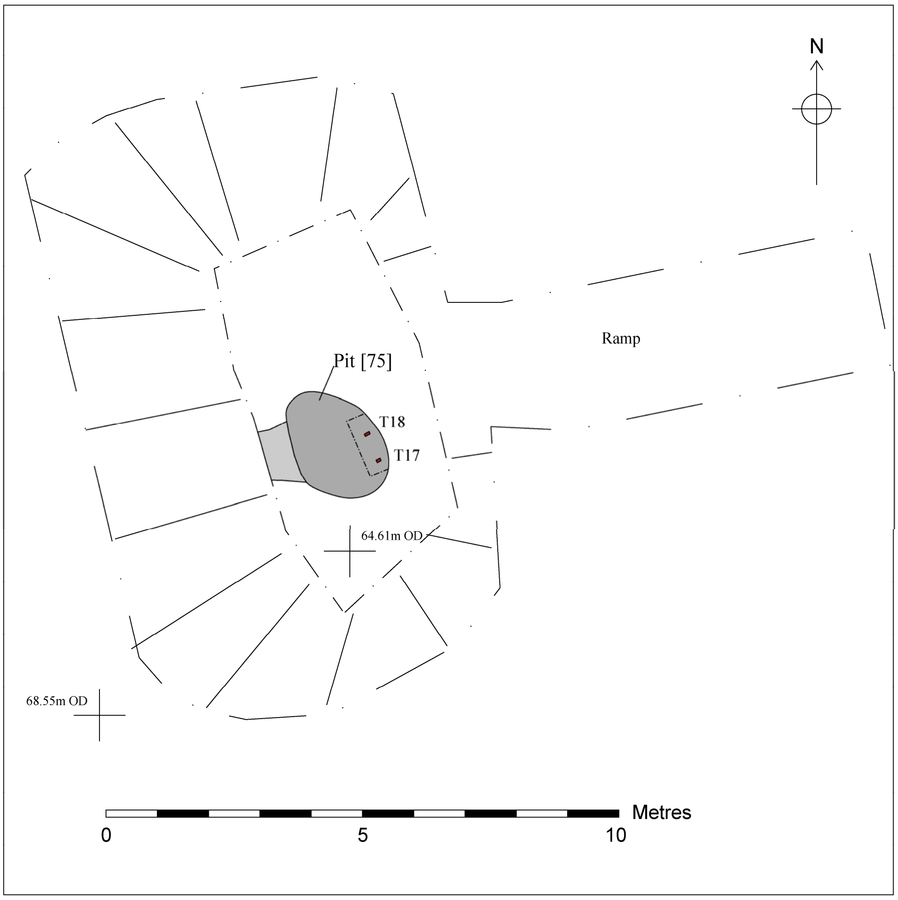

Figure 5: Close-up plan of Trench showing Pit [75] and Timbers T17 and T18

The Ladder Timbers: Assessment of the Condition

Visual Assessment of ladder timbers *Michael Bamforth*

Introduction

Three sub-samples were recovered from the top of the stiles of the wooden ladder recorded within Pit 75. The top of the ladder was first exposed in 2006 and both stiles, T17 and T18 were sub-sampled (S77 and S78 respectively). The ladder was subsequently re-buried and the sub-samples were initially stored in water before being transferred to a freezer at an unknown date. The top of the ladder style T17 was sub-sampled again in October 2018 (S661) with the intention of recording any subsequent degradation of the ladder.

This report section aims to visually assess the two sub-samples for condition.

Methodology

This assessment has been produced in accordance with Historic England guidelines for the treatment of waterlogged wood (Brunning and Watson 2010) and recommendations made by the Society of Museum Archaeologists (1993) for the retention of waterlogged wood. The system of categorisation and interrogation developed by Taylor (1998, 2001) and the condition scale developed by the Humber Wetlands project (Table 1) have been adopted within this assessment report. The condition scale is based primarily on the clarity of surface data. Material is allocated a score dependent on the types of analyses that can be carried out, given the state of preservation. The condition score reflects the possibility of a given type of analysis but does not consider the suitability of the item for a given process.

If preservation varies within a discrete item, the section that is best preserved is considered when assigning the item a condition score. Items that are set vertically in the ground often display relatively better preservation lower down and relatively poorer preservation higher up.

The material considered herein all scores 3 / moderate or 4 / good. Material that scores 3 will have a clearly visible primary conversion and evidence of tooling is likely to be visible. Material that scores 4 will have all the relevant surface data clearly visible - the primary conversion, tool facets and tool marks / signatures will all be visible if present.

Table 1: Table 1: Condition scale used in this report. After Van de Noort et al. 1995: Table 15.1

condition score		museum conservation	technology analysis	woodland management	dendro chronology	species identification
5	excellent	yes	yes	yes	yes	yes
4	good	no	yes	yes	yes	yes
3	moderate	no	yes / no	yes	yes	yes
2	poor	no	yes / no	yes / no	yes / no	yes
1	very poor	no	no	no	no	yes / no
0	non-viable	no	no	no	no	no

Results

The top of two stiles (T17 and T18) were re-excavated with around 100 mm of each exposed (Figure 6). Both are formed of boxed-heart oak timber and both had been sub-sampled by sawing during the previous intervention in 2006. The top of both stiles scored a 4 / good for condition. No radial drying cracks were noted and the worked surfaces appeared 'fresh' with no visible degradation. The angle between the sawn faces and the worked outer faces of the ladder presented as a sharp, clean angle, suggesting little visible degradation has occurred between the sawing event in 2006 and the re-excavation in 2018. Traces of the saw marks left by the 2006 intervention were still visible on the tops of both stiles. The sawn faces both had faint traces of a white material, hypothesized to be salts, present. Some heartwood rot, presumed to have occurred in antiquity, was visible in the centre of both stiles. This was more pronounced in the northern stile (T18) than the southern stile (T17). In both cases this has led to a void in the wood which is filled by the surrounding clay matrix.

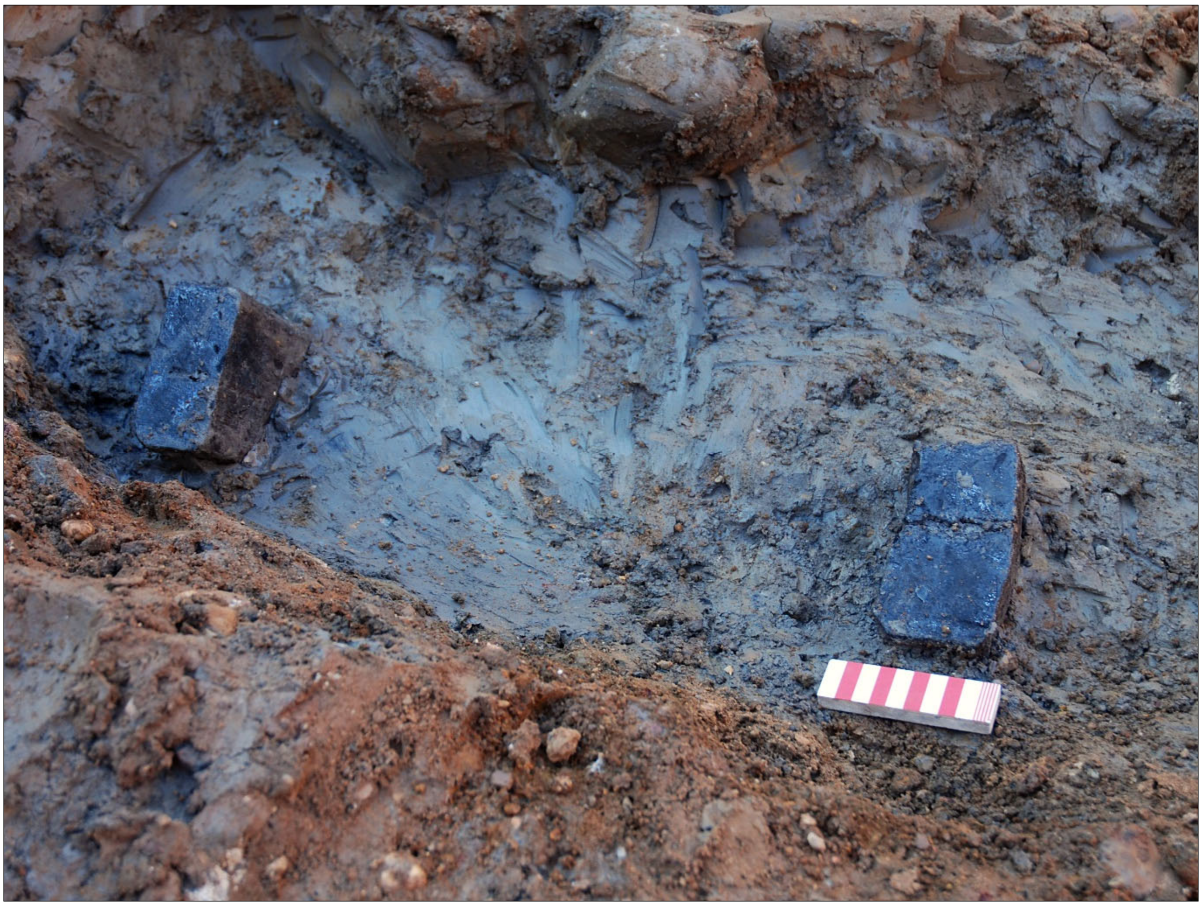

Figure 6: Detail of the tops of ladder stiles T17 (left) and T18 (right) in-situ, looking west.

Comparison of T17 sub-samples

- Timber 17, Sample 77 (recovered 2006)
- Timber 17, Sample 661 (recovered 2018)

S661 scores 4 / good whilst S77 scores 3 / moderate for condition. A side by side comparison of the two sub-samples shows that S77 displays a greater incidence of radial drying cracks and that the surface appears generally more degraded than S661. Subjectively, the 2018 sub-sample appears heavier, more fibrous and less prone to ablation and breaking than the 2006 sub-sample.

It is probable that some post-excavation degradation occurred to S77 after the 2006 intervention, whilst the sub-sample was stored in water. This will have prevented drying but will have exposed the sample to oxygen allowing biological processes to begin to break down the wood. Degradation will have been extremely retarded, if not halted, once S77 was transferred to a freezer.

Based on the photographic record of the 2006 excavation (Jarvis and Beamish 2015: Figures 18, 19, 20 and 24), much of disparity in condition between the two samples is probably due to the earlier sample being recovered from higher up the ladder, where preservation was poorer.

Figure 7: left: S77 (top) and S661 (bottom); Right: The lower sawn faces of T17 S661 (2018) left and S77 (2006) right

Discussion

The burial environment as seen in 2018 is not saturated and it has been suggested that this was the case during the initial excavation in 2006 (pers comm. James Harvey, ULAS). It seems likely that the role of the surrounding clay matrix is a strong factor in the survival of the waterlogged wood seen in this feature. Recent work at Star Carr has described the potentially extreme differences in preservation that can occur in waterlogged wood in close proximity within a burial environment (lateral distances of metres and vertical differences of centimetres) and the differing impact that previous exposures and re-burial can have on waterlogged wood within seemingly identical burial environments (High et al. 2018). It should also be noted that the stiles of the ladder are formed of oak heartwood, a species that would be expected, in a given burial environment, to survive in relatively better condition than almost any other waterlogged wood. Subjectively, the top of the ladder stiles seem as well preserved as could be expected of an artefact of this antiquity.

Laboratory Assessment of Timber 17 *Ian Panter, Charlotte Wilkinson and Kirsty High*

Introduction

This report section describes the condition assessment of the two adjoining sub-samples (S77 and S661) taken from a wooden ladder recorded within Pit 75.

The aims of the assessment were to:

1. Characterise the condition of each sample,
2. Identify whether there a significant variation between the degree of preservation of each sample, and
3. Use the evidence to comment on the potential for in situ preservation of waterlogged organic archaeological remains at the quarry.

Several tests were performed on the sub-samples in order to characterise and quantify the level of decay. The standard conservation tests assessed the gross physical condition, including density assays, maximum water content determination, and wood hardness. A more in-depth assessment of the chemical composition using infrared spectroscopy was also undertaken. The results and interpretation are presented below.

Methodology and Results

1. *Standard conservation condition assessment*

Method:

Standard condition assessment tests were applied to both samples to assess their condition (Panter and Spriggs 1996). These included density and maximum water content assays, and percentage loss of wood substance. A pin test was also performed on each sample to assess the hardness of the wood, a gross indicator of the severity of decay.

The density of a sample of wood is determined by the amount of "wood substance" (cellulose, lignin, short chain sugars etc.) present per unit volume (Dinwoodie 1989). It follows therefore that a reduction in the amount of wood substance resulting from decay will be reflected in a reduction in the density of the wood sample. By comparing the sample density with that of fresh wood of the same species (termed the "normal" density) it is possible to quantify the amount of decay of the sample.

Decay and breakdown of the cellular structure of the wood gives rise to an increase in the porosity of the wood as more and more voids are created, thereby leading to an increase in the amount of water retained by the wood. In effect, increasing water content equates to increasing decay of the wood.

As each sample consisted of two large pieces, the density assays were carried out on all pieces, first ensuring that the samples were fully water saturated by degassing under vacuum following standard techniques (Hoffman, 1981). The samples were then weighed in air and then submerged underwater and density was calculated using the following formula (Cook and Grattan, 1990):

$$\mathbf{Rg = 3x\ W_{sub}/(W_{air} - W_{sub})}$$

Where Rg = basic density of sample
W_{sub} = weight of wood submerged under water
W_{air} = weight of wood in air
Density is expressed as g/cm^3

The average sample density was compared with the "normal" density of fresh wood of the same species and the amount of material lost calculated using the formula:

$$\mathbf{\%LWS = [(Rgn - Rg) / Rgn] \times 100}$$

Where %LWS = percent loss in wood substance
Rg = sample density
Rgn = normal density of fresh wood.
For English oak, the normal density is taken as $0.74 g/cm^3$, although values will vary depending on ambient humidity and characteristics of the parent tree.

The maximum water content was determined by oven drying approximately a 0.1g sub-sample from each timber at 100ºC ± 5ºC until a constant dry weight was obtained.

The maximum water content (MWC) was calculated using the following formula:

MWC = [(Wet weight – Oven dry weight) / Oven dry weight] x100

As the maximum water content is expressed as a percentage of the oven dry weight, values can exceed 100%, depending upon the severity of the decay.

Results:

The results are presented as averages of two data sets for each sample (Table 2). Both samples appear well preserved, with sample 77 appearing to have undergone slightly more decay than sample 661, having lost more wood substance and possessing a higher water content. The pin test results corroborate these findings - the pin being able to penetrate marginally deeper into sample 77 than 661.

Table 2: Results of condition assessment

Sample	Depth of Pin Penetration mm	Basic Density g/cm^3	Loss in wood substance %	Maximum water content %
77	2-3	0.601	20	100
661	1-2	0.642	13	89

2. *Analysis of wood samples by Infrared Spectroscopy*

Method:

In FTIR analysis, infrared light is absorbed at specific wavelengths by specific chemical bonds. As such, it is used to infer information about the chemical structure of a material. In wood, characteristic absorption peaks can be attributed to either the lignin or cellulose components of wood, and as such is an ideal method for providing additional information on its chemical state of preservation. The relative intensity of these peaks provides information regarding the relative composition of the wood.

Each sample was received in two separate pieces. These have therefore been labelled S77A and B and S661 A and B, with each being analysed. For each of the four samples, thin shavings were removed from the outer edge using a scalpel. It can be assumed that wood at the very outer edge of the sample would be the most degraded.

The shavings from each sample were left to air dry for several days, after which no further sample preparation was carried out.

Samples were analysed on an Agilent Vertex FTIR spectrometer with ATR attachment, meaning that samples could be analysed directly. Samples (wood shavings) were placed on the crystal window and pressure applied. Samples were scanned between 650 and 4000 cm^{-1} using an averaged 16 scans and a scan rate of $4cm^{-1}$. Each sample was analysed twice to check for consistency. No spectral manipulation was carried out.

Data was first assessed visually, comparing the lignin related peaks at $1505cm^{-1}$ (the phenol ring) and 1268 cm^{-1} (methoxy functional groups) with those related to cellulose at 898 cm^{-1} and 1375 cm^{-1}. Peak areas were also calculated using the software 'Microlab', and used to estimate lignin to cellulose ratios.

Results:

Analysis of both pieces of samples S77 and S661 initially indicate that despite an obvious difference in texture between the two samples, chemically they appear very similar (Figure 8). Both samples retain a significant cellulose component, as shown by the peaks at 898 and 1375 cm^{-1}. Some differences in the shape of the peak at 898 cm^{-1} may indicate a difference in the level of cellulose decay, although further analysis would be required to fully assess this.

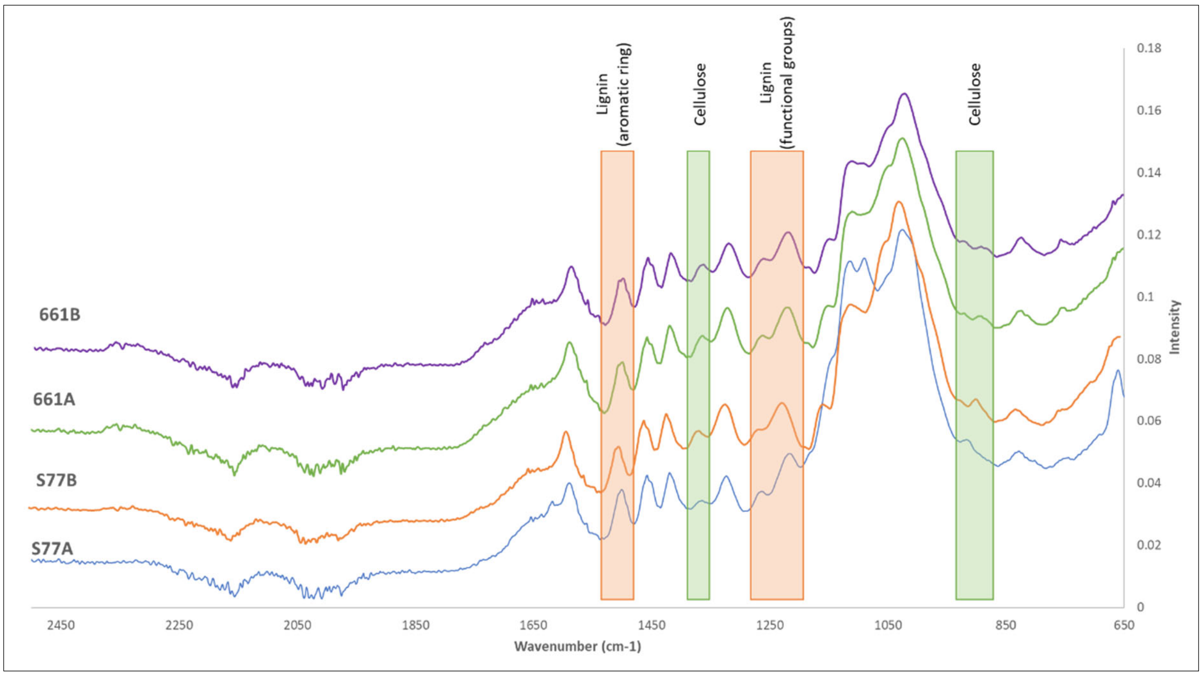

Figure 8: Comparison of fingerprint region of FTIR spectra obtained from the outer layer of the two samples (section A and B). Characteristic peaks of lignin and cellulose are highlighted.

A more exact measure of cellulose content can be obtained by comparing the ratio between the lignin peak at 1505cm^{-1} and the cellulose peak at 1375cm^{-1}: the higher the ratio, the lower the cellulose content (a proxy for increased decay). Comparison between all four samples (Table 2) suggest that the cellulose concentrations are in fact higher in sample S661.

Table 3: Comparison of cellulose concentrations

Sample	Area 1505 peak	Area 1375 peak	L:C ratio (estimate)
S77A	1.2934	0.072	17.96389
S77B	3.0737	0.2313	13.2888
S661A	1.6123	0.2398	6.72352
S661B	1.7029	0.133	12.80376

Initial analysis by FTIR suggests that both samples are well preserved, containing a significant cellulose component. There are only very slight differences between the two samples chemically, with sample S77 having a slightly lower cellulose content, indicative of decay.

Discussion

The results suggest both samples are well preserved, although there has been some loss of cellulose through decay processes. Together, the hardness and the maximum water content values indicate the wood can be categorised as "Class III" (De Jong, 1977). Here wood is characterised by water contents less than 185%, and a sound, hard core beneath a thin deteriorated surface layer, as illustrated below (Figure 9)

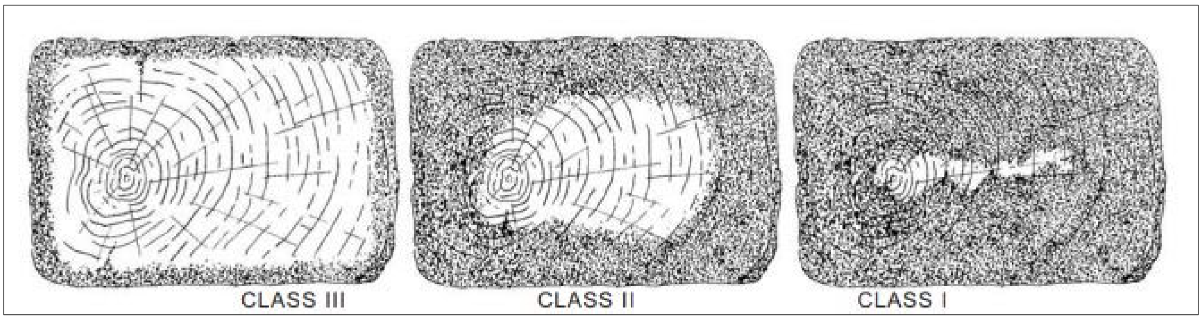

Figure 9: The De Jong classification of waterlogged oak (McConnachie et al, 2008)

The infrared spectroscopy and basic density assays indicate slight loss of cellulose from both samples with sample 661 having apparently undergone less alteration than sample 77.

The slight variation between the two samples is likely to be due to a number of reasons:

1. Post-excavation decay. Sample 77 was initially stored in water before being frozen between 2006 and 2018. The storage water will have been oxygenated to begin with and hence there may have been aerobic microbial activity which would account for the slightly higher loss of cellulose.
2. Variation in site hydrology. Sample 77 came from "further up the timber" (M. Bamforth *pers comm*). The uppermost section of the deposits may be a zone where the water table fluctuates more than the deeper deposits which remain saturated and less dynamic than the upper sequences. The slightly higher loss of cellulose recorded from sample 77 occurred before retrieval in 2006.
3. Inherent sampling issues observed with oak wood. Classic oak decay patterns are typified by pockets of decayed wood adjacent to zones of little or no decay. A more extensive sampling strategy would be required to alleviate sampling problems.

Conclusion

The evaluation successfully relocated the Late Roman/Early Saxon pit containing a wooden ladder, first discovered in 2006. These deposits are currently sealed beneath *c.* 2.5 m of gravel that permits the ingress of water down to the protective layer of alluvium that is sealing the archaeological deposits. The conditions beneath this layer were moist, but not waterlogged.

The inspection of the ladder timbers in the ground showed no visible degradation. The worked faces were fresh and the saw marks from the initial sub-sample retrieval were still visible. The visual inspection concluded that sub-sample of Timber 17 recovered in 2018 is in good condition, whilst that recovered in 2006 is in moderate condition. The results of the laboratory testing corresponded with the visual inspection, concluding that both samples taken from Timber 17 exhibited an excellent degree of preservation.

Both assessments highlighted that the sub-sample recovered during this programme of investigation exhibited a slightly better degree of preservation than the sub-sample taken in 2006. They suggested that the most likely reasons for this were that the first sample has suffered from a degree of deterioration since its retrieval. Also that the second sample was retrieved further down the profile of the pit and therefore may have remained more saturated.

In conclusion, the assessment of the timbers have shown there is **no evidence** to suggest that conditions within the quarry are not conducive to the continued in situ preservation of waterlogged organic archaeological remains, based on the current condition of the wooden ladder stiles as a proxy for the remainder of the buried waterlogged deposits located within this part of the quarry.

Acknowledgements

ULAS would like to extend its thanks to Aaron Laycock and Louisa Taylor of Tarmac for facilitating the work.

The fieldwork was carried out by James Harvey and managed by Matthew Beamish, both of ULAS. Michael Bamforth (York University) recovered the timber subsample and undertook the visual assessment of the ladder. The standard conservation tests were carried out by Charlotte Wilkinson (York Archaeological Trust) and the infrared spectroscopy was conducted by Kirsty High (University of York).

Dr Isabel Lisboa (Archaeologica) commissioned and monitored the work, on behalf of Tarmac. Richard Clark, the Senior Planning Archaeologist for Leicestershire County Council monitored the work on behalf of the planning authority.

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