DigVentures

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Stage 4: Tasks 4.1 – 4.14

Stratigraphic and Specialist Assessment Report

Co-authored by the Project Team

[redacted]

Stage 4: Tasks 4.1 – 4.14

Stratigraphic and Specialist Assessment Report

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Purpose of document

This document has been prepared as a stratigraphic and specialist assessment report on targeted field investigation at [redacted] in fulfilment of Stage 4, Tasks 4.1 – 4.14 for Historic England. The purpose of this document is to report on the results of targeted field investigations undertaken as part of Stage 3, synthesising the stratigraphic and lithostratigraphic information, and relaying the results of subsequent multi-proxy specialist assessment.

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Project summary

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Executive summary

This report details the results of targeted excavations at [redacted] The work was undertaken as part of an evaluation project supported by Historic England under the terms of NPPF Emergency Assistance Funding, in part completion of Stage 4 of the Project Design (Wilkinson et al. 2018). It represents the completion of Tasks 4.1 – 4.14, contributing to our understanding of the site's archaeological and palaeoenvironmental conditions (Aim 3), leading to a greater understanding of the state of preservation of material across the site (Questions 7 and 8) and enabling a chronological framework to be established for the palaeochannel (Questions 9 and 10). This report presents the results of the test pit excavation, incorporating specialist assessment and fulfilling the requirements of Review Point 5 of the Project Design (Wilkins et al. 2018).

Fieldwork undertaken in fulfilment of Stage 3 of the project comprised excavation of four test pits across the base of the quarry to investigate palaeoenvironmental remains and the potential for archaeological remains associated with the palaeochannel previously identified. These test pits targeted an area of the quarry where a Palaeolithic handaxe had been found in association with faunal remains and an area to the south where the palaeochannel survived to a greater depth, allowing its full stratigraphic sequence to be established. Once the sequence had been recorded, samples were taken for multi-proxy assessment – including pollen, plant macrofossils, Mollusca, insects and microvertebrates – faunal remains were lifted for conservation, and OSL samples taken from pertinent parts of the sequence.

Following the fieldwork stage, a full assessment of the remains was made and a chronology for the site and its depositional environment confirmed. The palaeochannel was first formed over 200 ka in MIS7 during a more temperate environment where *Mammuthus cf. trogontherii*, horse, bear, hyena, bison and deer were evident. The river downcut its bed in Phase 2 and aggraded during Phase 3; both periods likely attributable to a cooler phase of MIS7. Overlying the channel were Northmoor Member gravels dating to late substages of MIS5.

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1 INTRODUCTION

1.1 Project summary

1.1.1 The [redacted] project was formulated in response to the 2017 discovery of a Palaeolithic handaxe, found near well-preserved vertebrate remains, within a palaeochannel at [redacted] (hereafter 'the Site'; Figure 1) (NGR 406432 196105). A programme of non-intrusive and intrusive investigation was designed to assess the wider depositional context and taphonomic history of this and other associated material, supported by Historic England under the terms of NPPF Emergency Assistance Funding (Wilkins et al. 2018).

1.1.2 The potential significance of a newly discovered site assigned to Marine Isotope Stages (MIS) 9-7 (~330-180 ka BP) was presented in detail in the Project Design (Wilkins et al. 2018, Section 2). [redacted] with its combination of vertebrate and artefactual remains, and its attendant opportunities for the preservation of waterlogged material, was considered to provide a unique opportunity to investigate human- environment relations and concomitant impact of climate change. Furthermore, given its location at the headwaters of the River Thames, it provides potential for understanding connections and the movement of populations between well-known sites further downstream in the River Thames (e.g. Purfleet, Crayford, Stanton Harcourt) and sites at the northern extremities of occupation of Britain (e.g. Pontnewydd).

1.1.3 An assessment of previously collected materials recovered from the site suggested that the artefacts and the animal remains may not be contemporary (Russ et al. 2019; Review Point 3, and see Section 2.1.2, below). A programme of fieldwalking and investigation of the lithostratigraphic sequence through geoarchaeological boreholes indicated that though much of the site had been disturbed by commercial quarrying and collection activities, in situ deposits survived on the site and likely related to shifting fluvial environment with episodes of flood activity and slower moving marshy conditions (Hogue et al. 2019, Review Point 4, and see Section 2.1.3 below).

1.1.4 This document reports on the results of targeted field investigations, including stratigraphic assessment; multiproxy palaeoenvironmental assessment of pollens, plant macrofossils, molluscs, insects and microfauna; vertebrate assessment; and Optically Stimulated Luminescence (OSL) dating at [redacted] in fulfilment of Stage 4, Tasks 4.1 - 4.23 of the Project Design, Review Points 5 and 6 (Wilkins et al. 2018). Its purpose is to provide the results of fieldwork and provide an Updated Project Design in fulfilment of Stage 4. Excavations were led by the DigVentures team; lithostratigraphic recording and geoarchaeological interpretations were undertaken by Dr Keith Wilkinson and colleagues at University of Winchester; multiproxy environmental assessment was undertaken by Dr Tom Hill at the Natural History Museum (London), Dr Marta Perez-Fernandez and Prof Danielle Schreve at Royal Holloway University of London, Dr Enid Allison at Canterbury Archaeological Trust, and Dr Matt Law at Bath Spa University; vertebrate remains were assessed by Dr Hannah Russ with contributions from Dr Kate Scott, Prof Chris Stringer and Dr Louise Humphreys at Natural History Museum (London), and Dr Mike Buckley at the University of Manchester; on-site conservation was provided by Nigel Larkin; and OSL dating was undertaken by Prof Phillip Toms at the University of Gloucestershire.

Specialist contributions are presented here, providing the basis for initial statements of potential and significance as well as informing the Updated Project Design.

2 RESULTS OF PREVIOUS FIELDWORK

2.1.1 Over the spring of 2017 Neville and Sally Hollingworth (two local enthusiasts who regularly inspect adjacent quarry workings with the express permission of the Landowner) discovered a large number of vertebrate fossils and a flint handaxe at [redacted] The material was collected from the surface and in machine excavated trenches during quarrying and drainage operations, and was removed to a purpose-built storage facility at their family home. Through subsequent enquiries other material came to light, including a further handaxe (found by Mark O'Dell) and two additional mammoth bones (recovered by Theo May and Ben Hinton) taking the total known assemblage from [redacted] at that time to 111 items. In total the assemblage comprised 2 handaxes, 108 bones, teeth and fragments thereof, and one fragment of preserved wood (H.001 to H.111). Neville and Sally Hollingworth produced a photographic catalogue of the 111 specimens (Hollingworth and Hollingworth nd), identifying vertebrate remains to genus and respective element wherever they were able.

2.1.2 An assessment of previously collected material (Stage 2a: Russ et al. 2019) indicated that the two handaxes were Lower Palaeolithic (Acheulean), typically associated with MIS 13–9, ~550-300 ka in Britain. They demonstrated ridge rounding consistent with post-depositional movement in the burial environment, suggesting that they were redeposited at the site and represent evidence for hominin activity in the vicinity earlier than the accumulation of the vertebrate remains. The vertebrate remains included both steppe (*Mammuthus trogontherii*) and woolly mammoth (*Mammuthus primigenius*), which provide a preliminary date for the deposits to the end of the interglacial MIS 7 or beginning of the MIS 6 glacial. No cutmarks or other signs of butchery were observed on the bones, indicating that they had not been exploited by hominins. A review of the published geological information indicated the existence of gravels that outcrop across the study area, although the palaeochannel deposits known to exist at the site had not been previously mapped.

2.1.3 In May 2019 on-site assessment through landscape survey and deposit modelling (Stage 2b: Hogue et al. 2019) highlighted significant areas of modern disturbance caused by commercial quarrying. Furthermore, the Hollingworth's collection activities and the machine excavation this entailed in its final phase was attested both in a number of informal trenches in the quarry base and upcast from these latter. Most of the vertebrate remains identified during fieldwalking were located in areas adjacent to machine excavated trenches. However, it was considered likely that in situ deposits may have survived under substantial accumulations of up cast sediments and spoil heaps leftover from the earlier invasive extraction activities. Initial description of the lithostratigraphy indicated the survival of channel deposits up to 0.6m thick comprising multiple lithofacies and indicating a shifting fluvial environment from episodes of flood activity to times with slower moving water and marshy conditions. It appeared that the vertebrate remains were concentrated in facies reflecting a fast-moving large waterbody. Further details of the existing geotechnical record and the geological borehole work are given in Appendix 1 and Appendix 2.

3 RESEARCH AIMS AND OBJECTIVES

3.1 Aims and objects

3.1.1 The overarching aim of the project was to define and characterise the physical extent of the Site through a programme of non-intrusive investigations and intrusive excavation, obtaining baseline data to facilitate its future management, research, presentation and enjoyment (Wilkins et al. 2018, Sections 4 and 5). The project model was framed as four overarching aims each with associated key questions/objectives that provide a framework for the methods, stages, products and tasks required to deliver the project.

3.1.2 This report has been produced in fulfilment of Stage 4 (Tasks 4.1–4.14; Review Point 6), and Questions 7–10 of Aim 3, Understand the Site's archaeological and palaeoenvironmental conditions (Wilkins et al. 2018, 18):

- Q7. What is the current state of preservation of the archaeological and palaeoenvironmental material across the site?
- Q8. How well do artefacts and palaeoenvironmental remains survive and what is their significance?
- Q9. Can a dating framework for the palaeochannel be established, and how does this inform the palaeoenvironmental and functional context of the excavated material?
- Q10. What is the range and spatial patterning of artefacts recovered from the palaeochannel, and what can be inferred of the early hominin presence from this material?

4 METHODOLOGY

4.1 Project model

4.1.1 The archaeological fieldwork and laboratory work was carried out, unless otherwise stated, in accordance with the methodology defined in the Project Design (Wilkins et al. 2018) and in line with the suggestions outlined in the Landscape Survey and Deposit Modelling Interim Report (Hogue et al. 2019; Task 2.14). The excavation methodology for each test pit is outlined below in Section 4.2, and the sampling methodology for each sub-discipline in Section 4.3.

4.2 Excavation methodology

4.2.1 Excavations were undertaken between 20th May and 7th June 2019. Four test pits were excavated and existing standing sections adjoining test pits cleaned and recorded (Figure 2). All test pits were marked out on the ground using a GPS, and initially scanned for surface finds prior to excavation.

4.2.2 Each test pit was excavated by hand, if possible, to the underlying bedrock comprising the Oxford Clay Formation and Kellaway Clay Member. All lithostratigraphic units were excavated in 0.10m thick horizontal spits (or less where a new LU was encountered) and bulk 40L sub-samples wet-sieved and sorted onsite as a control measure to calibrate the loss of artefactual or vertebrate remains during excavation.

4.2.3 DigVentures' Digital Dig Team system was used for recording. Each stratigraphic unit was allocated a unique number based on its location in relation to the grid system established during fieldwalking (e.g. Test pit 1, grid square 34, 34001). A list of all context records is given in Appendix 3 alongside the link to the relevant DDT entry from where associated finds, samples, plans, sections, photographic records and 3D models can be explored. The ARCA team maintained complementary handwritten fieldnotes and sketch drawings of lithostratigraphic sections, which were subsequently transferred into RockWorks. Correlations between each of the DV Units, ARCA Units, facies and interpretative phasing is given in Appendix 4. For clarity the DV Units are used throughout the following and equivalent ARCA Units indicated in square brackets where necessary (e.g. Unit 34001 [i]).

4.2.4 Test pits and adjacent standing section faces remaining from earlier informal excavations were hand cleaned before being 3D programmatically modelled and laser scanned. Photogrammetry models are available for viewing online through the following links:

- Test Pit 1
  https://sketchfab.com/3d-models/tp1-f03bf50450d84e5f955c08ba50ae65fe

- Test Pit 2
  https://sketchfab.com/3d-models/tp2-9e8b4d6564ff4cd987ddf3debf03083b

- Test Pit 3
  https://sketchfab.com/3d-models/tp3-b307c55cd5e84011847de619a726f89d

- Test Pit 4
  https://sketchfab.com/3d-models/tp4-95064cb755674818ba3359f51795ae9e

4.2.5 All laser scanning was undertaken using the Leica MS60 total station at 10mm resolution and lithostratigraphic boundaries were identified using colour-coded mapping pins, inserted into section face along the lower bounding surface of each lithostratigraphic unit, and surveyed as series of polyline nodes. A copy of the laser scan data will be submitted with the archive.

Test Pit 1

4.2.6 A 3.7 x 2.3m test pit extending the existing trench in which the handaxe and vertebrate remains were recovered was proposed following Stage 2b (Hogue et al. 2019, Section 6.1). The main purpose of the test pit was to provide the necessary information to better understand the depositional sequence and establish baseline data for establishing the potential for survival of in situ artefactual and vertebrate remains. The spoil heap from which the handaxe was recovered was removed and sieved for discarded artefactual and vertebrate remains, although no further finds were recovered. Unfortunately, no in situ palaeochannel deposits survived underneath these spoil heaps, which sat directly on top of the Oxford Clay Formation. As such, further investigative work and test pitting was relocated *c.*3m north of the originally proposed excavation area targeting an area with vertebrate remains laying on the surface and immediately adjacent to ARCA BH8A and PT5052 (see Appendix 2). A relatively shallow thickness of deposits survived across the area – no greater than 0.2m – as they had been heavily truncated by machining associated with the earlier collection activities, and as such the excavation area was enlarged to increase the potential for recovering of artefactual and vertebrate remains. Test Pit 1 consisted of an *c.*6m x 1m area that was cleaned down to the top of the in-situ channel deposits, the immediately adjacent standing section edges leftover from earlier collection activities were cleaned and straightened, and an *c.*3m x 1m test pit that was then excavated down to the Oxford Clay Formation (Figure 3 and Figure 4).

Test Pit 2

4.2.7 The purpose of the test pit was to help characterise and gain a better understanding of the thickest part of the palaeochannel sequence (see Hogue et al. 2019, Section 6.1). Test Pit 2 was the formalisation of an existing trench created by the Hollingworths. It formed a U-shape, was open to the west, and measured *c.* 4.5 x 4.0m (Figure 5). It needed to be continuously pumped to remove standing water, while the east, south and west-facing standing sections were cleaned and recorded (Figure 6, Figure 7, and Figure 8). Even though pumping was sufficient to enable the collection of samples from the existing section faces, the continuous inundation of water made further excavation and extension of the trench impracticable. Test Pit 2 was in part previously recorded during the preliminary geoarchaeological work (ARCA PT 3941).

Test Pit 3

4.2.8 Test Pit 3 measured *c.*8m long and along most of its length measured *c.*1.0m wide, the northernmost *c.*2m comprised a *c.*0.40m wide extension. Test Pit 3 was excavated to link a trench previously excavated by the Hollingworths and Test Pit 2 (Figure 9, Figure 10, and Figure 11). As such, Test Pit 3 incorporated boreholes ARCA BH38, ARCA BH39 and ARCA BH40. The purpose of the test pit was to help characterise the deposits thinning towards to the margins of the palaeochannel and understand the depositional environment of the vertebrate remains previously noted on the surface (Hogue et al. 2019, Section 6.1). Test Pit 3 was excavated to the Kellaway Clay Member bedrock in its northern half and to the Oxford Clay basement at its southern end.

Test Pit 4

4.2.9 Test Pit 4 comprised a 1m x 1m test pit excavated adjacent to ARCA BH20 (Figure 12). During borehole evaluation ARCA BH20 could not be excavated more than *c.*0.5m below the quarry base because of the ingress of water and was terminated at the contact between fine grained and dense gravel strata (subsequently referred to as the boundary between Units 14002 and 14003). Even with the use of a pump a similar problem occurred during the excavation of the test pit, which reached only *c.*1m below the quarry base.

4.3 Sampling strategy

4.3.1 A range of sampling techniques were employed during the excavation to understand the site's archaeological and palaeoenvironmental conditions, as outlined in the Project Design (Aim 3, Wilkins et al. 2018). This included the recovery of monoliths to enable controlled examination of the sediment sequence in laboratory conditions and to allow sub-samples to be collected for palynological assessment (Table 1); bulk column samples for analysis of plant macrofossils, microvertebrates, insects and Mollusca (Table 2); targeted sedaDNA samples; and OSL samples for dating (Table 3). A full sample list is given in Appendix 7 and relevant descriptive information of samples submitted for specialist assessment are given in detail below.

Monoliths

4.3.2 Four monolith samples, each measuring 500 (height) x 100 (length across the section) x 100mm (depth into the section) were collected. In the case of Monolith 4, a projecting blank matching the monolith dimensions was cut using a trowel, the tin hammered (using a rubber tiling mallet) onto the blank and the corners surveyed, and finally the blank cut from the section using a spade. A blank was not required in the case of Monolith 1–3 and rather the tins were simply hammered into the section, their corners surveyed and then they were removed by cutting behind them with a spade. The monolith tins were each labelled and wrapped in plastic film before being transported to the University of Winchester for description and sub-sampling.

Pollen

4.3.3 The monolith samples were cleaned by removing the surficial 1-5mm of sediment with a scalpel, photographed, the strata described (see Appendix 5), and then sub-sampled for palynology before being placed in storage. A total of ten palynological samples selected for assessment were sent to Dr Tom Hill of the Natural History Museum (Table 1). Pollen preparation followed standard techniques including potassium hydroxide (KOH) digestion, hydrofluoric acid (HF) treatment and acetylation (Moore et al., 1991). A count of at least 200 total land pollen grains (TLP) excluding aquatics and spores was attempted for each sample.

Test Pit	Sample No.	Monolith No.	Depth	DV Unit	LU
1	86	4	0.08-0.09 m	31005	iv
1	86	4	0.46-0.47 m	31006	v
2	84	1	0.25-0.26 m	25009	A
2	84	1	0.35-0.36 m	25009	A
3	85	2	0.07-0.08 m	20012	H
3	85	2	0.19-0.20 m	20005	F
3	85	2	0.27-0.28 m	20005	F
3	82	3	0.05-0.06 m	20002	B
3	82	3	0.19-0.20 m	20003	D
3	82	3	0.40-0.41 m	20004	E

Table 1. Palynological sub-samples from monoliths

General Biological Analysis (GBA) Columns

4.3.4 Thirty-six samples of between 10 and 40 litres volume were collected for 'general biological analysis' (GBA) purposes (*sensu* Dobney et al. 1992) by cutting out blocks measuring 300 (length across the section) x 300 (depth into the section) x 20-100mm (thickness and depending on stratum properties) (Appendix 2). Such samples were removed with a clean spade and placed into labelled 10l sealable plastic tubs. The corners of each sample column so collected were surveyed, while the samples were left at Hills Aggregates' [redacted] compound for later processing (see Section 6).

4.3.5 During the period 19-21 August 2019 ARCA processed 18 of the 36 samples that had been taken for GBA purposes and were stored in the [redacted] facility at [redacted] (see Appendix 3). Processing was carried out adjacent to the present [redacted] quarry, while the water required was pumped from the lake to the north of the active works. Samples were soaked in water prior to processing and then wet sieved through 0.50 and 0.25mm mesh. Residues retained on both meshes were separately placed, together with an equal volume of water in labelled 10l tubs and ziplock bags. All samples (including those that had not been processed) were transported to the University of Winchester on completion of the processing works. Thereafter, those GBA samples selected for biostratigraphic assessment of microvertebrates, Mollusca, insects and plant macro remains were transported to the Department of Geography, Royal Holloway, University of London for study and subdivision (Table 2).

Sample No.	Test Pit	Column	Depth (m)	DV Unit	ARCA Unit
9	1	I	0.00-0.09	31002	iv
10	1	I	0.09-0.17	31002	iv
11	1	I	0.17-0.25	31006	v
14	2	I	0.10-0.15	25002	K1
18	2	I	0.30-0.35	25003	K2
22	2	I	0.47-0.52	25005	K4
26	2	I	0.75-0.80	25008	B1
67	3	I	0.18-0.28	20003	C
69	3	I	0.38-0.41	20003	C

Table 2 GBA samples submitted for assessment

Plant Macrofossils

4.3.6 Marta Perez-Fernandez (Royal Holloway, University of London) undertook macrofossils assessment on 100ml sub-samples. The samples were sieved through a 0.125mm sieve using distilled water and gentle hand pressure. The material remained in a wet state during the identification process. Small sub-samples were successively placed in a water-filled petri dish and gently teased apart to extract any seeds/seed part and other plant fragments. The samples were initially scanned wet for the presence of plant remains using a Motic binocular microscope. Each sample was scanned to establish the quantity, quality and diversity of plant macrofossil remains. Where preservation allowed, plant remains recovered were identified to genus and where applicable to species. Absolute counts of discrete plant components (e.g. seeds and fruits) were made. Abundance of other remains and components (e.g. roots, unidentifiable organic matter, algae, etc.) was estimated using a key (Hughes and Barber, 2004) to highlight the concentrations/quantities of material identified from each sample.

Identifications were made using a combination of the modern comparative reference material available at Royal Holloway University of London and reference material, and standard seed atlases and references, *Flora of the British Isles* (Claphan et al, 1957), *New Flora of the British Isles* 2nd edition (Stace, 1997) and *Digital Seed Atlas of the Netherlands* (Cappers et al, 2006). The term 'cf' denotes a tentative identification.

Microvertebrates

4.3.7 Nine sub-samples equivalent to 10L unprocessed sediment (apart from <9> and <14> which were equivalent to 20L) were selected for microvertebrate assessment. Only the larger size fraction (>0.5mm) was required for assessment of microvertebrate remains. Each sample was weighed, washed, and dried in a drying cabinet at 55°for 24 hours. After drying, each sample was graded through a nest of sieves (>8mm, >2mm, >1mm, >0.5 mm and then scanned under a low-power binocular microscope (Motic SMZ-168 with .75 to 5x magnification).

4.3.8 For mollusc and insect remains, sub-samples equivalent to 5L unprocessed sediment were sub-divided and distributed to the relevant specialists by Danielle Schreve (Royal Holloway, University of London). For <9>, <10>, <11>, <14> and <26 no processing was undertaken before distribution. For. <18>, <22>, <67> and <69> samples were first scanned for microvertebrates and then sub-divided and distributed due to relatively small bulk samples sizes.

Insects

4.3.9 For the study of the insect remains all dried material was re-hydrated (from those samples initially sorted for microvertebrates; see Section 4.3.8) and separate fractions re-combined. The samples were then gently wet-sieved to 0.3mm and the organic component was separated from mineral material by the 'washover' method. For two samples, the amount of organic material recovered was very small and the washover was examined in its entirety. Paraffin flotation to extract insect remains was carried out on the remaining washover fractions following the methods of Kenward et al. (1980). The resulting paraffin flots and the two washovers were scanned in petri dishes of industrial methylated spirits (IMS) for the presence of insects and other invertebrates using a low-power stereoscopic zoom microscope (x10 – x45). Abundances of beetles (Coleoptera) and bugs (Hemiptera) were estimated semi-quantitatively as + (1 - 3 individuals), ++ (4 – 10), +++ (>10). Other invertebrate remains in the samples were recorded simply as present (P) or common (C). The state of preservation of the insect material was recorded, and the potential to provide detailed environmental data was assessed for each assemblage. Taxa have been categorized into broad ecological groups based on the system of Kenward et al. (1986), see Appendix 8. Nomenclature for Coleoptera follows Duff (2018).

Mollusca

4.3.10 Residues were weighed and air dried, then sorted into fractions using a nest of sieves (4mm, 2mm, 1mm, 500μm, 250μm) before being scanned under a low power microscope for Mollusca. Mollusca were identified to the level of genus or species using a reference collection. Ecological information was derived from Evans (1972), Kerney and Cameron (1979), Macan (1977), Kerney (1999), and Davies (2008). Nomenclature follows Anderson (2008).

sedaDNA

4.3.11 Dr Ben Pears (University of Southampton) collected nine samples (DV Sample No. 31–48) for sedaDNA analysis from sections in Test Pits 1, 2 and 3 by inserting (with the aid of a rubber tiling mallet) sealable plastic sample vials into cleaned section faces. Two such vials were taken at each sample location, while each vial position was surveyed, then removed, sealed, labelled and taken to the University of Southampton for further study. None of the sedaDNA samples were selected for further assessment-level reporting.

OSL

4.3.12 A total of seven OSL samples were collected by inserting (using a rubber-headed tiling mallet) 50mm-diameter, 200mm-long plastic tubes (two tubes per sample – three in the case of OSL1) into sections of Test Pits 1, 2 and 3. Sample tubes were photographed in situ and their location surveyed before extraction. During the latter procedure, considerable effort was made to prevent exposure of the open ends of the tube to light, while the latter were sealed using four or more layers of duct tape to prevent light ingress. A separate sample of sediment was collected (in two layers of zip lock bags) in the sediment between each pair of sample tubes for laboratory moisture content and background radiation measurement. On 4 September 2019 the OSL samples were transported to the University of Gloucestershire for further processing and six OSL samples selected for dating (Table 3)

Test Pit	Sample No.	Field Code	DV Unit	ARCA Unit
1	62	OSL 3a	31006	BH39V
1	63	OSL 3b	31006	BH39V
2	57	OSL 1a	25009	A
2	58	OSL 1b	25009	A
2	59	OSL 1c	25009	A
2	60	OSL 2a	25004	K2
2	61	OSL 2b	25004	K2
3	64	OSL 4a	20003	C
3	65	OSL 4b	20003	C
/	76	OSL 5a		49
/	77	OSL 5b		49
/	80	OSL 7a		28
/	81	OSL 7b		28

Table 3. OSL samples submitted for assessment

6 STRATIGRAPHIC AND LITHOSTRATIGRAPHIC RESULTS

Keith Wilkinson (ARCA, University of Winchester) with contributions from Monika Knul, Paul Lincoln, Jenni Sheriff (ARCA, University of Winchester) and Josh Hogue (DigVentures)

6.1 Introduction

6.1.1 The following stratigraphic and lithostratigraphic assessment fulfil Stage 4 (Tasks 4.1 and 4.2) and addresses aspects of Aim 3 Questions 7–10 of the Project Design (Wilkins et al. 2018, see Section 3.1.2 above) by establishing a geological and chronological narrative for development of deposits at [redacted] Five phases of palaeochannel development were recorded in the strata. Initially the river was a broad channel or series of channels (Phase 1) that likely downcut into a deeper channel (Phase 2), followed by faster flow in multiple channels (Phase 3) and finally slower flow in more sinuous channels (Phases 4 and 5). The lifecycle of the river was observed across all test pits and is outlined in detail in Sections 5.2 – 5.5.

6.1.2 The [redacted] deposits outcropping in the quarry walls and as excavated during Stage 3 composed of the lithofacies given in Table 5, several of which are the same as described in the Phase 2A and Phase 2B geoarchaeological work (see Appendix 1 and Appendix 2).

6.2 Test Pit 1

6.2.1 Unconformably (Miall 1996 6th order bounding surface) overlying the Oxford Clay Formation basement and filling localised hollows in that stratum were fossiliferous sediments of facies 6 (Unit 31006 [v]), which were in turn separated by a sharp boundary (Miall 1996 2nd order bounding surface) from the overlying gravel strata (Units 31002 and 31004–5 [iv-ii]) (Figure 3 and Figure 4). The extracted mammoth tusk and other vertebrate remains (see Section 8) rested either on Unit 31006 or the Oxford Clay (Unit 31003), and were banked up by gravels of Unit 31002 [iv]. The latter are of facies 3 and comprise sets of less than 0.05m thickness. Unit 31002 was conformably (Miall 1996 2nd order bounding surface) overlain by two further sand and gravel units, comprising firstly fine sands containing limestone pebbles and granules, and shells of the mollusc species, *Valvata piscinalis* (Unit 31005 [iii]. facies 6) and secondly a clast-supported pellet gravel (Unit 31004 [ii], facies 3). These latter and Unit 31002[iv] all pinched out to the south as a result of truncation, the latter presumably as a result of quarry activity given the presence of poorly sorted, unstructured matrix-supported gravels (Unit 31001[i]) overlying the unconformity.

6.3 Test Pits 2 and 3

6.3.1 Test Pits 2 and 3 are treated together here as the units in the two pits were stratigraphically linked with the connection between the two supplied by Units 25001=20006. The earliest stratum unconformably (Miall 1996 6th order bounding surface) overlying the Oxford Clay Formation bedrock in the Test Pit 2 sequence was Unit 25009 (facies 7) (Figures 5, 6, 7 and 8). Indeed, this unit comprised weathered particles of the Oxford Clay, from which it could only be differentiated based on fossil inclusions (shells of freshwater Mollusca) and a lesser compaction. The former indicate that the silt/clay had been fluvially reworked and deposited either within an abandoned channel or on a floodplain. Unit 25009 was then unconformably overlain by bedded gravels of Units 25006 (facies 1) and 25007 (facies 4), indicating a transition to bedload flow in a high energy environment. These coarse-grained strata varied in structure and clast-support, (i.e. to coarse pebbles) while the latter in the west facing section (Unit 25006 [C]), suggested more rapid flow in this location. There were also some indications of flow direction, for example there was localised imbrication in the north-facing section suggesting flow from south-south-east to north-north-west (Figure 8). Similarly, fine, lenticular beds of silts to medium sands that climbed to the north and east [I1 and I2], had formed within Unit 25006 in the west and north facing sections, suggesting flow in the same direction. These lenticular beds were also (unlike the surrounding gravel facies) rich in mollusc shell and particularly *Bithynia* sp., suggesting accretion in a large body of water. The gravel strata of Unit 25006 were in turn unconformably overlain by gravel and fine-grained channel or scour hollow fills (Units 25006 [E], 25011 [G] and 25010 [H] – facies 2 and EE) in the south-facing section. The latter interpretation is more parsimonious given that the strata had accumulated in a cut immediately to the west (i.e. upstream according to the data outlined above) of two rounded, boulder-sized septarian nodules that sat on the surface of Unit 25009 (Figures 5 and 6). The lower of these boulders was of Kellaway Clay, but the upper was a conglomerate derived from Jurassic lithologies outcropping to the north and west of the site.

6.3.2 Fine-grained deposits unconformably (Miall 1996 2nd order bounding surface) overlaid the gravel strata of Unit 25006, collectively forming a 0.5m-thick lenticular bed in the west and eastern part of the south-facing sections between it and Unit 25001 [J]. As is described further below, the latter stratum was also found in Test Pit 3, thereby providing a link between the stratigraphies of Test Pit 2 and Test Pit 3. The 2.5m+ wide lenticular bed (Units 25005, 25004, 25003 and 25002, facies 8 and XX) was normally bedded as a whole - trending from predominantly sand- to silt-clay dominated strata - and was locally laminated, particularly within Unit 25003. It might have formed within either a channel through which moderate-low energy flow was directed or a large scour hollow. Whichever, the feature was succeeded by further clast- and matrix-supported gravels (Unit 25006, facies 1) that were indicative of higher velocity flow, again in a north-eastwards direction given the pattern of imbrication in the west and south-facing sections.

6.3.3 As noted above, Unit 25001 [J] of Test Pit 2, was also encountered at the base of Test Pit 3 as Unit 20006 (facies 1) (Figures 9, 10 and 11). Overlying the latter and separated from it by an unconformable contact (Miall 1996 5th order bounding surface) was Unit 20013 (G), a massive, well-sorted brown silt (facies 10), forming the lowest fill of a 3m wide palaeochannel (here termed 'palaeochannel **a**'). However, following deposition of Unit 20013 (G), palaeochannel **a** was abandoned and/or moved to the east and fills of a second 2m wide palaeochannel ('palaeochannel **b**') were emplaced. However, either at the same time as palaeochannel **b** was active or afterwards, palaeochannel **a** was reactivated and filled by an Oxford Clay-derived, massive silt/clay (Unit 20012, facies 7). The fills of palaeochannel **b** comprise Units 20005 (F), 20004, 20003, 20002 and possibly, 20001. Unit 20005 (F) was a thinly laminated silt/fine sand and organic mud (facies 8), which in turn was truncated, probably as a result of erosion of the channel sides by the passage of high energy flow, resulting in an unconformity (Miall 1996 2nd order bounding surface). Palaeochannel **b** was then infilled by initially laminated sands (Unit 20003, facies 5 and facies 8), then massively (Unit 20002, facies 6), and finally normally bedded silts to medium sands (Unit 20002, facies 9). The colour of the fine-grained particles in the last of these units suggest derivation from the Oxford Clay Formation. Units 20002 and 20003 were truncated and were separated from Unit 20001, a clast and matrix-supported gravel of similar properties to Unit 20006 (facies 1), by an unconformity (Miall 1996 5th order bounding surface). While Unit 20001 may have been a high energy fill of a rejuvenated palaeochannel **b**, it is more likely given its extent, that it was either the lowest part of the Northmoor Member or even Northmoor Member strata redeposited during quarry operations. Indeed, the truncation of Units 20002 and 20003 could have been caused by a mechanical excavator. The overall impression of the infilling of palaeochannel **b** was that it took place in moderate to low flow energies and that, initially at least, flow was punctuated. Later flow was of a more consistent and moderate energy.

6.3.4 Palaeochannel **b** extended eastwards as far as a cliff in the Kellaway Clay Member bedrock, against which it and its fills butted [Unit 20004 (E)] and onlapped (Units 20003 and 20002) (Figure 9, 10 and 11). Further to the east still, Test Pit 3 joined one to the Hollingworth's test pits which was recorded during the geoarchaeological borehole stage of works as 'ARCA BH38'. Here, vestigial Oxford Clay deposits (Unit 20015) overlaid the Kellaway Clay, while within involutions of the former were matrix-supported gravels of Unit 20008 (ARCA BH38 0.15-0.25m, facies 4) and also including a boulder-sized mammoth tusk in one such hollow. As Figure 9 and 10 demonstrates, Unit 20008 is stratigraphically earlier than the fills of palaeochannel **b**.

6.4 Test Pit 4

6.4.1 The basal gravels (Unit 14003, facies 1) were at least 0.5m thick, and were organised in c. 0.1m-thick sub-horizontal sets dipping slightly to the south and west, and differentiated by colour and the quantity of matrix (Figure 12). The gravels were unconformably (Miall 1996 5th order bounding surface) overlaid by further matrix-supported gravel (facies 4) and also silt-fine sand strata (facies 6), which were collectively designated as Unit 14002. Facies 4 was found both locally above and below facies 6, the contacts between the facies were diffuse and both facies were massively bedded and fossiliferous (they contain shell of the freshwater prosobranch mollusc, *Bithynia* sp.). The sequence was completed by further dense, matrix-supported gravels of Unit 14001 (facies 1), which were separated from Unit 14002 by an unconformable (Miall 1996 5th order bounding surface) boundary.

6.5 Quarry walls

6.5.1 Formal descriptions of the deposits exposed in the quarry walls are provided in Appendix 6, while only a brief summary is given here. The deposits were comprised of a variety of facies (not included in Table 5), consisting mostly of horizontally-bedded, clast- and matrix-supported sheet gravels (see Appendix 6). These latter were predominantly of sub-rounded limestone and sandstone, but moderate quantities of quartzite clasts were also noted. Occasionally beds were cross bedded (planar and trough cross bedding were both noted), but even these were arranged horizontally. Fine-grained beds were rare and where present comprised sand and granular sets within the cross bedded strata, and occasional lenticular beds of sand in the lea of gravel structures. Silt/clay beds were extremely rare and occurred only towards the base of the sequence (possibly indicating derivation from the Kellaway Clays). The predominantly coarse-grained sequence outlined above was overlain by massive silt/clay deposits that formed on the present Thames-Churn floodplain prior to quarrying. The present soil had developed within the latter.

6.6 Interpretation

6.6.1 The broad sequence of deposition in the [redacted] quarry as witnessed by strata exposed in the test pit sections and the quarry walls can be divided into several phases.

Phase1

6.6.2 The earliest manifestation of the palaeochannel was likely as a broad channel or series of channels that ran through the site north and west of a cliff in the Kellaway Clay bedrock that stood at the south and east of the quarry. The diversity of lithologies recorded suggest that during this phase a variety of flow regimes existed within the channel, ranging from low to high energy (facies 3, 6 and 7), while channel sinuosity also varied. Nonetheless, there appears to have been a broad trend for increasing energy levels through time. A key source of sediment was strata of the Oxford Clay Formation into which the channel was cut. Vertebrate bone was deposited in the channel during its early low energy cycle and these fossils were later banked up by gravels deposited under high flow energies. This phase of channel-deposition was witnessed in Test Pit 1 (Units 31006, 31002, 31005 and 31004, equivalent to ARCA Units v–ii), the base of Test Pit 2 (Unit 25009), and the easternmost margin to Test Pit 3 (Unit 20008).

Phase 2

6.6.3 The channel was then likely downcut, deepening the channel, and thereby truncating and removing the deposits that were laid down during its earliest manifestation. The downcutting left Unit 20008 perched >1m above the other residual channel deposits.

Phase 3

6.6.4 Following downcutting, renewed coarse-grained accretion took place in a high energy flow regime across the whole former channel area. However, in contrast to the broad channel that flowed during the earliest manifestation of the river, the ran as multiple shallow channels of low sinuosity and flowed in a SSW-NNE direction. In contrast to Phase 1, the majority source material was from limestone geologies to the north and west. Strata of Phase 2 were predominantly of facies 1, and were found in Test Pit 2 (Units 25007, 25006 and 25001) and Test Pit 3 (Unit 20006). At some stage during deposition of the gravels of Phase 3, either a channel became cut off from the main axial flow or a large scour hollow developed in the area of Test Pit 2. This depression (Phase 3a) was then infilled by sediments that were deposited in moderate to very low flow energies (Units 25004-25002, facies 8). The channel/scour hollow then once more became incorporated in the wider channel belt (Unit 25006).

Phase 4

6.6.5 During Phase 4, the bedform and flow of the channel altered once again, and multiple small (3–5m wide, <1m deep) channels developed. Flow passed down these sinuous features during alternating episodes of moderate to low energy, leading to their infilling, abandonment and rejuvenation. This phase was represented only in Test Pit 3 and by Units 20005–20002 and 20012 (facies 8, facies 5, facies 9 and facies 6);

Phase 5

6.6.6 Events between Phases 4 and 5 are unclear given that contacts between the Northmoor Member deposits and the palaeochannel fills were either not preserved within [redacted] quarry (i.e. they had been removed by quarrying), or they were buried beneath the battened slump which had formed against the quarry walls. Phase 5 deposition was of sheet gravels of a broadly similar character to those forming in Phase 3, although the thickness of the Phase 5 deposits suggested that the bedform of the latter was longer lasting.

7 BIOSTRATIGRAPHIC ASSESSMENT

7.1 Introduction

7.1.1 The following biostratigraphic assessment fulfils Stage 4 (Tasks 4.4 and 4.5) and addresses aspects of Aim 3 Questions 7–10 of the Project Design (Wilkins et al. 2018, see Section 3.1.2 above) by contributing baseline data regarding the survival of pollen, plant macrofossils, molluscan, insect, and microvertebrate remains within the deposits necessary for establishing a climatic and environmental framework for understanding the formation of the deposits at

7.1.2 Biostratigraphic assessment was undertaken in line with the methodological procedures defined in the Project Design (Wilkins et al. 2018), Landscape Survey and Deposit Modelling Interim Report (Hogue et al. 2019), and refined above (see Section 4.3). A summary of the results for each proxy is given below and further supporting information is given in Appendices Appendix 8–Appendix 11.

7.2 Pollen

Tom Hill (Natural History Museum)

7.2.1 Quaternary pollen was found in very low abundance within all the samples under assessment. Only Monolith 4 (sample depths 0.08m and 0.46m) had pollen in higher relative abundance, but still insufficient amounts to achieve a full assessment count. Of the taxa occasionally present, the main species were *Pinus* (pine), Poaceae (wild grasses) Asteraceae (daises etc), Lactuceae (dandelions), Caryophyllaceae (Pink Family) and Chenopodiaceae (Goosefoot Family). The two samples from Monolith 4 also contained occasional grains of *Carpinus* (hornbeam) in addition to those summarised above.

7.2.2 The overall poor pollen preservation was somewhat surprising given the relatively organic-rich nature of some of the samples. To confound the assessment further, the pollen signal was confused by the extensive presence of pre-Quaternary palynomorphs throughout. More specifically, Jurassic pollen and spores, in addition to Jurassic dinoflagellate cysts and acritarchs, were encountered in abundance within all samples. Most of the taxa that were encountered were associated with the surrounding bedrock that was encountered within the immediate area (Stephen Stukins, pers. comm). Examples included species of the dinoflagellates *Lithodinium, Meiurogonyaulux, Ctenidodinium, Rigaudella* and *Rhynchodiniopsis*.

7.2.3 The pollen grain of the extinct coniferous plant *Classopollis* was in abundance in all samples under assessment, whilst pre-Quaternary bisaccate grains were also extremely common. In addition, the level of preservation of these pre-Quaternary palynomorphs was found to be excellent in many of the samples.

7.2.4 The high level of preservation of the pre-Quaternary palynomorphs hindered assessment due to the substantial dilution of the pollen signal assumed to have developed from the surrounding vegetation as the time of sediment accumulation. As such no full assessment counts were possible for any of the samples under consideration. The pollen encountered was too restricted in abundance and floral diversity to provide much in terms of palaeoenvironmental interpretations. In contrast, the overall level of preservation and abundance of pre-Quaternary palynomorphs indicates that the sediments associated with the strata under investigation must have either travelled a very short distance from their bedrock source area to the area of deposition or, perhaps in some of the lowermost samples, sampling of the Jurassic strata has perhaps occurred.

7.2.5 The sequences under assessment were taken from deposits believed to underlie the Northwood Member, and hence likely predate c. MIS5. Whilst the dominance of Jurassic palynomorphs hindered the study, it was further impacted by the relative abundance of pre-Quaternary bisaccate pollen within this Jurassic signal. Due to their abundance and excellent preservation, it was subsequently not possible to differentiate between geologically derived bisaccates and known Quaternary bisaccate taxa (*Pinus, Abies, Picea*) with sufficient confidence. This is somewhat unfortunate due to the common use of the presence of *Abies* (fir) and *Picea* (spruce) within UK pollen sequences when attempting to apply broad age constraints to stratigraphic archives. *Abies* and *Picea* are not native to the UK during Holocene and hence their presence can often indicate earlier interglacial episodes. The presence of hornbeam in Monolith 4, does provide a crude age estimate in that it confirms these sediments predate the Holocene interglacial. Hornbeam was not a native species in the earlier Holocene, only arriving in and recolonising the UK c. 3,000yrs BP. Consequently we can be confident that the deposits date to a previous interglacial, but that is not unsurprising given the age of the overlying Northmoor Member and the presence of mammoth tusks within the associated strata.

7.3 Plant Macrofossils

Marta Perez-Fernandez (Royal Holloway University of London)

7.3.1 The survival of plant macrofossils was generally mixed. Overall rush (Juncaceae) seeds were the most commonly occurring plant remains in these samples. Occasionally other seeds and fruits were also present, but often it was not possible to identify these to species level due to their broken and/or highly degraded nature. The information inferred from these samples indicates wet conditions with occasionally drier periods. The rushes, grasses and green algae suggests that local conditions are wet and open grassland and that there was some degree of free-flowing water. Although there was some herbaceous vegetation generally occupied transitional zones between open water and terrestrial habitats, this can be associated with freshwater or brackish systems, and the water may be slow moving or stagnant.

7.3.2 There was evidence of woody material and/or roots in the samples from the top of the sequences, possibly indicating that the palaeoechannel was drying out but still lacking of conditions to support many terrestrial plant communities. In the case of fibrous material, it was difficult to establish definitive species level identifications in the absence of seeds or other diagnostic features, such as surface, sculpturing or definitive cellular patterns. Reeds and grass material was therefore classified under the broad family of Juncaceae (rushes), Cyperaceae (sedges) and Poaceae (grasses). The composition of plant macrofossil remains recorded for each sample is discussed below and presented in Appendix 8.

Test Pit 1

7.3.3 Three samples were examined for plant macrofossils from TP1: two from Unit 31002 and one from Unit 31006.

7.3.4 The quantity and diversity of plant macrofossils remains was relatively poor in Sample <9> with a high frequency of woody detritus and unidentifiable grasses. Frequent ostracods and common insect fragments were also present. The poor quantity of plant macrofossils remains indicates a base-poor environment, where amphibious and terrestrial plant communities are rare and unsupported.

- <9> Unit 31002
  - Juncaceae
  - *Silene* cf
  - *Thalictrum* cf

7.3.5 Plant macrofossils and insect remains were relatively rare in Sample <10> and there was a moderate presence of roots/woody material, grasses and a few snails. This indicates conditions were devoid of nutrients required to support the majority of aquatic and terrestrial plant communities. It is possible that the surface was therefore very wet and unstable.

- <10> Unit 31002
  - Cyperaceae
  - *Potamogeton*

7.3.6 There was an increase in grasses, reeds and green algae in Unit 31006 with a major increase in ostracods and insect fragments. The frequency of rushes and grasses indicates that an open wet grass environment was beginning to develop comprising emergent herbaceous stands of vegetation that occupied transition zones between open water and terrestrial habitats. Conditions were wet and base-poor supporting few mono-dominant aquatic plant species; in the absence of any seeds, genus and species was very difficult to determine.

- <11> Unit 31006
  - Juncaceae
  - *Carex*
  - Characeae

Test Pit 2

7.3.7 Four samples were examined for plant macrofossils from TP2: one each from Units 25002, 25003, 25005 and 25008.

7.3.8 The seeds that dominated the assemblage from Sample <14> were Juncaceae – with very few other macrofossils – and there was a relative absence of green algae in contrast with the rest of the samples. The poor quantity of plant macrofossil remains indicates a base-poor environment, possibly still wet but unstable.

- <14> Unit 25002
    - Juncaceae
    - *Thalictrum* cf
    - *Silene* cf

7.3.9 A moderate quantity and diversity of plant macrofossils and other macrofossils were found to be present in Sample <18>. There was an increase in reeds and more terrestrial seeds along with possible Birch budscale (broken), Birch catkin (broken) and a possible Ericaceae leaf (fragment). There were also abundant well preserved ostracods and abundant Chironomids. This assemblage indicates that conditions were more stable and base-rich to support a variety of amphibious and terrestrial ground flora. Willowherbs (*Epilobium*) and pondweed (*Potamogeton*) are waterlogged indicators and the presence of birch and Ericaceae suggest the presence of trees and heathland close to the site.

- <18>Unit 25003
    - Juncaceae
    - *Epilobium*
    - *Carex*
    - *Potamogeton*
    - Characeae

7.3.10 There were a high frequency of rushes, grasses and green algae in Sample <22>. This assemblage shows there would have been a very similar environment to Sample <18>, although the evidence for trees or shrubs nearby has disappeared.

- <22> Unit 25005
    - Juncaceae
    - *Carex*
    - *Silene* cf
    - *Thalictrum* cf
    - Characeae

7.3.11 Plant macrofossil frequency was relatively poor in Sample <26> with rushes disappearing totally and a reduction on the number of the other macrofossils. There were two possible fruit stones but they were to fragmented to be identified. The presence of macrofossils was relatively poor, and the lack of rushes and reduction in green algae seems to indicate a drier period.

- <26> Unit 25008
  - *Carex*
  - *Silene* cf

Test Pit 3

7.3.12 Two samples were examined for plant macrofossils from TP3, both from Unit 20003:

7.3.13 There was a high frequency of rushes, grasses, Caryophyllacea and green algae in Sample <67>. This habitat comprised species dominated by rushes and grasses, with an increase in terrestrial seeds, but still indicative of wet conditions. There was a moderate frequency of insect fragments and ostracods present.

- <67> Unit 20003,18-28cm
  - Juncaceae
  - *Carex*
  - *Silene* cf
  - *Characeae*

7.3.14 There was moderately frequency of rushes, grasses and green algae in Sample <69>, but their quantities had reduced drastically in comparison with Sample <67>. There was a relatively high number of insect fragments and ostracods. The low frequency of plant macrofossils seems to indicate very wet and poor conditions where low lying ground flora were not supported. However, there was a high increase in green algae, insect remains and ostracods.

- <69> Unit 20003, 38-41cm
  - Juncaceae
  - *Carex*
  - *Characeae*

Conclusions

7.3.15 Plant macrofossil studies have been used in other similar sites to [redacted] to provide evidence for local and regional environments. In Hackney (Green et al, 2006) the plant macrofossils provided information about the climatic conditions at the time of deposition of the rest of fossils (bones, insects, mollusca, etc). Macrofossils at Stoke Goldington, Great Ouse (Green et al, 1996) and Barling, Essex (Bridgland et al, 2001) identify local and regional environments.

7.3.16 As with the majority of palaeoecological techniques there are some risks assuming that a plant macro fossil assemblage will reflect the exact composition of plant communities from which the fossils were derived (Grosse-Bracuckmann, 1990). Because of their variable local production and dispersal their representation is very difficult to quantify, nevertheless their representation is linked closely to the vegetation that produced them, leading to reconstructions at an ecological or site scale and to the possibility of interpretation of vegetation change and dynamics (Birks & Birks, 2000).

7.3.17 At [redacted] plant macrofossils were variably preserved among the samples, with a varied amount of material within them, however this preliminary assessment already shows a good correlation between the assemblages with the mollusca and insect evidence presented here. Furthermore, due to the lack of pollen preservation in this site, palaeobotany will provide the environmental context for the finds of this site and support evidence for the rest of the ecological techniques. Although the assemblages were not particularly rich, analysis could provide for more variation for the macrofossils. Macrofossils are not usually produced in abundance so additional samples may be necessary to obtain a meaningful assemblage.

7.4 Mollusca

Matthew Law (L-P Archaeology and Bath Spa University)

7.4.1 Overall the molluscan shell assemblage was well-preserved across the samples examined, with no apparent recent intrusions. The assemblage generally reflects a well-vegetated, slow-moving river channel system with temperatures cooler than fully interglacial conditions. An estimated abundance of items present in the samples is presented in Appendix 9.

7.4.2 Of all the samples recovered during excavation, just one <26> from Unit 25008, did not contain any shell; otherwise, shell was largely well preserved, with occasional brown staining evident of on some shells. No shell within the samples had the appearance of fresh, modern shell (proteinaceous periostracum intact or glossy, translucent appearance), suggesting that there had been no recent intrusion of material into the sediments. Molluscan diversity was generally low, although counts of shells were high in several samples. The high shell counts likely reflect relatively slow deposition, whereas the low diversity may reflect a limiting ecological factor. This is likely to be climatic, and would suggest that the fauna relate to a period of relatively low temperatures, most likely a transitional period into or out of glacial or stadial conditions.

7.4.3 All samples in TP1 and TP3, as well as <18> in TP2, were dominated by a *Valvata-Pisidium-Bithynia* fauna. This is indicative of slow-moving or still water with well-oxygenated (and hence well-vegetated) conditions and a muddy substrate. A likely environment would have been a mature, low-energy lowland river. Another significant component identified was *Radix balthica*, which is ubiquitous across a range of freshwater habitats.

7.4.4 Snails of the freshwater genus *Bithynia* had flat, plate-like calcareous opercula which became separated from the main shell after death. These occur in lower numbers in the samples than the denser shell, suggesting that there has been some winnowing by a current (O'Connor 2017, p. 134). Below Sample <69> in TP3 there was increased diversity, with low quantities of the freshwater snails *Acroloxus lacustris* and *Hippeutis complanata*. These are also snails of slow-moving, well-vegetated water bodies.

7.4.5 There were very low numbers of terrestrial snail shells within the samples, which are likely to have been washed in from marginal sediments. Three taxa were common: the ubiquitous genus *Trochulus, Vallonia* spp. (snails of open habitats) and *Pupilla muscorum*, which is also associated with open habitats (although which was also common in marshy habitats in cold stages of the Pleistiocene). A slug plate (Limacidae sp.) was present in Sample <14> from TP2 Unit 25002. The low terrestrial diversity is also likely to reflect the climatic conditions relating to a transitional period.

7.5 Insects

Enid Allison (Canterbury Archaeological Trust)

7.5.1 Six of the samples produced small to moderately-sized assemblages of beetle remains, with two samples from TP2 and TP3 producing larger assemblages of over 100 individuals. Bugs and other groups of insects were represented by small numbers of taxa.

7.5.2 The only identifiable insect remains in the remaining sample were fragments of a water boatman (Hemiptera: Corixdae). A full list of taxa noted during scanning is given in Appendix 10 and lists for individual samples in Appendix 11.

7.5.3 In most samples fragmentation of insect sclerites was moderate. Many sclerites in all samples were torn with edge damage, while others were somewhat better preserved. Levels of chemical erosion were generally moderate. There was relatively little loss of colour or three-dimensional structure in most samples, but it was obvious when some of the material was dried for closer examination, that thinning had occurred. This quickly became apparent on removing the material from IMS: drying of sclerites/fragments results in crinkling, rolling and folding which could present problems for comparison with reference material which entails removing specimens from the liquid. General observations for individual samples are shown in Appendix 11. Many of the reasonably complete sclerites in all the productive samples are potentially identifiable to a useful taxonomic level.

<u>Test Pit 1</u>

7.5.4 Three samples were examined, all producing moderate numbers of insect remains suggesting aquatic and waterside/marginal conditions. Small numbers of *Daphnia* ephippia (resting eggs) and ostracod carapaces were also recorded. A number of leaf beetles (Chrysomelidae) and weevils (Apionidae, Curculionidae) have the potential to provide details of local vegetation. Scarabaeid dung beetles (Aphodiinae spp) were well-represented in all three samples suggesting the availability of dung in the local area. The potential of all three samples for further analysis is limited by the size of the assemblages and by the condition of some of the remains, but is judged to be 'moderate'.

Test Pit 2

7.5.5 Four samples were examined and the remains recovered were consistent with aquatic deposition and waterside mud. Other invertebrates noted included ostracods and in single samples, occasional *Daphnia* ephippia and *Lophopus crystallinus* statoblasts. Sample <26> from Unit 25008 produced only fragments of a water boatman (Corixidae), and traces of indeterminate beetle cuticle.

7.5.6 The largest assemblage, consisting of an estimated 100 - 150 individuals, was from <18> recovered from Unit 25003. Ground beetles (Carabidae) and a range of plant-feeding taxa (Chrysomelidae, Apionidae, Curculionidae), all common, have the potential to provide details of local terrestrial vegetation and habitats. *Chaetocnema arida* group, for example, is associated with various grasses, rushes and sedges. Beetles primarily associated with dung were relatively well-represented (Aphodiinae spp, *Sphaeridium*, *Cryptopleurum*) pointing to its availability locally. This sample has a good potential for analysis. The potential of the smaller assemblages from the other two productive samples is low to moderate (see Appendix 11).

Test pit 3

7.5.7 Two samples were examined. The uppermost sample <67> produced a sizable assemblage of insect remains consisting of an estimated 150 individuals, ostracod carapaces were common and there were occasional statoblasts of *Lophopus crystallinus*. Many of the taxa are consistent with an aquatic/marginal environment. Two species of riffle beetles (Elmidae) are found exclusively in clean, clear, well-oxygenated running water. Other species are indicative of waterside mud: *Ochthebius ?bicolon* is usually found in mud by running water (Duff 2012, p.326) while *Georissus crenulatus* occurs at the edges of water bodies, often by running water, and also at seepages (Hansen 1987, p.86; Foster et al, 2014, p.35). Plant-associated taxa (Chrysomelidae, Apionidae, Curculionidae) were common, and dung beetles (Aphodiinae, ?Geotrupinae) notably well-represented. Generally, the assemblage is suggestive of a water channel, probably with swampy, well-vegetated backwaters or water margins, and an availability of dung. The assemblage has a good potential for further analysis.

7.5.8 The lower of the two samples <69> produced a much smaller assemblage with a moderate potential for analysis. The remains were more poorly preserved that those in the rest of the productive samples (see Appendix 11). A riffle beetle (Elmidae) was suggestive of running water, and *Hydrochus* and a tentatively identified *?Notaris* of wetland conditions and vegetation.

7.6 Microvertebrates

Danielle Schreve (Royal Holloway University of London)

7.6.1 The yield from the samples was extremely low in Quaternary microvertebrates. Many samples yielded abundant derived fossils from the Jurassic Oxford Clay bedrock, including common fragments of *Gryphaea* and rare fish bones and teeth, the last being very dark stained, almost black, well mineralized and frequently with a shiny surface. Where present, the Quaternary material is stained a mid to dark brown, suggesting some degree of separation from the pre-Quaternary fossils, although differentiation can be difficult.

Test Pit 1

7.6.2 The following specimen was recorded in TP1:

- Sample <11>, 17-25cm:
  - Diaphyseal fragment, undetermined small mammal

7.6.3 All other samples in TP1 (9 and 10) were sterile.

Test Pit 2

7.6.4 The following specimens were recorded in TP2:

- Sample <14>, Unit 25002:
  - Thick cortical bone fragment, 66x27mm, of large mammal, probably Elephantidae sp.

- Sample <18>, Unit 25003:
  - One small undetermined bone fragment
  - Three small bone fragments of undetermined fish
  - One fin spine and one partial vertebra of three-spined stickleback, *Gasterosteus aculeatus*

- Sample <22>, Unit 25005:
  - Small fragment of bone of undetermined fish
  - Three undetermined bone fragments (one comprising an 8mm pellet of cancellous bone)
- Sample <26>, Unit 25008>:
  - Distal femoral epiphysis of undetermined small mammal
  - Three small bone fragments of undetermined fish
  - One pharyngeal tooth of carp family, Cyprinidae sp.

Test Pit 3

7.6.5 Both samples in TP3 (<67> and <69>) were sterile.

Summary

7.6.6 The vertebrate yield from the samples was extremely low and generally poorly preserved, apart from the fish remains from <18> and <26>, presumably representing autochthonous components within a fluvial depositional context. The large cortical bone fragment of probable Elephantidae sp. reflects some local in-washing of terrestrial components from the adjacent bank side. The presence of small, undetermined bone fragments, some with the bone surface entirely removed, indicate rolling, abrasion and derivation in an aquatic environment.

7.6.7 Little can be deduced from the small assemblage recovered from the [redacted] samples. Only the presence of three-spined stickleback offers some palaeoecological insight. This species is widespread in Britain today and elsewhere in Europe, extending north along the coasts of Fennoscandia, northern Russia, the Baltic and Iceland, and south and east, across northern central Europe down to the Black Sea. Although inshore marine populations are known, *G. aculeatus* is typical of inland freshwater habitats, particularly quiet, weed-filled pools and backwaters. It is also found in the marginal vegetation of streams and in rivers with sandy or muddy bottoms (NatureServe, 2015). Cyprinids (carp family) are widespread in British water today.

8 FAUNAL REMAINS

Hannah Russ (DigVentures) with Kate Scott, Nigel Larkin, Chris Stringer, Louise Humphreys, and Mike Buckley

8.1 Introduction

8.1.1 The assessment of the faunal remains assessment fulfils Stage 4 (Tasks 4.7 and 4.7) and addresses aspects of Aim 3 Questions 7–10 of the Project Design (Wilkins et al. 2018, see Section 3.1.2 above) by providing information on the conservation procedures adopted and contributing baseline data regarding the condition and preservation of the faunal remains as well as an understanding of the range of animals species at [redacted]

8.1.2 In total, 14 faunal specimens comprising individual elements or refitting fragments were identified. Most of the faunal remains were identified as individual bone or tooth fragments or refitting fragments and lifted without the need for on-site conservation (SF1, SF2, SF4, SF5, SF6, SF7, SF9, SF10, SF15, and SF16). A couple of mammoth tusks were also identified SF3 and SF8. SF3 required on-site conservation prior to lifting and further conservation is required before analysis. SF8 was left *in situ* due to time constraints, although numerous loose associated fragments were recovered that were not consolidated by sediment and would have washed away with the reflooding of the quarry. Bone fragments SF12 and SF14 were identified during excavation of the multiproxy columns and retrained with the related column samples. A full breakdown of the assemblage is provided in Appendix 12.

8.2 Conservation Procedures

8.2.1 All but one of the samples were lifted without the need for on-site conservation. The only faunal specimen lifted following on-site conservation was mammoth tusk SF3. Prior to lifting the tusk was wrapped in acid-free tissue and aluminium foil encased in plaster and hessian with a wooden splint. Much of the sediment surrounding it was encased within the plaster. The surrounding sediment and field jacket acted to consolidate the thousands of pieces of tusk together and hold its shape, without which it would have fallen irrevocably apart and lost its original form.

8.2.2 All other specimens were cleaned off-site. Each was cleaned of their encrusting sediment with a mixture of small wooden tools (to avoid making scratches), dry brushes and the occasional small wet brush (keeping the specimen as dry as possible and wiping it dry immediately afterwards with a paper towel). Some sediment was left where it did not obscure details or where it provided support (such as in the neural canal of the mammoth thoracic vertebra SF6). Breaks in two specimens were repaired with the reversible conservation adhesive Paraloid B72 used as an adhesive and consolidant (diluted with acetone). The repaired specimens were the mammoth tooth lamella SF10 which was in three pieces and unidentifiable fragment SF4 from which has a smaller piece had broken off.

8.3 Condition

8.3.1 The condition of the vertebrate remains was assessed prior to conservation work. Two factors were considered in terms of determining condition – fragmentation and bone surface preservation. Fragmentation was recorded using the zonation system described by Dobney and Rielly (1988), while condition was graded from one to five, with one indicating excellent surface preservation, and five indicating extremely poor surface preservation/complete loss of bone surface (Lymann 1994).

8.3.2 The vertebrate remains recovered had variable levels of fragmentation and surface preservation. Near complete specimens included a *Mammuthus* sp. tarsal SF16 and thoracic vertebra SF6 (comprising two refitting fragments). All other specimens presented as fragments of elements, with mammoth tusk SF8 being the most fragmentary (n=60). Surface preservation ranged from 'good' (grade 2) and extremely poor (grade 5). The most complete bones, *Mammuthus* sp. tarsal SF16 and vertebra SF15, also has the best surface preservation in the assemblage, and along with *Mammuthus* sp. rib fragment SF9, all graded 2 (good surface preservation). With the exception of the remnants ofextremely fragmentary mammoth tusk SF8, which had extremely poor surface preservation (grade 5), the remainder of the assemblage had moderate (grade 3, n=5) or poor (grade 4, n=5) surface preservation.

8.4 Assemblage

Test Pit 1

8.4.1 Faunal remains were recovered from Units 31001 and 31002. Unit 31001 comprised two specimens, near complete *Mammuthus* sp. tarsal SF16 and a portion of vertebra SF15, also likely mammoth (Mammalia cf. *Mammuthus*). Unit 31001 represented the spoil from previous interventions at the site in 2017, and therefore the faunal remains were not recovered in situ.

8.4.2 Unit 31002 contained eight specimens (SF1, SF2, SF3, SF4, SF5, SF6, SF9, SF10 and SF11), comprising eight bone fragments and three tooth fragments, as well as the mammoth tusk that was not available for assessment. The remains recovered from Unit 31002 included three rib fragments, one identified as mammoth SF9, and the other two as probable mammoth fragments SF2 and SF5. Three tooth fragments representing single lamella tooth plate SF10, mandible ramus fragment SF1 (zones 3 and 6 according to Dobney and Reilly 1988) and two fragments of near complete thoracic vertebra SF6 were all identified as mammoth, with the mandible fragment thought to represent a juvenile individual. SF4, two refitting bone fragments, could not be identified to any element or species but was from a very large mammal.

<u>Test Pit 2</u>

8.4.3 Only a single faunal remain was recovered – SF14. It was found during multiproxy column sampling and retained with those samples. It was a cortical fragment of a large mammal, likely of *Mammuthus* sp. It was found within Unit 25002.

<u>Test Pit 3</u>

8.4.4 Faunal remains were recovered from Units 20007 and 20008. Unit 20007 comprised unidentifiable bone fragment SF7. It could be identified only as the remains of a medium-to-large mammal. Even though initially the cortex and trabecular bone was thought to share some characteristics consistent with hominin remains, further examination showed this not to be the case. The specimen differs from any of the other vertebrate remains from the site – it is less dense, a different colour, and has a different cortical and trabecular bone structure. Given the unclear identification based on the specimens morphology species identification was attempted using the protein fingerprinting technique ZooMS. Unfortunately, initial assessment indicated that there was no collagen survival and as such the bone could not be assigned to species using ZooMS.

8.4.5 Unit 20008 yielded extremely fragmentary remains of mammoth tusk SF8. The specimen was in extremely poor condition – actively crumbling during the assessment work despite careful handling. The surfaces were powdery, and the larger fragments were cracked. This specimen was recorded as the most poorly preserved in the assemblage. Unit 20008 included bone fragment SF12 which was noted within the column samples taken during excavation of the test pit and retained alongside the sample.

9 OSL

Phil Toms

9.1.1 The OSL dating of sediments fulfils Stage 4 (Task 4.8) and addresses Question 9 of Aim 3 in the Project Design (Wilkins et al. 2018, see Section 3.1.2 above) by creating a dating framework for the palaeochannel. The resulting chronology identified the earliest formation of palaeochannel deposits to MIS7, with further infilling of the channel during MIS7 and 6, and the development of the overlying Northmoor Member to the latter part of MIS5.

9.1.2 The methodological procedures, diagnostic information and data drawn upon to deliver the OSL dates is below is outlined in Appendix 13 and Appendix 14. Table 4 outlines the available data including obtained OSL estimates alongside a conclusion on the analytical validity of each sample, where there are caveats, the reader is directed to the relevant section of the appendix that explains the issue further in general terms.

Field code	Lab code	Overburden (m)	Grain size (µm)	Moisture content (%)	Ge γ-spectronmetry (*ex situ*)			β D_r (Gy.ka^{-1})	γ D_r (Gy.ka^{-1})	Cosmic D (Gy.ka^{-1})	Preheat (ºC for	Low Dose Repeat Ratio	High Dose Repeat	Post-IR OSL Ratio
					K (%)	Th (ppm)	U (ppm)							
OSL 1A	GL19028	4.64	125-180	17 ± 4	1.44 ± 0.09	9.80 ± 0.58	1.63 ± 0.13	1.20 ± 0.14	0.82 ± 0.10	0.10 ± 0.01	220	1.00 ± 0.04	1.00 ± 0.04	0.96 ± 0.04
OSL 2A	GL19029	4.27	125-180	16 ± 4	0.76 ± 0.07	4.92 ± 0.41	1.62 ± 0.13	0.70 ± 0.09	0.49 ± 0.07	0.11 ± 0.01	220	1.01 ± 0.05	1.00 ± 0.04	0.99 ± 0.04
OSL 3A	GL19030	4.69	125-180	11 ± 3	0.44 ± 0.05	2.92 ± 0.34	0.86 ± 0.14	0.44 ± 0.06	0.30 ± 0.06	0.10 ± 0.01	220	0.98 ± 0.05	0.99 ± 0.04	1.00 ± 0.04
OSL 4A	GL19031	3.81	125-180	17 ± 4	0.85 ± 0.07	5.76 ± 0.47	3.58 ± 0.19	0.97 ± 0.11	0.72 ± 0.09	0.11 ± 0.01	180	1.01 ± 0.04	0.99 ± 0.03	0.99 ± 0.04
OSL 5A	GL19032	1.00	180-250	4 ± 1	0.14 ± 0.04	2.54 ± 0.29	0.49 ± 0.09	0.21 ± 0.05	0.20 ± 0.05	0.18 ± 0.02	200	1.01 ± 0.04	1.03 ± 0.03	0.99 ± 0.04
OSL 7A	GL19037	1.00	180-250	5 ± 1	0.28 ± 0.05	2.50 ± 0.31	0.62 ± 0.11	0.31 ± 0.05	0.24 ± 0.05	0.18 ± 0.02	180	1.00 ± 0.04	0.99 ± 0.03	0.99 ± 0.04

Field Code	Lab Code	Total D_r (Gy.ka^{-1})	D_e (Gy)	Age (ka)	Analytical validity of sample suite age estimates and caveats for consideration	
					Generic Considerations	Sample Specific Considerations
OSL 1A	GL19028	2.12 ± 0.18	432.1 ± 34.5	204 ± 24 (22)	Absence of in situ γ spectrometry data	None
OSL 2A	GL19029	1.30 ± 0.11	278.1 ± 19.2	214 ± 23 (21)		None
OSL 3A	GL19030	0.84 ± 0.07	189.5 ± 11.0	225 ± 23 (21)		None
OSL 4A	GL19031	1.81 ± 0.15	338.9 ± 20.7	187 ± 19 (17)		Significant U disequilibrium (see Appendix 10 and Fig. 5)
OSL 5A	GL19032	0.59 ± 0.05	75.4 ± 4.7	129 ± 14 (13)		Accept age estimate tentatively
OSL 7A	GL19037	0.74 ± 0.06	82.4 ± 4.5	112 ± 11 (10)		None

Table 4 D_r, D_e and Age data of submitted samples located at c. 52°N, 2°W, 85m. Age estimates expressed relative to year of sampling. Uncertainties in age are quoted at 1σ confidence, are based on analytical errors and reflect combined systematic and experimental variability and (in parenthesis) experimental variability alone (see 6.0). ***Blue*** *indicates samples with accepted age estimates,* ***red***, *age estimates with caveats.*

10 DISCUSSION

Keith Wilkinson (ARCA, University of Winchester) and Josh Hogue (DigVentures)

10.1.1 As has been outlined in Section 6.6, the strata exposed in the base and walls of [redacted] Quarry have been attributed to four depositional and one erosional phase. In this section OSL ages obtained from the test pits and quarry walls, and the currently available vertebrate biostratigraphy are integrated with the phasing in order to propose an outline chronology for events at the site. The facies described in Section 6.1 are then used to suggest how depositional environments changed during the formation of the site's stratigraphy. Finally, the implications for the archaeological record of both the chronology and depositional setting are assessed.

10.2 Chronology

10.2.1 Phase 1 deposits have been dated by OSL from Unit 31006 [v] in Test Pit 1 to 225±23 ka (GL19030) and from Unit 25009 [A] in Test Pit 2 to 204±24 ka (GL19028) (Figure 13), suggesting that the Phase 1 palaeochannel deposition occurred during the MIS6–8 interval (Figure 14). However, given that the Phase 1 deposits are likely to have formed in a temperate environment (see Section 10.3 below), while the vertebrate fauna from the channel is of interglacial character, it would seem most likely that the strata are of MIS7 age. The fossils recovered from the palaeochannel fills during the recent excavations (most probably all from Phase 1 deposits given their distribution) have been assigned to *Mammuthus sp.* (see Section 7.0) and fossils collected previously by the Hollingworths includes *Mammuthus cf. trogontherii*, as well as, bear, bison (Russ et al. 2019) and possibly other species including horse, hyena and deer (Wilkins et al. 2018, p.16). The discovery of *Mammuthus cf. trogontherii* and horse together, and in deposits characteristic of temperate environments (see Section 10.3 below), provides further confirmation for the MIS7 OSL age of depositional Phase 1 (Lister and Sher 2001). Indeed the [redacted] vertebrate fauna from Phase 1 deposits is almost identical to that from Stanton Harcourt (albeit without straight-tusked elephant, *Palaeoloxodon antiquus* at the former), and amino acid racemisation and OSL ages from that site also indicate an MIS7 age (Bowen et al. 1989, Zou et al. 1997), albeit that uranium series and electron spin resonance of mammoth tusks indicate later dates (Zhou et al. 1997). The discovery of *Carpinus* (hornheam) polymorphs from Unit 31005 [iii] and Unit 31006 [v] are also consistent with the Phase 1 deposits dating from an interglacial prior to the Holocene (see Section 7).

10.2.2 Deposits from Phase 3a have been OSL dated to 214±23 ka (GL19029) from Unit 25004 (K3) in Test Pit 2, thus demonstrating an apparent age inversion between GL19028 and GL19029 (Figure 13). However, given the overlap between the two ages at one standard deviation, and very significant overlap at two, the samples can be considered as providing indistinguishable ages (Figure 14). Nevertheless, there is less sedimentological and biostratigraphic grounds for suggesting an MIS7 age for Phase 3a and hence Phase 3 given that the deposits indicate formation in a broad, multichannel belt in high energy conditions. It is therefore possible that Phase 3/3a might be of MIS7 or MIS6 age (Figure 14). Further evidence is provided by a single OSL date of 187±19 ka (GL19031) from Phase 4 deposits in Unit 20003 (TP3), albeit that this sample suffered uranium disequilibrium problems (see Section 9). This latter age suggests that palaeochannel **b** was infilling in MIS6 or 7 but given that these channel infills were likely deposited in a temperate environment, an MIS7 age seems more likely. Taken together therefore, it is probable that Phases 1–4 are all of MIS7 age, while it is possible that the downcutting of Phase 2 and the coarse-grained deposition of Phase 3 might be attributable to one of the two cool phases in MIS7 (MIS7b or more likely, MIS7d) (Figure 14). If this scenario were correct, Stage 1 might be attributable to MIS7e (or possibly MIS7c). As noted above, the Stanton Harcourt channel deposits have also been attributed to MIS7 on the basis of multiple lines of evidence, while the channel fills of facies association A at Latton are also argued to be from the same interglacial on the basis of biostratigraphy (Mollusca, Coleoptera and vertebrates) and a U-series age on a horse tibia of >127 ka (Lewis et al. 2006).

10.2.3 Two OSL dates provide indications of the chronology of Phase 5, i.e. the Member. Unit 48 in Section F is dated to 129±14 ka (GL19032), while Unit 28 in Section D has an OSL age of 112±11 ka (GL19037) (Figure 13) (see Section 9). These two ages overlap with one another at one standard deviation and significantly overlap at two but have only a minor coincidence with the dates from the palaeochannel (Figure 14). In other words, the OSL ages demonstrate a chronological discontinuity between the palaeochannel (Phase 1–4) and the Northmoor Member (Phase 5). Formation of the latter can in theory be attributable to MIS5 or MIS6 according to GL19032 and GL19037. However, assuming that the two samples date a similar period of deposition, there is a <10% chance that GL19037 is of MIS6 age, meaning that an MIS5 date is more likely. Furthermore, the sheet gravel strata of the Northmoor Member are very unlikely to derive from deposition in an interglacial climate (see Section 9), and it is therefore likely that accretion was in a post-MIS5e (Ipswichian) sub-stage, i.e. MIS5d or MIS5c. It should be emphasised, however, that both GL19032 and GL19037 were collected from the base of the Phase 5 accumulation at [redacted] and no attempt was made to date the upper strata of the Northmoor Member. In other words, strata higher in the Northmoor Member sequence at [redacted] might post-date MIS5c.

10.2.4 Deposits of the Northmoor Member have been dated by OSL to between 113±25 and 64±15 ka (facies associations A and B) at Ashton Keynes (Lewis et al., 2001) and 148¬65 ka (facies association B) at Cassington (Maddy et al. 1998), providing wider evidence for the development of the unit during MIS5 and MIS4. Indeed Lewis et al. (2001), suggest that the transition from MIS5a to MIS4 (i.e. dramatically cooling climates and the adoption of a braided channel system) can be recognised in the change from facies association A to facies association B at Ashton Keynes. Maddy et al. (1998) argue for a similar change through their facies associations A–D at Cassington, with the MIS5 to MIS4 boundary at the at facies association B to C contact. Although the upper part of the Northmoor Member was not dated at [redacted] ages of 42.3–44.8 ka (39,560±780 BP, Beta 115383) have been obtained by ^{14}C from facies association B at Latton (Lewis et al., 2006) and 58-87 ka by OSL from facies association C at Cassington (Maddy et al., 1998). Furthermore, Late Glacial (MIS2) ages exist from fills of channels scoured into the Northmoor Member at Ashton Keynes (18±2 ka by OSL, and 13.1–13.4 [11,400±80 BP, Beta 115384] and 13.4–13.8 ka [11,690±80 BP, Beta 115385] by ^{14}C of bulk organics[1]) (Lewis et al., 2001). These data suggest that the Northmoor Member continued to accrete through MIS4 and perhaps into MIS3 (the Latton ^{14}C age for facies association B is towards the maximum age achievable by that method and may be an underestimate), and was then reactivated

[1] Calibrated using IntCal13 (Reimer et al., 2013) and OxCal 4.3 (Ramsey, 2009).

by channelling and subsequent deposition in MIS2. Interestingly, there is no evidence for accretion during late phases of MIS3 or early parts of MIS2, i.e. intervals thought to be the main focus of Northmoor Member accretion in publications from the mid-1990s and earlier (see Section 2) (e.g. Bridgland 1994; Gibbard 1985; Gibbard 1999).

10.3 Depositional environment

10.3.1 The lithofacies of Phase 1 palaeochannel sedimentation (facies 3, facies 6 and facies 4) are indicative of debris flows (gravel facies) and sediment gravity flows (sand facies) (Miall 1996, p. 79). The morphology of the deposits and their constraint within a relatively narrow area to the north and west of the Kellaway Clay bluff, would seem to suggest deposition within a single meandering channel. Biological proxies from [redacted] for Phase 1 (samples 9, 10, 11 and 26) are consistent with fluvial deposition with relatively low frequencies and low abundance of terrestrial plant macrofossils, insects, coleoptera, molluscs and small vertebrates. Frequencies of freshwater green algae (Characeae) however indicate episodes where the river was more slowly flowing. Similarly, *Valvata-Pisidum-Bithynia* mollusc species, indicate slow moving conditions, although the relatively low frequencies of *Bithynia* reflects some winnowing by current (O'Connor 2017, p. 314). The interpretation of a single meandering channel is notably identical to that made for facies association A at the Latton site, 1.7 km to the north, while it is also the case that the latter is thought to have been confined within a fold of the Kellaway Clay bedrock (Lewis et al. 2006).

10.3.2 It is difficult to infer a climatic setting given the facies present at [redacted] although some inferences may potentially be drawn from further analysis of the multiproxy environmental samples. Plant macrofossils including rushes (Juncaceae), sedges (*Carex*) and grasses are generally suggestive of grassland environmental conditions beyond the channel, although unidentifiable stone fruits fragments were also recovered. Insect and other invertebrate remains including leaf beetles (Chysomelidae), weevils (Apionidae, Curculionidae) and scarabaeid dung beetles (Aphondiinae spp) may also help to further refine the vegetation and climate setting during Phase 1 at [redacted]

10.3.3 If Phase 1 does indeed correlate with facies association A at Latton, a temperate environment with temperatures equivalent to today is evidenced by coleopteran data from the latter (Lewis et al. 2006). Biological proxies from Latton for this channel phase also indicate that the environment beyond the channel was inhabited by grassland, although there is also some evidence for yew (*Taxus baccata*) wood and scrub (Lewis et al. 2006). Nevertheless, as is further discussed in Section 10.4 below, there are minor but significant differences in the relationship between channel deposits and archaeological artefacts between the [redacted] and Latton (and indeed Stanton Harcourt) channels.

10.3.4 Phase 2 at [redacted] is an inferred downcutting event that has been attributed to cooling conditions of MIS7d (possibly MIS7b), during which time base levels must have fallen [as is demonstrated by the benthic foraminiferal stack record (Figure 14), which shows (in part) global ice volume (Lisiecki and Raymo, 2005) and the stream passing through the site would consequently readjust. Indeed, Bridgland's model of fluvial terrace formation suggests downcutting and scour at the transition from interglacial (MIS7e) to cold conditions (MIS7d) (e.g. D. Bridgland & Westaway 2008, 'phase 4').

10.3.5 Phase 3 deposition is also likely to be from a cool episode in MIS7 (most probably MIS7d) during which deposition occurred as inertial bedflow in turbulent water flowing in a series of shallow, short-lived channels that developed across the palaeochannel area (Miall 1996, p. 79). The deposits of Phase 3a likely formed as waning flood deposits in the lea of a gravel barrier, while applying the Bridgland model to the Phase 3/3a accretion as a whole would place these events during the cooling of his phase 5 (Bridgland and Westaway 2008). Biological proxies from [redacted] for Phase 3 (samples 14, 18, and 22) indicate a relatively low energy fluvial environmental consistent with water margin conditions, with notably high frequencies and higher abundance of terrestrial plant macrofossils, insects, coleoptera, molluscs and small vertebrates. Plant macrofossils included willowherbs (*Epilobium*) and pondweed (*Potamogeton*) indicating waterlogged conditions, although higher frequencies of reed, rushes and grasses, and notably terrestrial specimens, such as Birch budscale, catkin and Ericaceae leaf, indicate more stable and base-rich environment with trees and heathland in close vicinity. Insects were most abundant in Phase 3, including ground beetles (Carabidae) and a range of plant-feeding taxa (Chrysomelidae, Apionidae, Curculionidae) indicating local terrestrial vegetation and habitats –. *Chaetocnema arida*, for example, is associated with various grasses, rushes and sedges. Furthermore, beetles primarily associated with dung were relatively well-represented (Aphodiinae spp, *Sphaeridium, Cryptopleurum*) pointing to its availability locally. *Trochulus, Vallonia* spp. and *Pupilla muscorum* terrestrial snails associated with open habitats were also observed. Macrovertebrate remains were rare and did include fish bones, although the presence of a large cortical bone fragment of probable Elephantidae sp. reflects local in-washing of terrestrial components from the adjacent bank side.

10.3.6 Phase 4 sedimentation at [redacted] might correspond to macro scale operation of Bridgland's phase 1 downcutting (to form the small palaeochannels), and phase 2 aggradation (i.e. infilling of the palaeochannels) in a warming climate that is possibly MIS7c. Facies within palaeochannels **a** and **b** are all fine-grained and suggest deposition by moderate energy sediment gravity flow while the channels were open, and during waning flood events and in backswamp environments following abandonment (Miall 1996, p. 79). Biological proxies from Phase 4 (samples 67 and 69) were consistent with fluvial conditions with episodes of high energy deposition and more marshy conditions with relatively low frequencies and low abundance. Plant macrofossil were found in relatively limited numbers indicating relatively wet conditions. Riffle beetle (Elmidae) was found consistent with running water, although taxa suggestive of a water channel, probably with swampy, well-vegetated backwaters or water margins, and an availability of dung was also found. Mollusca included freshwater snails *Acroloxus lacustris* and *Hippeutis complanate*, as well as snails of slow-moving, well-vegetated water bodies. No microvertebrates were found.

10.3.7 Phase 5 deposition at [redacted] is equivalent to facies association B from Latton (Lewis et al., 2006) and facies association B from Ashton Keynes (Lewis et al., 2001) (there are no equivalents at [redacted] of the MIS2 facies association C and D fine-grained channel infills at Ashton Keynes or similar facies association C channel deposits at Latton). The predominantly sheet gravels that form Phase 5 deposition were deposited in multiple shallow channels in high energy flow and as inertial bedload (Miall 1996, 79). Lewis et al. (2006) report biostratigraphic evidence suggesting changing environments and climates during deposition of facies association B at Latton. Pollen data suggest that conditions were treeless throughout and rather vegetation was dominated by grassland, with taller herbs close to the water course, albeit that the latter declined over time. Coleoptera suggest that during the initial deposition of facies association B, climates were temperate and oceanic, but that the conditions became cooler and more continental later on. Lewis et al. (2006) suggest that all these conditions occurred during MIS4, but it is also possible that the initial temperate phase might relate to an MIS5 substage and only the latter cooling to MIS4 (as at Ashton Keynes). As has previously been noted, the OSL ages for Phase 5 at [redacted] are from the earliest parts of the Northmoor Member exposed on the site and which date firmly to MIS5. Therefore, it is likely that deposition was at least initially in the treeless, but temperate climate that is envisaged for Latton.

10.3.8 It should be noted that none of the strata exposed, either the test pit sections or the quarry walls have any indication of periglacial deformation. This absence suggests either that the strata were sufficiently isolated from such conditions – which presumably pertained during MIS 2, 4 and 6 – by deposits which have subsequently been removed, or that periglacial environments were relatively benign in this part of the upper Thames valley [contra the conditions to the east (e.g. at Stanton Harcourt - see D.R. Bridgland 1994)].

10.4 Archaeology

10.4.1 Two handaxes have been recovered from the [redacted] site (Russ et al. 2019). One of these was found at the processing plant and might therefore originate from elsewhere within the quarry. The other was found in upcast produced during machine excavation of a sondage in 2017 (pers. comm. Sally Hollingworth) and in the vicinity of the Test Pit 1. Given that deposits of the Northmoor Member had been removed from this location prior to the excavation of Test Pit 1, it is highly likely that the handaxe originally sat in the palaeochannel sediments. However, it is unclear from which of Units 31002, 31004, 31005, and 31006 [ii–v] the handaxe was removed and particularly whether it came from the vertebrate fossil-bearing 31002 [iv]. Nevertheless, all the palaeochannel deposits exposed in Test Pit 1 were laid down in depositional Phase 1 and therefore date to MIS7. It is notable in this regard that Lower Palaeolithic artefacts (at least eight of them) were found in the MIS7 sediment gravity flows of facies association A at Latton (all by Neville Hollingworth, one of which was in situ), i.e. in a very similar stratigraphic position to that from Test Pit 1 at [redacted] (Lewis et al. 2006).

10.4.2 While artefacts are undoubtedly present in the Stage 1 palaeochannel, the nature of the deposits in that feature suggest that artefacts are unlikely to be in situ. Rather they will have been transported by fluvial processes from their place of discard, while any sediment that originally surrounded them at/immediately following discard will have been winnowed. However, although the palaeochannel fills, particularly those of Phase 1, indicate deposition in a medium–high flow regime, the coarsest gravel particles in the beds are coarse pebbles cf. the fine boulder-size of the handaxe. In other words, the flows that entrained the gravel and sand strata in Test Pit 1 (facies 3 and facies 6), may not have had sufficient traction to move the handaxe. Indeed, and despite their lower density, the same is probably true of the vertebrate fossils sitting at the contact between the Oxford Clay (Unit 31003 [v]) and Unit 31002 [iv]. In other words, it is possible that artefacts and vertebrate fossils are, together with the septarian nodules noted at the Oxford Clay–palaeochannel deposit interface, lags remaining from previous higher velocity flows and against which palaeochannel deposits have been emplaced. Such an interpretation is rather different to that advanced for the 27 artefacts (of which 4 were found in situ) and numerous vertebrate fossils from Dix Pit, Stanton Harcourt, which are thought to have been deposited on emergent bars of a meandering river and then buried by subsequent gravel deposition (Buckingham 2007; Scott and Buckingham 2001).

10.4.3 On the basis of strata exposed in section in the test pit sections and quarry walls, there is very limited evidence for floodplain deposition and none at all for terrestrial processes (with the limited number of terrestrial specimens likely to have been washed in from marginal sediments – see Sections 7.3–7.6). Rather, as has been discussed in Section 10.3 above, based on the exposures presently available the deposits all formed within a fluvial environment, i.e. in locations where hominin activity is unlikely to have been either prolonged or intense. Nonetheless, if deposits in the floodplain at the margins of the river and/or terrestrial sediments remain obscured, the site may still hold some limited potential for the discovery of in situ hominin activities residues/remains.

11 CONCLUSIONS

Keith Wilkinson (ARCA, University of Winchester) and Josh Hogue (DigVentures)

11.1.1 The above stratigraphic assessment represents the completion of the Stage 4 (Tasks 4.1 – 4.14; Product 15) and addresses Questions 7–10 of Aim 3, of the Understand the Site's archaeological and paleoenvironmental conditions(Wilkins et al. 2018, p. 18):

11.2 Preservation

11.2.1 While the investigations at [redacted] reported here did not result in the discovery of archaeological artefacts beyond those found in 2017, they did provide information on the depositional and chronological setting of the handaxe previously found by Sally Hollingworth (Q7). The handaxe was likely a lag recovered from the base of a MIS7 channel feature that passed through the quarry on a broadly south-west to north-east trajectory. As with the much more numerous vertebrate fossils found in a similar position (Test Pit 1), the artefact were likely banked up by and covered by coarse-grained deposits (Phase 1) that then protected them from subsequent erosion events (e.g. Phase 2, later MIS7 downcutting event, and later periglacial processes during MIS2, 4 and 6 glacial stages). However, because of the high-energy fluvial environment of the handaxe and vertebrate remains the conditions were not particularly suitable for the deposition and survival of associated multi-proxy environmental indicators (e.g. plant macrofossils, insects, coleoptera, molluscs and small vertebrates). Multi-proxy environmental indictors survived well and in greater abundance however in association with a later manifestation of the river which run as multiple shallow channels of low sinuosity and flow (Phase 3), albeit with only a relatively limited number of associated vertebrate remains (Test Pit 2 and 3).

11.3 Significance

11.3.1 Given that no artefacts have been found in situ within the MIS7 deposits at [redacted] it cannot be determined whether there was any relationship between archaeological artefacts and the vertebrate remains (Q8). Indeed, the same situation pertains at Latton, where, although one artefact was extracted from the gravels of facies association A, its relationship with vertebrate fossils could not be established (Lewis et al. 2006). The lack of new archaeological discoveries at [redacted] and the equivocal nature of artefact-vertebrate fossil association, may indicate that it simply is not an archaeological site. Conversely it may be a product of the small area subject to hand excavation. Even in the case of larger excavation areas artefact density is typically low. For instance, Stanton Harcourt entire excavation area was approximately 150 x 100m (~150,000 m^2), yet yielded only 27 stone tools (Buckingham 2007). In contrast, only *c.* 13.5 x 4.25m (~58 m^2) of in situ deposits were excavated during the recent excavations at [redacted] Nonetheless, [redacted] reflects a critical resource for understanding the nature and magnitude of climate change in the past and contextualising apparent shifts in hominin behaviour and adaption due to the survival of multi-proxy environmental indicators albeit beyond the area principally under investigation and associated with vertebrate remains - as highlighted in Historic England (2020) *Curating the Palaeolithic* guidance the importance and potential of Pleistocene deposits should still be considered in the absence of archaeological remains.

11.4 Dating framework

11.4.1 Stratigraphic and lithostratigraphic assessment of the sequence excavated at [redacted] supported by OSL dating and multi-proxy assessment, has enabled a broad chronology for the palaeochannel to be established (Q9). The earliest manifestation of the river – in Phase 1 – likely occurred over 200 ka in MIS7, with Phases 2 – 4 representing changes to its flow regime occurring during the same Marine Isotope Stage. However, Phase 5 was represented by overlying gravels belonging to the Northmoor Member. The OSL ages for the unit place it firmly in MIS5, thereby confirming the ages of the unit at nearby Ashton Keynes (Lewis et al. 2001) and Cassington (Maddy et al. 1998), but contrary to the previous textbook view which suggested an MIS2–3 age (Bridgland 1994; Gibbard 1999, 1985). An MIS5 age for the Northmoor Member has implications for the archaeological potential of that unit, given that hominins are thought to have been absent from Britain during the MIS4–6 interval (e.g Currant & Jacobi 2001). Indeed only one site, near Dartford in Kent, has been suggested to be of MIS5b–d age on the basis of chronometric dating (Wenban-Smith et al. 2010), while none have been so claimed for MIS4–5a or MIS5e–6).

11.5 Early hominin presence?

11.5.1 No artefacts were identified during the recent investigations and as such no new inferences can be drawn regarding the range and spatial patterning of the artefacts on the site itself (Q10). However, the fieldwork has helped to elucidate comprehension of the development of the confluence of the River Chum and Thames, and highlights the potential difficulties with future monitoring and protection of the important research for understanding the quaternary period in Britain

11.5.2 Lewis et al (2006) have suggested that the Northmoor Member gravels in the area of the present [redacted] formed within a low angle alluvial fan forming where the relatively steep River [redacted] (which drops by 5m km^{-1} its source [redacted] Cheltenham to Cirencester) meets the Thames floodplain (which has a slope of 0.7m km^{-1} between Somerford Keynes and Lechlade). Such a low angle fan setting in which channels might switch from one part of the fan to another might explain the MIS7–2 ages obtained from deposits within a narrow altitudinal range at [redacted]

[redacted] Latton and Ashton Keynes. Such a scenario, however, presents difficulties from a conservation point of view as the age of gravel deposits cannot be predicted on the basis of elevation or indeed present geological mapping. Indeed, each locality needs to be separately examined prior to and during aggregate removal in order to determine the depositional environment, chronology and hence Palaeolithic archaeological potential.

12 ARCHIVE RECOMMENDATIONS

12.1.1 Additional fieldwork The stratigraphic assessment allows for the formalisation of an Updated Project Design (Task 4.16–4.23) in order answer and/or refine the answers to the Aim 1–4, Questions 1–12 outlined in the original Project Design (Wilkins et al. 2019).

12.2 Stratigraphy and lithostratigraphy

Keith Wilkinson

12.2.1 Given the significance for understanding the age of the Northmoor Member and detailed geostratigraphic and biostratigraphic information, further publication of the results is recommended. It would significantly contribute to existing evidence from Latton (Lewis et al., 2006) and Aston Keynes (Lewis et al., 2001) which provided comparative records for which the chronology is less well understand. Further analysis of the Mollusca and insect remains would greatly add to our understanding of the environment during these periods. This work is critical to contextualising our understanding of the human occupation of Britain and understanding better periods of occupation, hiatus and abandonment. The results should be published in a suitable Quaternary Science journal such as Quaternary Science Reviews or Journal of Quaternary Science.

12.2.2 Laser granulometry would be recommended from the monolith samples, collecting particle size data to augment field descriptions and provide further detail to interpretations. This would entail the recovery of ten 5cm thick samples per monolith, resulting in a total of 40 samples for analysis. It is also recommended that clast lithological analysis of 16.0-11.2mm and 11.2-8mm clasts in eight of the bulk samples is undertaken. This will enable the source of gravel particles to be fully characterised, in particular whether the Northmoor Member and the palaeochannel fills have different sources.

12.2.3 Further fieldwork at [redacted] would benefit from physically linking Test Pits 1 and 3 by either a single trench or a series of test pits that trace the deposits from one to the other. Currently the stratigraphic relationships have been inferred from similar sediment morphologies, biostratigraphic assessment and OSL dating; however, a detailed sequence for the infilling of the wider palaeochannel could be established if a physical relationship was made. It is also recommended that a link between the palaeochannel with the Northmoor Member would be beneficial, involving cleaning and recording one of the sections in the north face of the quarry. Following this, a full lithological analysis of the Northmoor Member would be undertaken.

12.3 Pollen

Tom Hill

12.3.1 Due to the overall lack of identifiable Quaternary palynomorphs within the deposits, no further works are recommended.

12.4 Plant macrofossils

Marta Perez-Fernandez

12.4.1 Quantifying plant remains can be difficult. Due to preservation of the material several seeds from a number of different ecological environments can potentially survive in a whole or fragmented state. Certain species that are described as hyper abundant or containing a high number of seeds can alter or distort the assemblage and therefore interpretations. As a result, larger numbers of samples and sample volumes are required from waterlogged deposits in order to obtain and study representative plant communities in any detail.

12.4.2 Consecutive samples every few centimetres along a section or when a change in the stratigraphy is evident would be recommendable. The samples should be floated (rather than sieved) to avoid any breaking of the already fragile material. Larger samples (from 500ml to 1 litre) could provide richer assemblages.

12.5 Insects

Enid Alison

12.5.1 Preservation of beetles and bug sclerites is generally moderate. Chemical erosion is limited mainly to thinning of cuticle in most samples. Much of the material is identifiable sufficiently closely to provide data on aquatic and terrestrial conditions.

12.5.2 Two of the samples have a good potential for analysis, with the remainder generally judged to have moderate or, in one case, low potential (see Appendix 11). It is recommended, however, given the importance of the site, that all eight samples are fully sorted for insect material and analysed. This will aid the understanding of depositional processes, and will provide data for reconstruction of both aquatic and local terrestrial environments over the time that the channel sequence accumulated, these being two of the research objectives. Depending on how closely some of the material can be identified, there is also a potential to produce data on climatic conditions associated with particular parts of the sequence of deposits using the Mutual Climatic Range method. This is based on the mutual intersection of modern climatic ranges of selected species in the fossil record.

12.5.3 The caveat with any reconstructions associated with deposits that accumulated in a running water channel is that there could have been some degree of re-deposition of material due to changing water regimes. Also, the insects recovered may represent a somewhat wider catchment area than those that would be obtained from an isolated water body.

12.5.4 Dung beetles were well-represented in all the samples which points to the presence of dung in the area adjacent to the water channel, although it should be noted that these beetles have a good dispersal ability which enables them to find new sources of dung, and some species overwinter in flood refuse (Jessop 1986, p. 19-25).

12.5.5 The paraffin flots containing the insect material are currently stored in jars of industrial methylated spirits (IMS). Storage of extracted insect material once analysis is completed is problematic, however. Material kept in IMS tends to deteriorate in the long-term, often eventually becoming pale 'ghosts'. Storage in water or even freezing may be a better option for long-term storage with the rest of the site archive. With well-preserved material, drying is a further option, but for delicate material, such as that from the current site, this may result in further fragmentation.

12.6 Molluscs

12.6.1 Matt Law

12.6.2 The molluscan shell assemblage is well-preserved and does not appear to include recent intrusions.

12.6.3 Taken as a whole, the assemblage reflects slow deposition within a well-vegetated slow-moving water body, with enough flow to winnow opercula of *Bithynia tentaculata*. The relatively low diversity most likely reflects climatic conditions, with temperatures cooler than those of fully interglacial conditions.

12.6.4 Full analysis of the assemblage is recommended, to better understand and contextualise its palaeoecological and palaeoclimatic interpretation. It is recommended that a text integrating the different palaeoecological proxies examined be brought to publication, with full and open availability of the datasets, and all material submitted to an appropriate archive.

12.7 Microfauna

Danielle Schreve

12.7.1 The paucity of the assemblage recovered unfortunately means that little of significance can be said regarding the prevailing palaeoenvironment, climate or age of the deposits on the basis of the microvertebrates.

12.7.2 Despite the processing of over 60kg of sediment, no identifiable small mammal remains were recovered and only Test Pit 2 produced any significant finds in the form of a few diagnostic fish remains. Samples from Test Pit 3 did not produce any small vertebrates. Possible reasons for this may stem from the coarseness of the sediment sampled and the choice of sampling location. Some samples, for example <9> from Test Pit 1, were composed of extremely coarse gravel, some of it cobble size. These types of sediment are highly unlikely to yield microvertebrates, although historically, they have produced substantial quantities of large mammal remains in quarry sites in the Thames valley, particularly in the pre-mechanisation era.

12.7.3 Nevertheless, the yield from [redacted] is particularly low, suggesting that either the depositional environment was unsuitable for the preservation of fragile microvertebrate remains (perhaps unlikely, given that molluscan shells were visible in the residues) or that the sampling point was located too far away from the palaeochannel edge for the recovery of terrestrial vertebrates. Marginal points on the edge of river channels are more likely to yield remains of terrestrial species (eg. Schreve et al., 2002). In similar cases, where vertebrate yield has been low in otherwise fossiliferous sediments, distance from the sampling point to the bank has been inferred as a contributing factor (eg. Green et al., 2006). However, while this may explain the lack of terrestrial vertebrates in the samples, even the yield of fish remains is notably scant.

12.7.4 In terms of future work, the identification of sampling points closer to the palaeochannel edge and over a much wider area would be a potential way to proceed. In a fluvial context, however, this can be a rather 'hit and miss' process and the occurrence of large mammal material does not offer a guide as to the likely presence of small vertebrate remains. The relatively greater presence of material in TP2 is therefore not seen as especially significant. Any future sampling focus should be on fine-grained sediments.

12.7.5 The [redacted] finds have been stored in labelled 10mm glass test-tubes with plastic stoppers (with the exception of the larger bone fragment from Sample 14, which is in a labelled resealable bag). They will be returned to DigVentures for archiving.

12.8 Conservation

Nigel Larkin

Mammoth tusk

12.8.1 The large mammoth tusk excavated from the site at [redacted] is currently still in its protective field jacket: wrapped in acid-free tissue and aluminium foil encased in plaster and hessian with a wooden splint, stored on a pallet. There is much sediment encased within the plaster, consisting of sands and gravels, and the tusk itself comprises thousands of pieces of tusk held together in a tusk shape by the surrounding sediment and the field jacket – without which it would have fallen to pieces.

12.8.2 For the tusk to be measured, photographed, studied and described, the field jacket and the sediment has to be slowly removed from the specimen, the surface of the specimen has to be cleaned (removing the sand, mud and gravel, and the consolidant applied in the field) and the tusk has to be thoroughly stabilised with fresh consolidant. Once this process of cleaning and consolidating has been completed for what is now the top side of the specimen but is actually the underside as found, a strong supportive jacket will need to be made of archival materials (such as Plastazote foam and Jesmonite acrylic resin with woven glass fibre) for what is currently the upper surface. Then the whole specimen in its partial field jacket and new archival jacket will need to be turned around the right way (e.g. as found in the field). The remaining portion of the field jacket can then be removed and the topside of the specimen (as found) can be cleaned, consolidated and repaired (with reversible Paraloid B72 in acetone).

12.8.3 The tusk, in its archival permanent supportive jacket, will then be placed on a permanent purpose-made pallet made to the required size so that it can be picked up and moved around on the pallet, rather than being picked up in its jacket, minimising the risk of damage to the tusk.

Long-term storage

12.8.4 All material, whether treated with PVA, Paraloid B72 or remaining untreated, should be assumed to be fragile. The direct handling of bones and teeth etc should be kept to a minimum, and disposable gloves should be worn (in future, people may be sampling the material for isotopes, DNA etc). Most importantly, the material should be stored and moved in (or on) adequately sturdy archival media. Ideally specimens should lay on appropriately shaped 'nests' of acid free tissue, itself lying on inert Plastazote foam, within sturdy acid-free cardboard boxes or polypropylene crates (such as standard 'Euro crates' or 'Really Useful Boxes' that handily stack). All remains should be stored, where possible, between 45–50% relative humidity, and not fall below 40% or above 60%. Materials should be kept away from diurnally fluctuating sources of warmth (such as radiators) and sources of 'coolth' (such as windows and doorways), as daily fluctuations in temperature and relative humity can cause subfossil material to split and crack. Storage should follow British Standard 5454 and guidelines outlined at the National Museum Directors Conference (2009).

12.9 Faunal remains

Hannah Russ

12.9.1 It is recommended that an analysis of the assemblage recovered in 2019, including the material unavailable during this assessment, is undertaken in conjunction with that for the remains previous assessed from the site (Scott 2019). The analysis should include calculations of number of individual specimens (NISP), minimum number of elements (MNE) and minimum number of individuals (MNI) to establish the number of animals represented by the combined assemblage and the range of species present. The analysis should consider the speciation of the mammoth remains that could not be determined during the assessment phase. Where possible, mammoth molars and bones should be measured according to standard protocols (see Lister & Joysey 1992 and Lister & Sher 2015 Supplement). Measurements for mammoth remains should be plotted against Lister's extensive database on UK and continental European Middle to Late Pleistocene. It is recommended that metrical analyses of the Bovidae remains discovered in 2017 is undertaken in order to confirm the identifications made during the assessment phases (Wright 2014; Wright and Viner 2015). A taphonomic assessment of all material recovered from [redacted] in 2017 and 2019 should be undertaken after the completion of cleaning and consolidation work to record any evidence for animal activity or anthropogenic modification that might be present on the bone surfaces. The vertebrate remains from [redacted] should be analysed within the context of the stratigraphic and spatial analyses of the site, and then considered in comparison to other MIS 7, MIS 6 and lastglacial sites (such as Purfleet, Crayford, Stanton Harcourt and Pontnewydd), for biostratigraphic and evolutionary interpretation.

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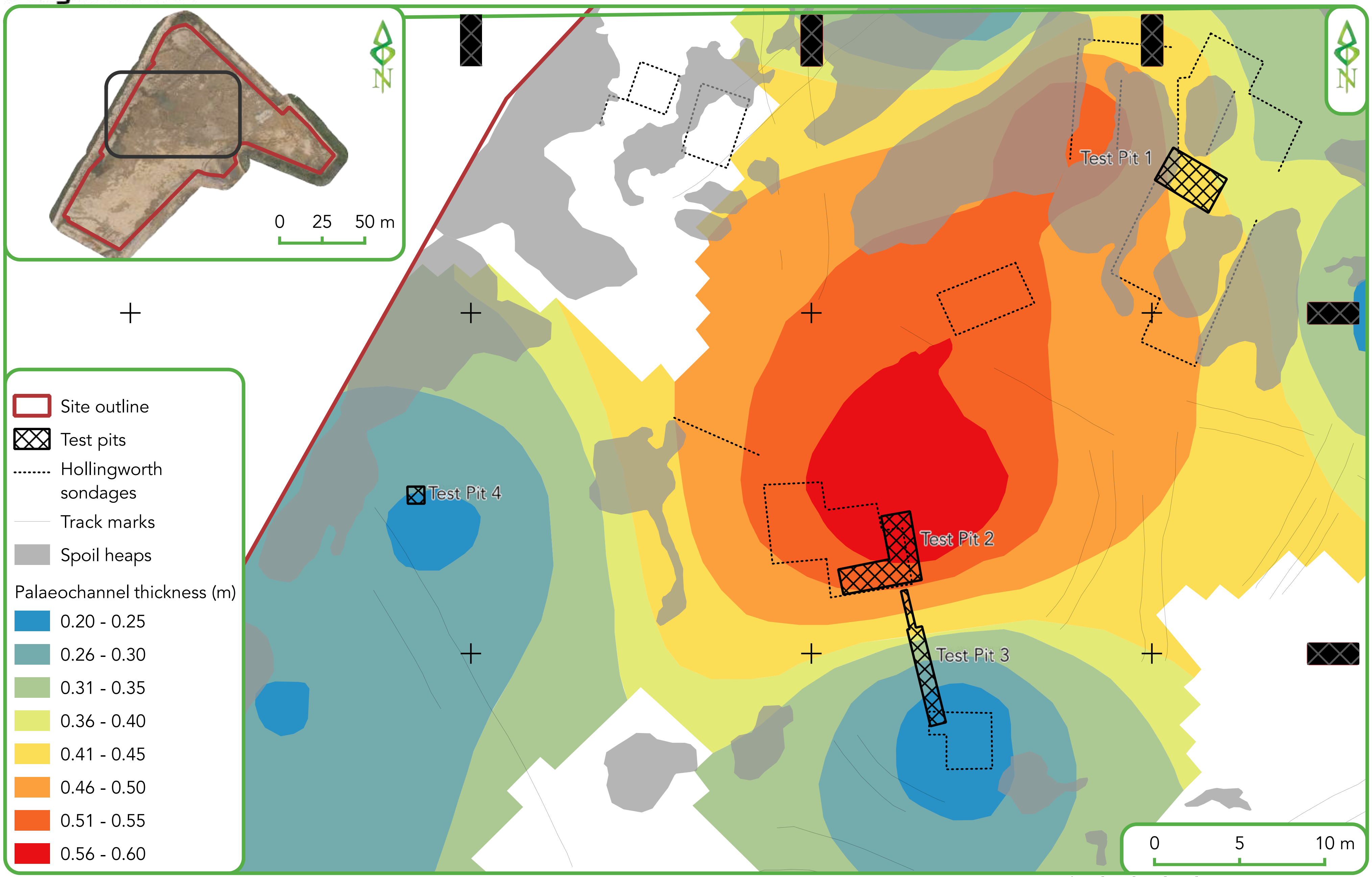

Figure 2 - [redacted] Test pit locations

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Figure 3 - [redacted] Test Pit 1 Plan

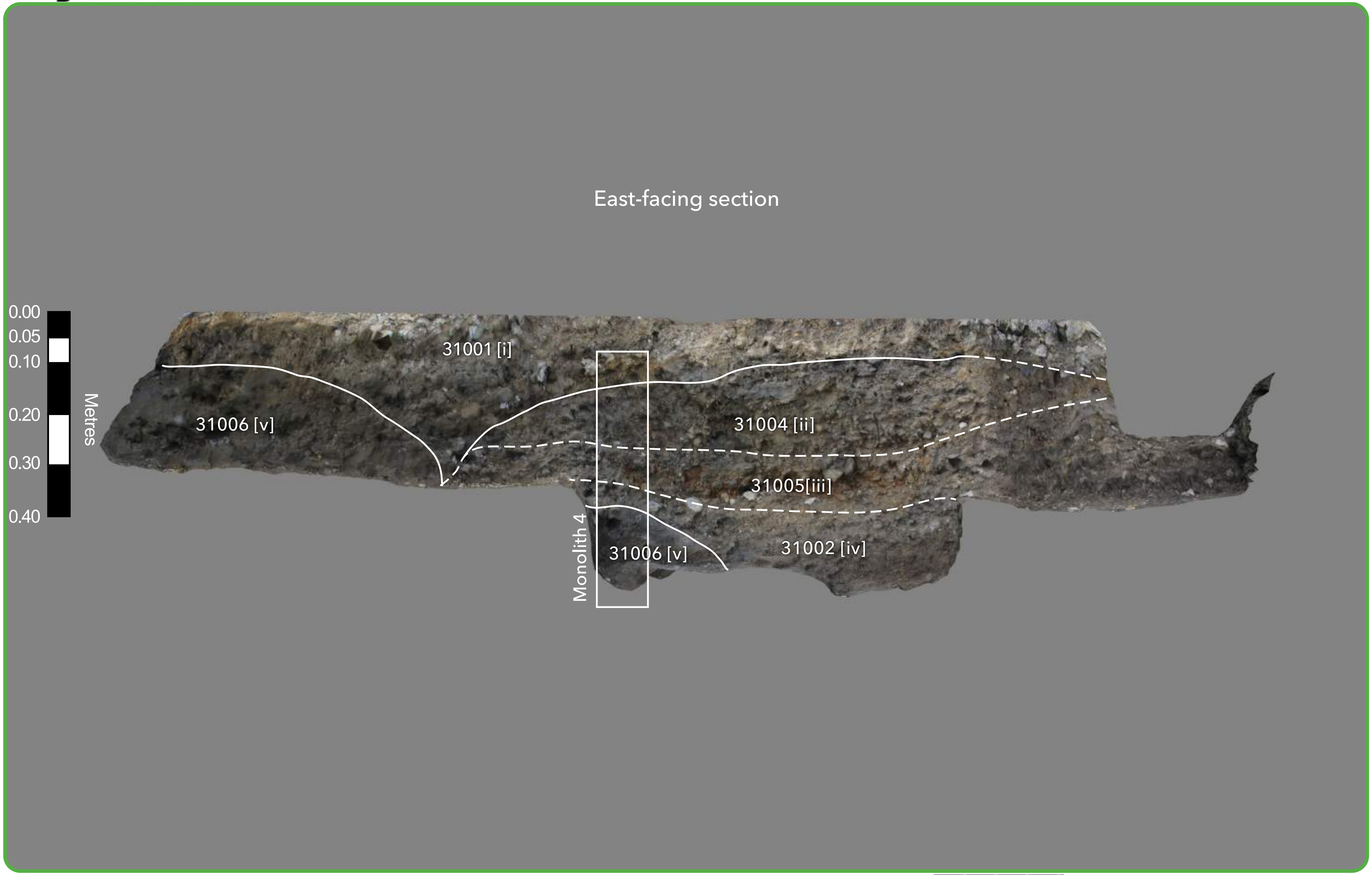

Figure 4 - [redacted] East-facing section of Test Pit 1

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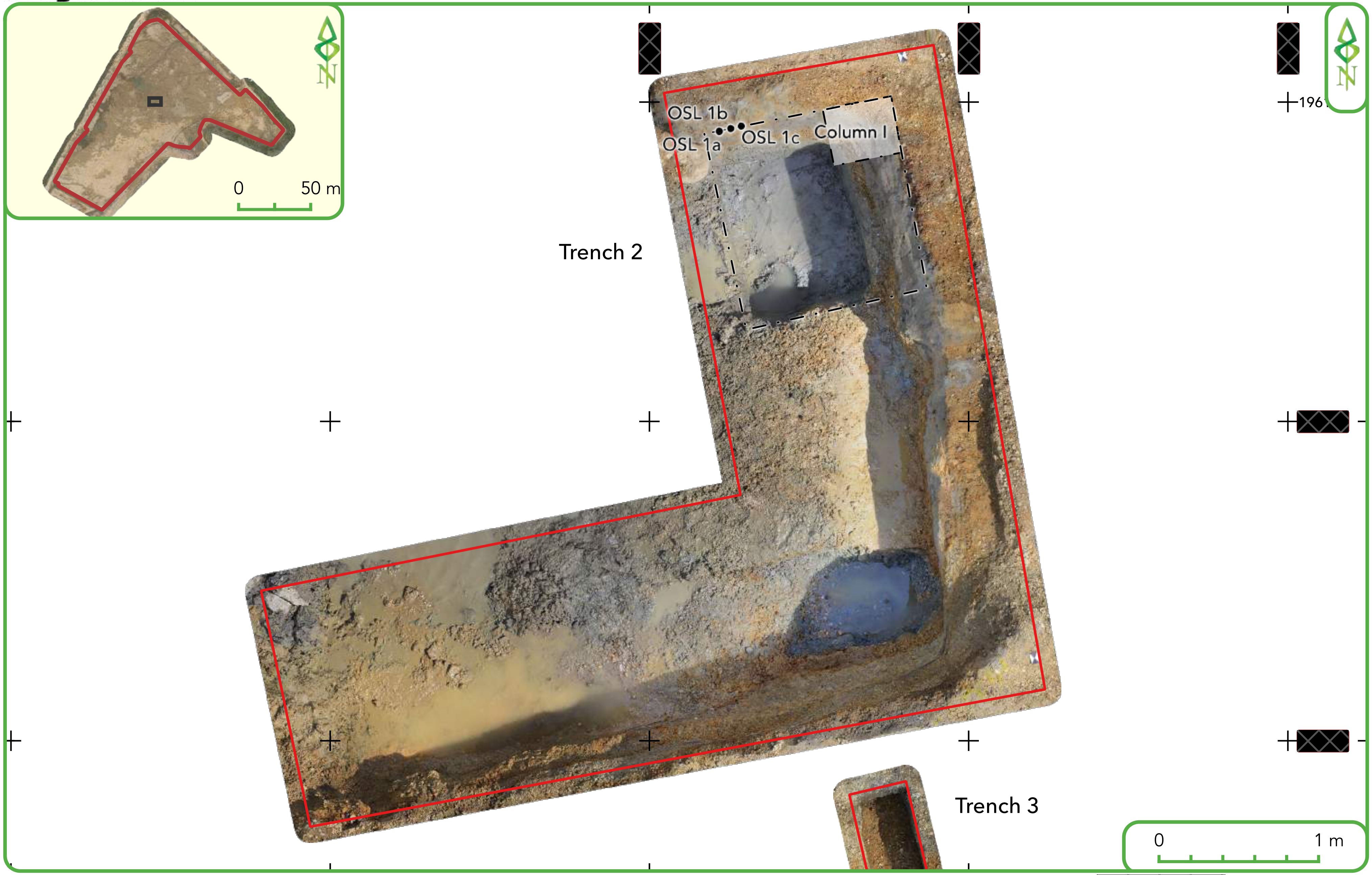

Figure 5 - [redacted] Test Pit 2 Plan

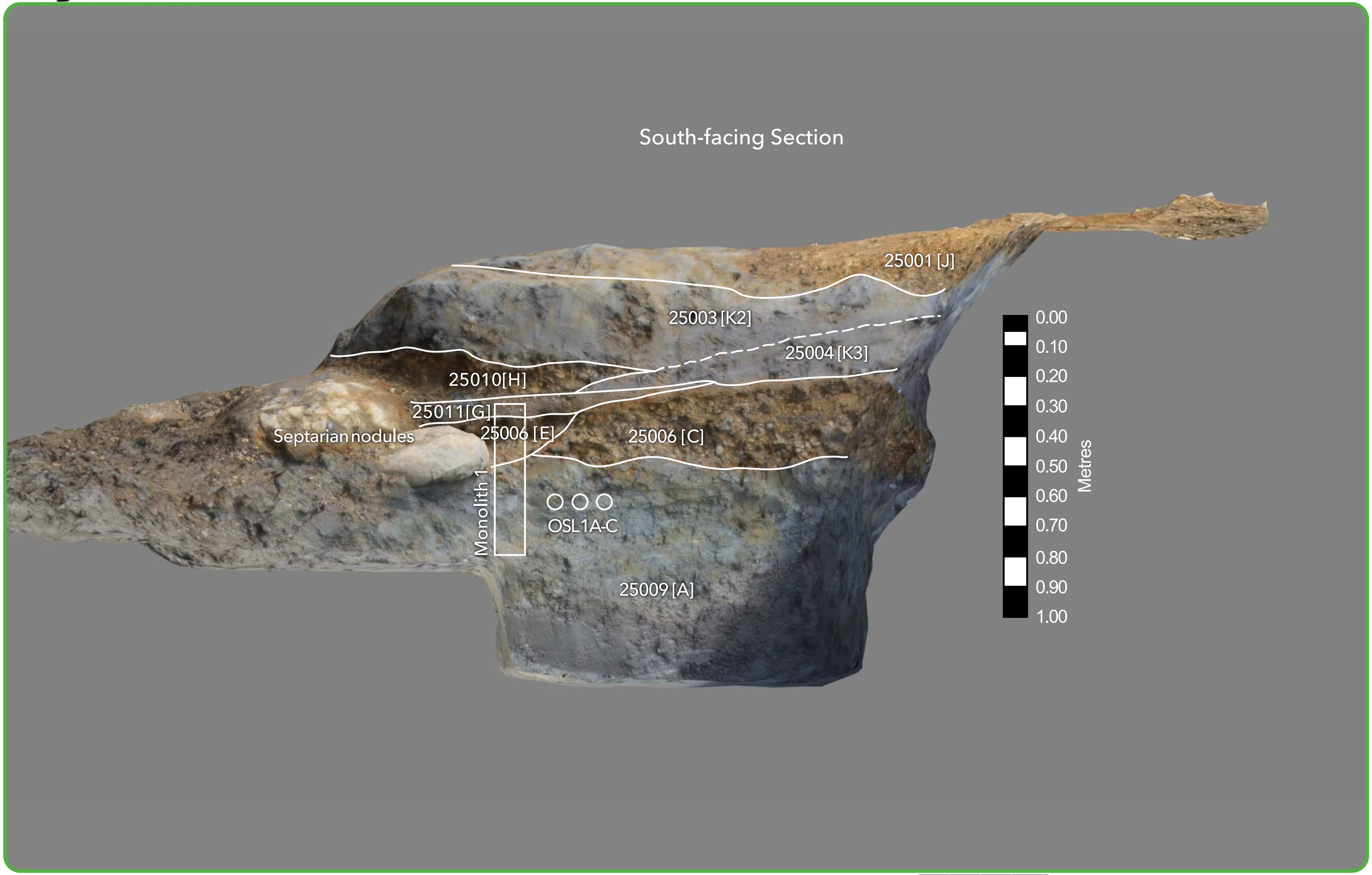

Figure 6 - [redacted] South-facing section of Test Pit 2

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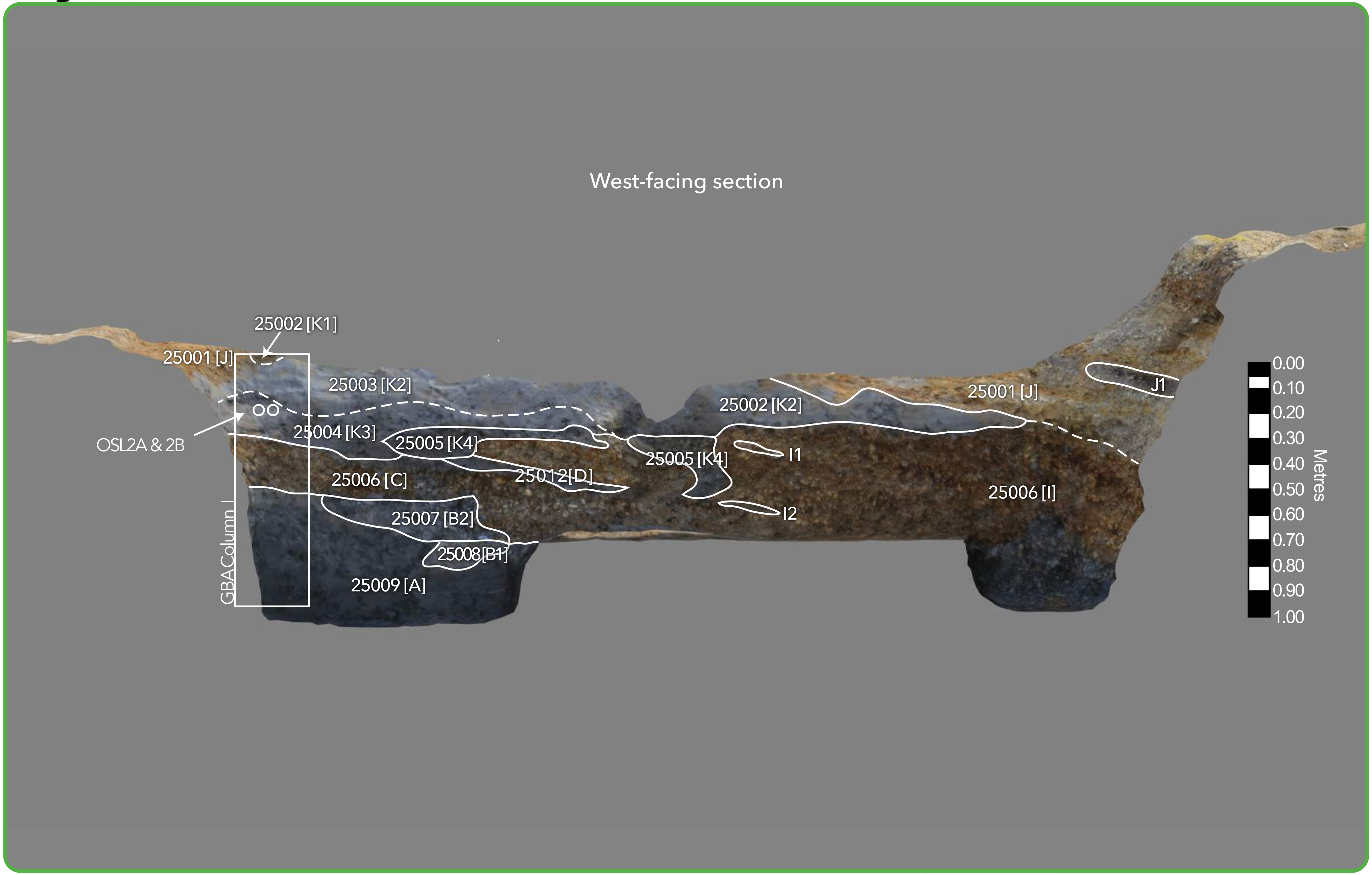

Figure 7 - [redacted] West-facing section of Test Pit 2

Figure 8 - [redacted] North-facing section of Test Pit 2

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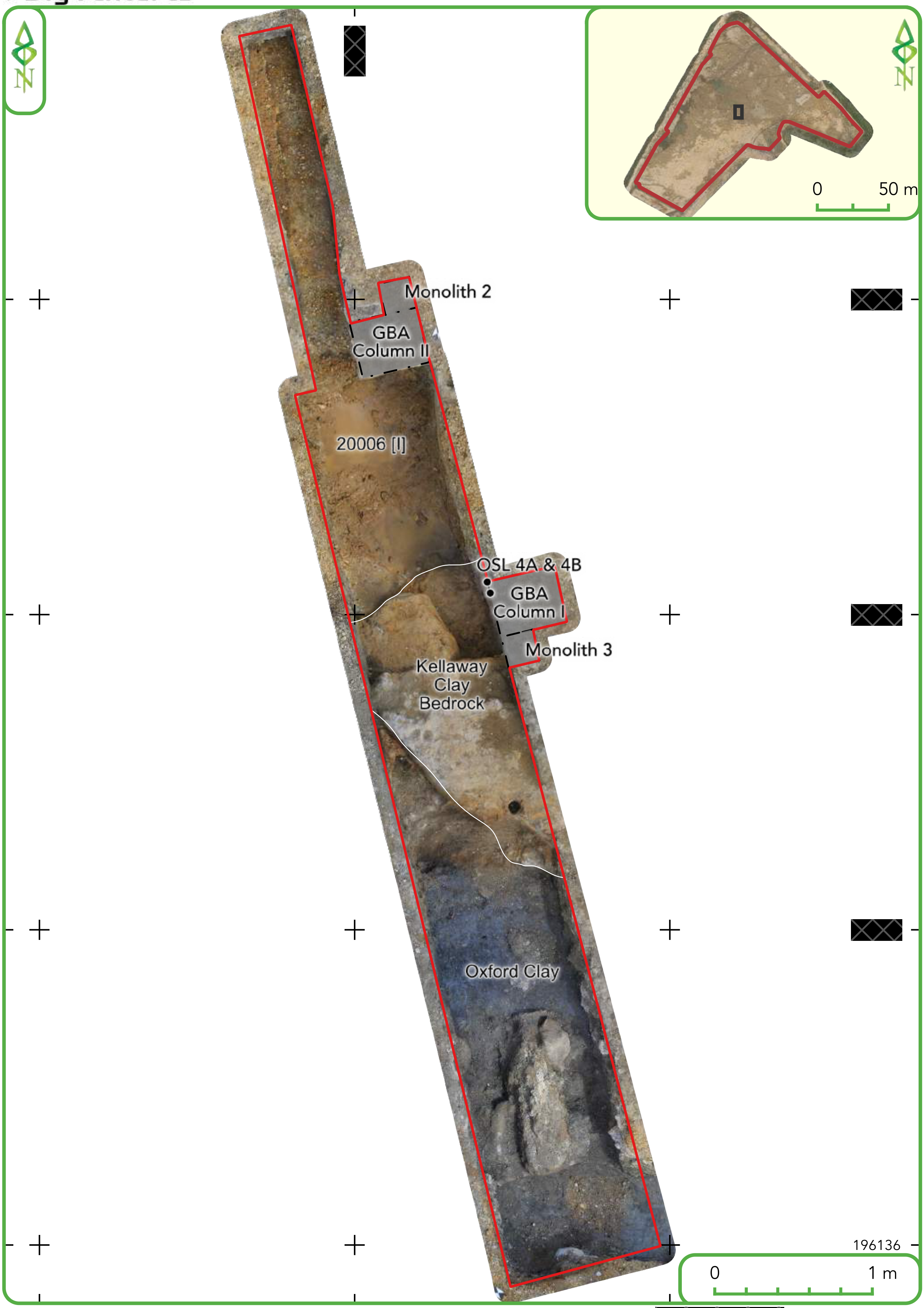

Figure 9 - [redacted] Test Pit 3 Plan

West-facing section

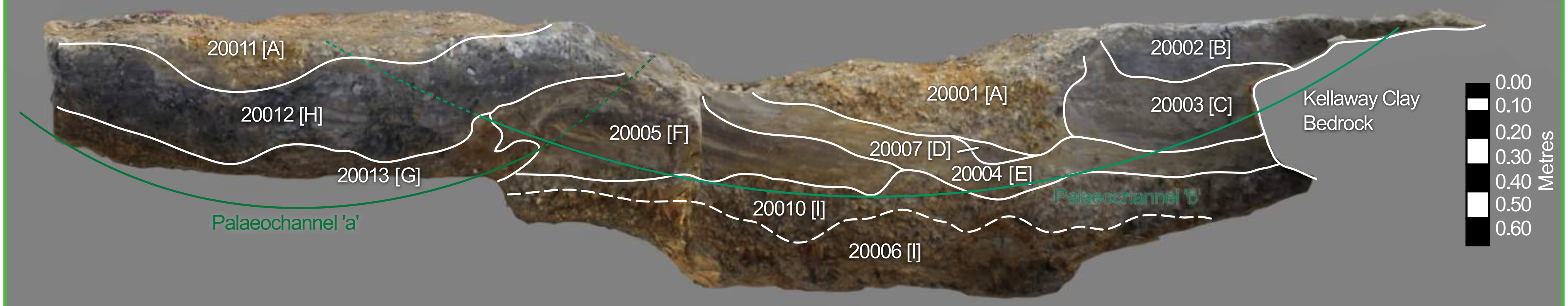

Figure 10 - [redacted] West-facing section of Test Pit 3

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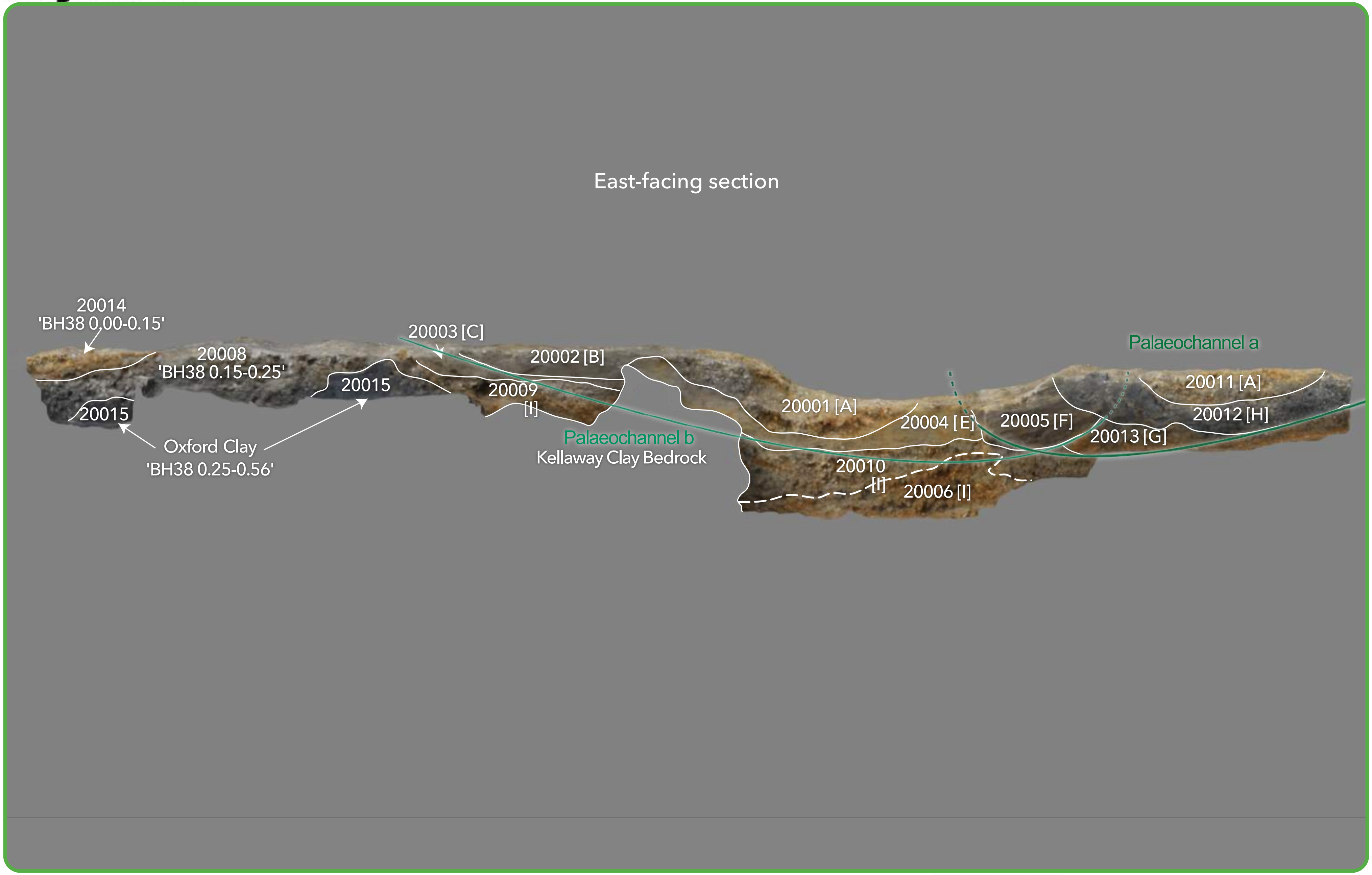

Figure 11 - [redacted] East-facing section of Test Pit 3

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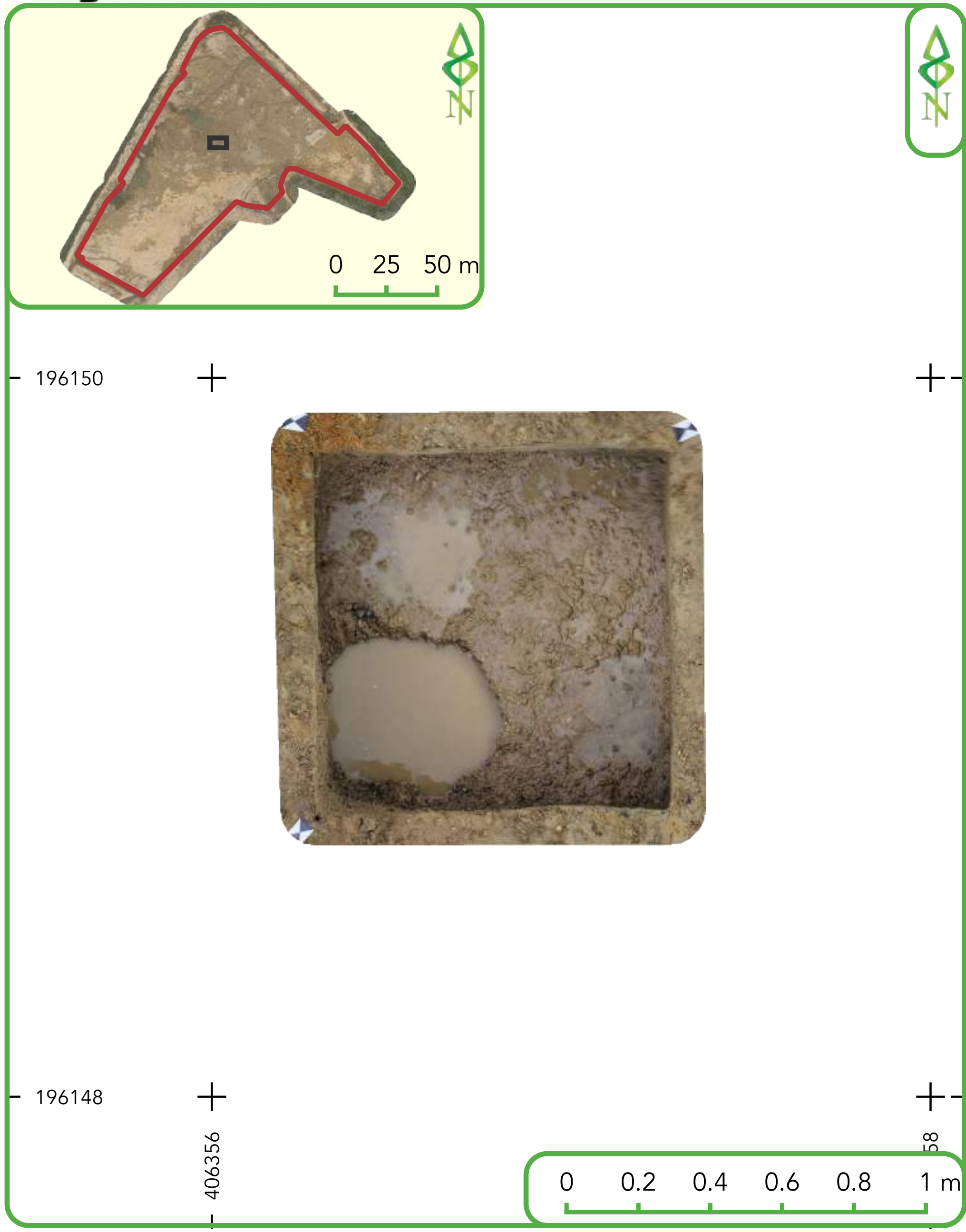


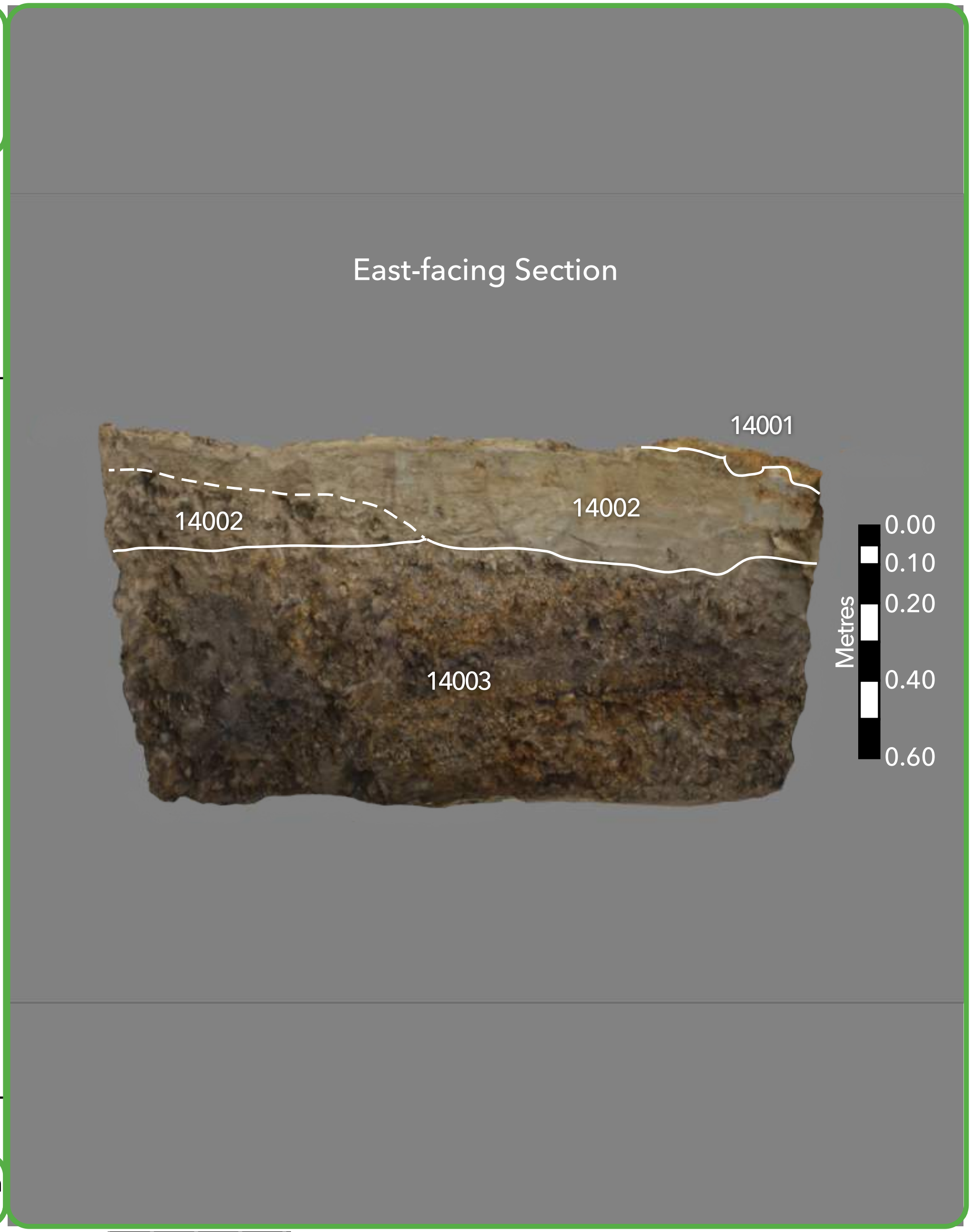


Figure 12 - [redacted] Test Pit 4 Plan (left) and east-facing section (right)

Figure 13 Logs of sampled test pit and quarry wall sections

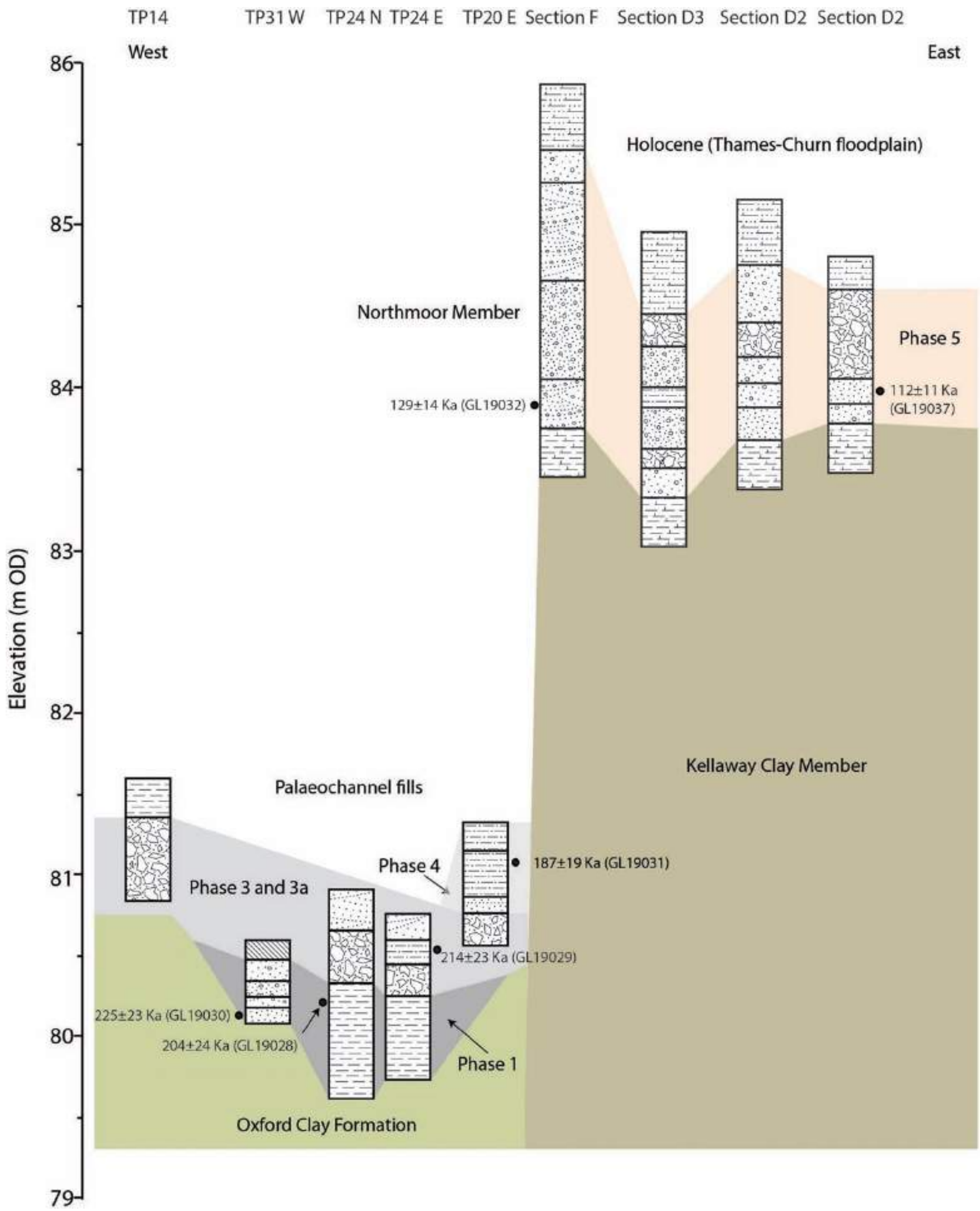
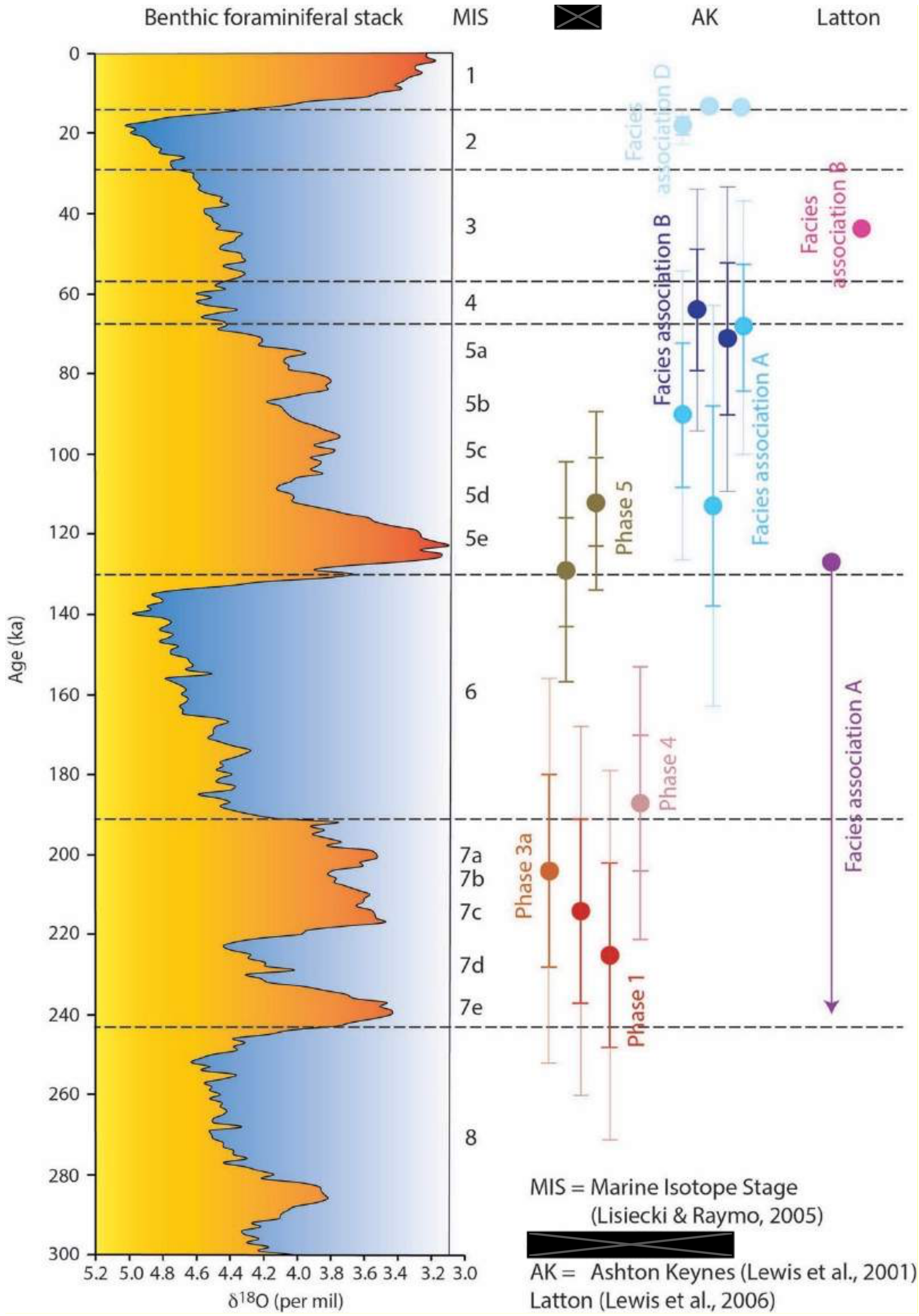


Figure 14 Ages, phases and facies associations from [redacted] Latton, Ashton Keynes, Cassington and Stanton Harcourt plotted again Lisiecki and Raymo's (2005) global stack of $\delta^{18}O$ from benthic foraminifera with MIS5 and MIS7 sub-division nomenclature follow



Appendices

APPENDIX 1. STAGE 2A - UPDATED GEOARCHAEOLOGICAL ASSESSMENT

By Keith Wilkinson, Monika Knul, Paul Lincoln and Jenni Sherriff

Introduction

The initial stages of archaeological study of [redacted] comprised the compilation of desktop reviews of the existing published and unpublished resource. The geoarchaeological component of these studies (Stage 2a of the Project Design) consisted of an assessment of existing lithostratigraphic records from the study area itself, the wider area that was the subject of [redacted] 1988 aggregate extraction application [redacted] an area encompassed by a 2km radius from the centre of the [redacted] site. The aims of the assessment were to (a) provide a stratigraphic context for the fieldwork that followed, and (b) determine whether the palaeochannel that was to be investigated by the project, could be traced beyond the study area (Wilkins et al 2018, table 3, 27).

Methodology

Lithostratigraphic data were obtained from two sources, firstly the British Geological Survey (BGS) borehole database (British Geological Survey 2019a), and secondly records of test pit and borehole stratigraphy of the [redacted] site collected by [redacted] as part of its application to extract aggregate from the site [redacted] There are 63 records in the BGS borehole database for an area described by a 2km radius circle plotted from the study area centre (Figure 15). However, 21 of these boreholes were restricted/classified and could not be viewed, 33 were boreholes drilled for hydrological purposes and from which no lithology was described, while 6 of the remainder lacked absolute elevation data[2]. In other words, only three suitable records could be harvested from the BGS borehole database (BGS SU09NE28-30). The stratigraphic records provided by Hills Aggregates Ltd comprised 27 test pit and 11 borehole records. Of these, one borehole (Hills CWQ BH1) and two test pits (Hills CWQ TP1-2) were drilled/excavated within the study area, while all the remainder (except for Hills CWQ TP25-27) were positioned within the wider area of the 1988 aggregate extraction application. Absolute elevation data were not recorded for the Hills Aggregate Ltd boreholes and test pits. However, given that Ordnance Survey contour data suggests that the application area was relatively flat prior to extraction, a benchmark value of +83.8m OD located immediately south of the site (at the location of BGS SU09NE29) was applied to all the boreholes and test pits

Positional and lithological data from the 3 suitable records in the BGS borehole database and the 38 records provided by Hills Aggregates Ltd were transferred to a database of the RockWare 15 geological utilities program (RockWare). That software was then employed to construct the composite cross sections as shown below in Appendix 2 Results.

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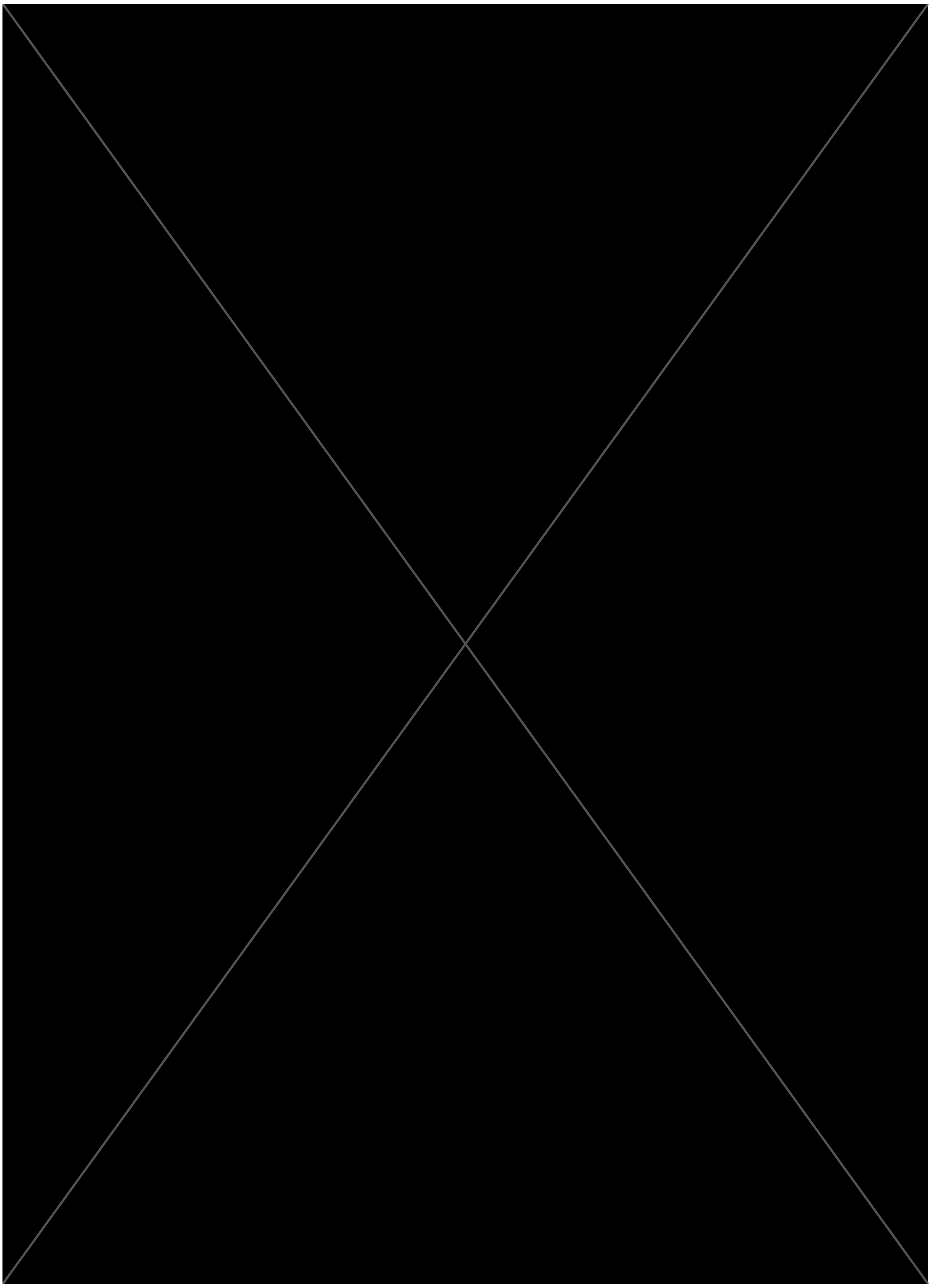
[2] Given the considerable changes in topography brought about by aggregate extraction in the now [redacted], it was not considered appropriate to apply present elevation data to borehole records made in the early 1980s and earlier.



Results

Before describing the broad lithostratigraphy of the site and the area beyond on the basis of the geotechnical borehole and test pit data, it is necessary to set out a few caveats. Firstly, because the absolute elevations of the Hills Aggregates Ltd test pits and boreholes are not known and a constant +83.8m OD was applied to these records, the exact elevations of sub-surface contacts are also subject to a potential error. Secondly, the lithological 'descriptions' of the Hills test pits and boreholes are sparse in detail and units are frequently described in one or two words, e.g. 'topsoil', 'gravel' and 'blue clay'. Lithological descriptions in the BGS records are slightly more detailed, but even so, neither they nor the Hills records enables the gravels to be sub-divided on the basis of their structural or grain size properties, while it is not even possible to separate the two relevant Jurassic strata – Oxford Clay Formation and Kellaway Clay Member – from one another.

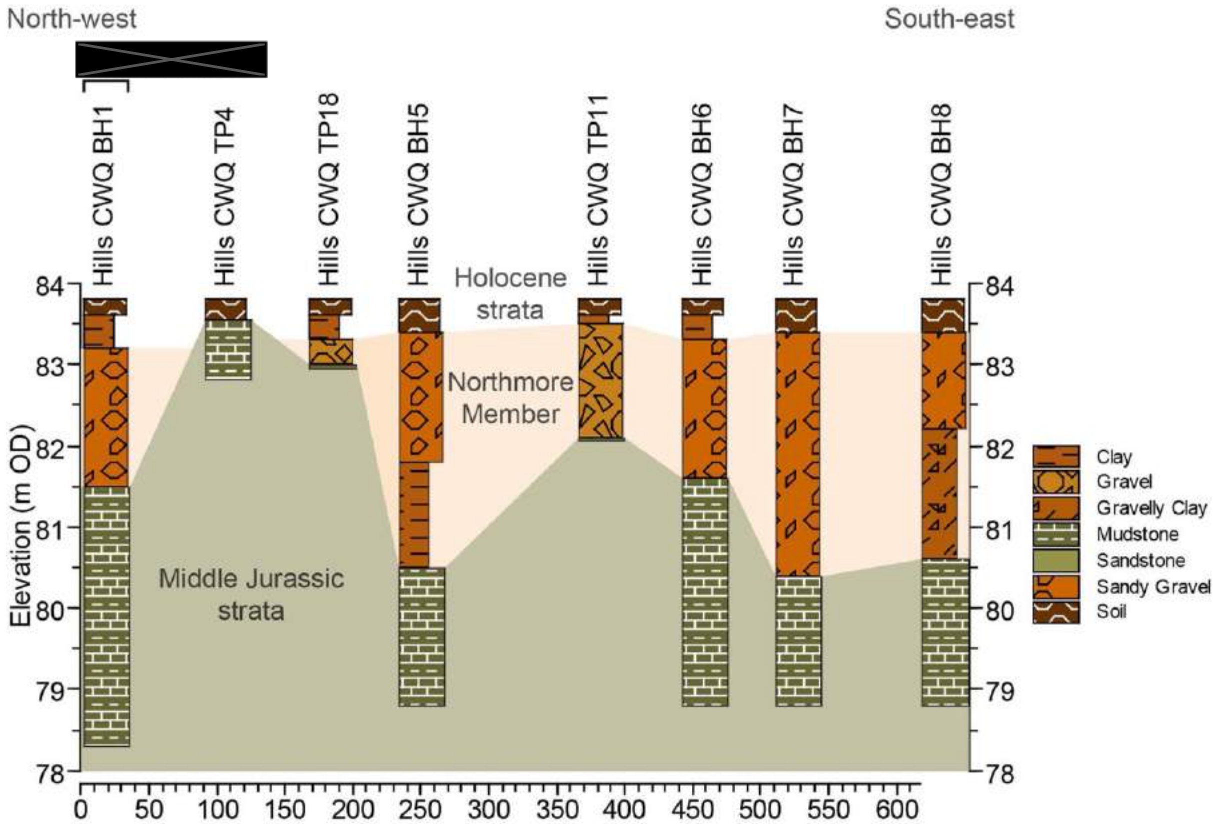


Figure 16. North-west to south-east composite cross section through [redacted] *and the wider study area of the 1988 aggregate extraction area*

Figure 17 shows a north-south composite cross section through the study area and the wider application area to the south. The borehole and test pit stratigraphy demonstrate that the Jurassic geological basement (termed 'mudstone' and 'sandstone' in Figure 16 and Figure 17, but representing both the Oxford Clay Formation and Kellaway Clay Member) outcrops around +81m OD. The possible exception is the extreme north of the site in Hills CWQ TP1 where the Jurassic bedrock was not encountered despite the relevant test pit being excavated to c. +80m OD (although see the caveats presented above). Further, between 1.5 and 3.9m of gravels overlie the bedrock across both the study area and the application area to the south. Where greater descriptive detail is provided (e.g. in BGS SU09NE29), the gravels are termed 'sandy' and they must therefore be, at least in part, matrix-supported, while there are hints in some records (e.g. Hills CWQ BH5 and BGS SU09NE29), that facies comprising gravels in a silt/clay matrix may sit at the base of the gravel sequence.

In contrast to the relative uniformity of gravel outcrop elevation and thickness on a north-south axis (Figure 16 and Figure 17), there is some variation in both in a north-west to south-east direction (Figure 16). There appears to be only a thin veneer (<0.5m) of gravel in the area immediately east of the study area (Hills CWQ TP5 and Hills CWQ TP18) and rather the Jurassic bedrock outcrops at +83m OD and higher. Gravel thickness increases again in a south-easterly direction of Hills CWQ TP18 to c. 1.5m in Hills CWQ BH5, Hills CWQ TP11 and Hills CWQ TPBH6, and then to c 3m in Hills CWQ BH7 and areas to the south and east. These data suggest that a bedrock promontory exists to the east of the site and which may have diverted and/or obstructed the flows that caused gravel deposition.

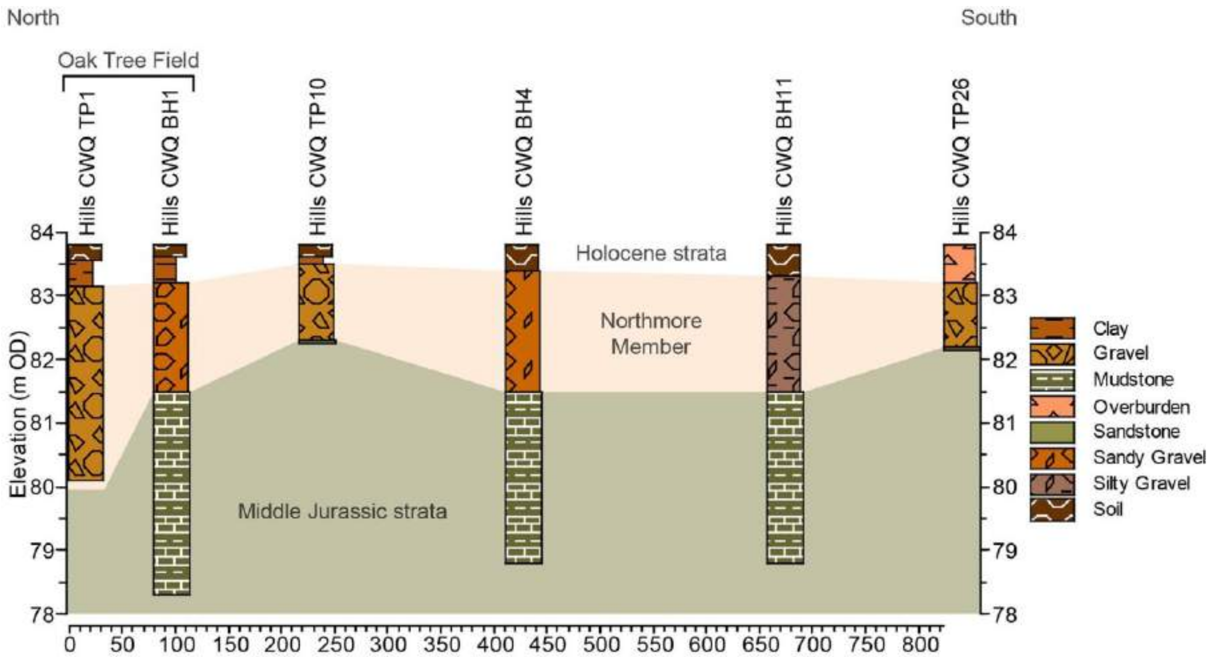


Figure 17. North-south composite cross section through [redacted] *and areas to the south*

The gravels, and Jurassic bedrock in the case of records from immediately east of the study area such as Hills CWQ TP4, are overlain by between 0.2 and 0.8m of 'topsoil' and 'subsoil' (represented as 'clay' and 'soil' in Figure 16 and Figure 17) in all records. It is unclear from the descriptions whether the topsoil and subsoil are developed within the gravels, or in a fine-grained overbank alluvium.

Interpretation

The existing geotechnical records have poor descriptive and spatial resolutions. As such it was difficult to draw precise inferences from the data recovered from the boreholes and test pits. It is also the case that of those boreholes/test pits drilled/excavated through the site itself, only CWG TP1 coincided with the palaeochannel. Even in the latter case the only indication of the presence of a palaeochannel was the thick sequence of gravels recorded (extending below the bedrock outcrop as recorded in other adjacent records), rather than lithological differences in the strata recorded. Nevertheless, the geotechnical records do provide context for the lithostratigraphy of the site and indicate that a reasonably consistent thickness of 1.5-3.9m of gravel outcrop across the wider study area, while the bedrock surface slopes upwards immediately east of the site.

APPENDIX 2. STAGE 2B - UPDATED GEOARCHAEOLOGICAL ASSESSMENT

By Keith Wilkinson, Monika Knul, Paul Lincoln and Jenni Sherriff

Introduction

The second phase of geoarchaeological work, as stated above, was intended to be a borehole survey of deposits within [redacted] quarry (Stage 2b of the Project Design) and had the objective of generating a deposit model on the basis of which archaeological test pits would be positioned (Wilkins et al 2018, 31–32). However, after drilling two boreholes (ARCA BH26 and ARCA BH27, see
Figure 18), it was found that <0.5m of the Pleistocene depositional sequence was preserved over most of the base of the quarry and that could be more quickly penetrated in a spade-sized 'test pit'. This latter approach therefore provided the majority of data on which the deposit models were developed.

Methodology

Thirty-four 'boreholes' were originally planned for the site as shown in
Figure 18. These sample locations were planned in an ArcGIS project developed for the site, uploaded to a Leica System 1200 RTK GPS, and that equipment used to mark the relevant positions in the field. Four of the sample positions were boreholes and thirty were spade width test pits, but in in all cases they were drilled/dug from the quarry base to the Jurassic basement. The boreholes were drilled using an Atlas Cobra TT petrol-powered hammer driving 75 and 60mm diameter Eijkelkamp gouge augers. Strata recovered in the auger heads was photographed, described using standard geological terminology (Jones et al. 1999, Munsell Color 2000, Tucker 2011) and then discarded (i.e. used to backfill the hole). Sections exposed in spade test pit walls were photographed and the exposed sediments described using the same criteria as used for the boreholes. Although not an activity specified in the Project Design, it was also decided to record sequences exposed in the walls of the test pits excavated in 2017 by Neville and Sally Hollingworth. The relevant sections were therefore hand-cleaned, photographed, sketched and then described using the method outlined above (see 'PT' codes in
Figure 18). Corners of the 2017 test pits were surveyed in with the Leica System 1200 GPS, while a series of further control points were also surveyed and marked in the quarry base as reference points for total station survey during the final (archaeological test pit) phase of work on the site. Fieldwork to undertake the activities outlined above was carried out between 23 April and 3 May 2019.

The borehole, spade-dug test pit and 2017 test pit wall lithostratigraphic and locational data were added to the same RockWorks 15 database that housed the geotechnical records described in Section 3. That software was then employed to produce composite cross sections, and surface (of the Jurassic basement) and deposit thickness (of the palaeochannel fills) models. Given the irregular distribution of sample points, a kriging algorithm based on the eight nearest neighbours was used to produce the latter, which were transferred to the ArcGIS project on completion. Lithological data recovered at each borehole/test pit sample point and relevant positional data are included as Appendix 3.

Figure 18. The [redacted] quarry site showing the location of geoarchaeological boreholes and test pits, sections of 2017 test pits that were described and archaeological test pits excavated by Dig Ventures and ARCA

Results

Composite cross sections through the palaeochannel at the base of the [redacted] quarry are shown in Figure 19, Figure 20 and Figure 21, while surface and deposit thickness models are included as Figure 22 and Figure 23. The latter demonstrate that the Jurassic bedrock lies at elevation of c. +82.0m OD in the eastern part of the quarry and +81.0 to +80.2 m OD in the centre and west. A bedrock scarp can clearly be seen in Figure 22 across the southern part of the quarry. As Figure 23 demonstrates, the area to the north and west of the scarp is partly filled by up to +0.60m of palaeochannel fill. The composite cross sections also clearly show palaeochannel strata lying to the west of the scarp developed in the Kellaway Clay Member, the latter indicated by a bedrock elevation some 1.62.0m higher in the easternmost extreme of each transect. Moreover, in all boreholes/test pits where palaeochannel deposits were encountered, their lower contact is always with weathered mudstones of the Oxford Clay Formation. Collectively these data indicate that the palaeochannel at the [redacted] site developed within the Oxford Clay-filled fold in the Kellaway Clay Member discussed in Section 2 above. Indeed, as is outlined further below, the more easily weathered (cf. the Kellaway Clay) sediments of the Oxford Clay Formation provide the source material for many of the palaeochannel fills. The cross sections also show the asymmetry of the channel form, with the eastern side being relatively steep and the west grading gently into undisturbed Oxford Clay.

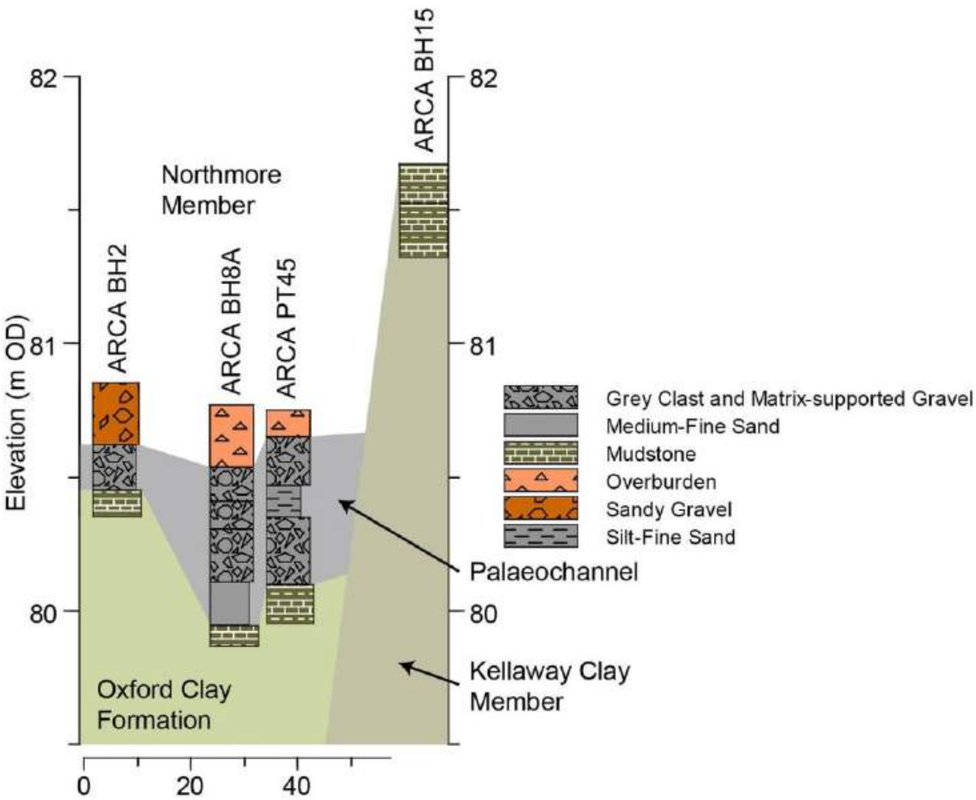


Figure 19. North-west to south-east composite cross section through the palaeochannel fills later exposed in Test Pit 1 (at ARCA BH8A)

The test pit/borehole survey demonstrates that the palaeochannel has heterogenous fills comprising the following facies:

i. Clast-supported limestone pebble gravel in a granular matrix (filling troughs) ('Grey clast and matrix-supported gravels' in Figure 19Figure 21)'
ii. Dark greyish brown (Munsell 2.5 Y 4/2) fossiliferous (mollusc shell and vertebrate remains) limestone pebble gravels and sands ('Grey clast and matrix-supported gravels' in Figure 19Figure 21)'
iii. Dark greyish brown (Munsell 2 Y 4/2) fossiliferous (mollusc shell) limestone pebbles in a silt/clay matrix ('Silt with gravel' in Figure 19Figure 21);
iv. Dark grey (Munsell 2.5 Y 4/1) fossiliferous (mollusc shell) fine sands and silt ('Silt-fine sand' in Figure 19Figure 21)
v. Dark grey (Munsell 2.5 Y 4/1) fossiliferous (mollusc shell) silt/clays with occasional sub-rounded limestone pebbles ('Silt with gravel' in Figure 19Figure 21);
vi. Dark greyish brown (Munsell 10 YR 4/2) fossiliferous (mollusc shell), lenticular-bedded organic silt/clay ('Organic mud' in Figure 19Figure 21);

These fills sit on dark grey (Munsell 5 Y 4/1) compact silt/clays of the Oxford Clay Formation, although septarian boulders were found at the interface in some western parts of the quarry (e.g. ARCA BH7) and in one of the Hollingworths' test pit sections (ARCA PT 3941). The palaeochannel fills are in turn unconformably overlain over much of the base of the quarry by yellowish brown (Munsell 10 YR 5/6) to strong brown (Munsell 7.5 YR 5/6) matrix-supported limestone pebble gravels and coarse sands. These latter deposits were assumed to be vestiges of the Northmoor Member that had not been removed by quarrying, supporting evidence for which were locations in the east of the quarry (e.g. ARCA BH18) where such strata unconformably overlay dark grey (Munsell 2.5 Y 4/1) sands and conglomerates of the Kellaway Clay Member.

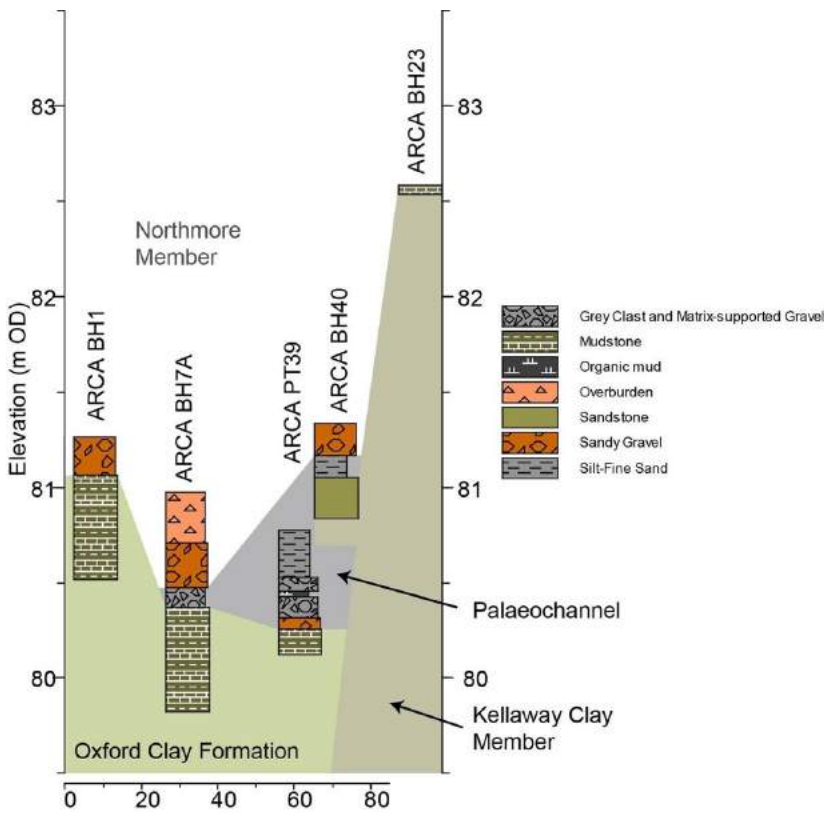


Figure 20. North-west to south-east composite cross section through the palaeochannel fills later exposed in Test Pits 2 and 3

In general, and with the exception of facies i which sits in troughs at the base of the sequence, there is a tendency for the palaeochannel fills to coarsen upwards from silt/clay through sand to gravel dominated facies. Figure 19 exemplifies this succession for the north-western part of the palaeochannel and demonstrates the presence of c. 0.80m of reverse-bedded palaeochannel sediment overlain by recently disturbed (by quarrying) strata of the Northmoor Member. Nevertheless, deposits exposed in the Hollingworth test pit at ARCA PT39-41 (later Test Pits 20 and 24 – see Section 5 below), demonstrate the succession of two such reverse-bedded sequences and separated by matrix-supported gravels very similar to those of the Northmoor Member (Figure 20). Finally, the palaeochannel was both less laterally extensive and had thinner fills (a maximum of 0.37m) in the southern part of the area investigated in the geoarchaeological test pits/boreholes compared to the areas to the north (Figure 21).

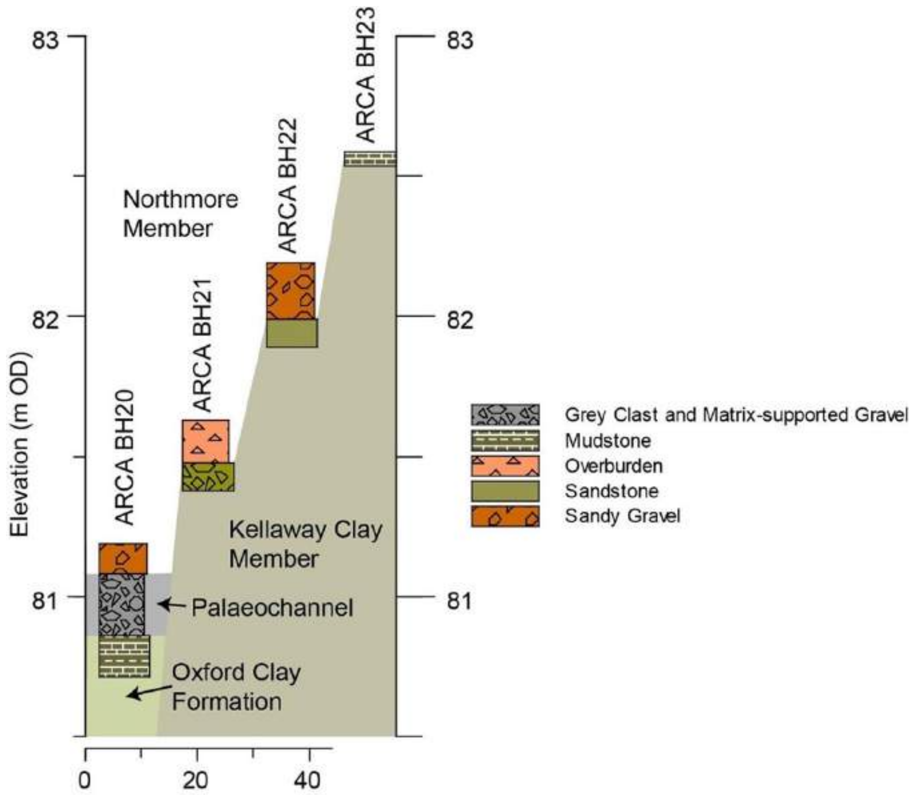


Figure 21. North-west to south-east composite cross section through the palaeochannel fills later exposed in Test Pit 4

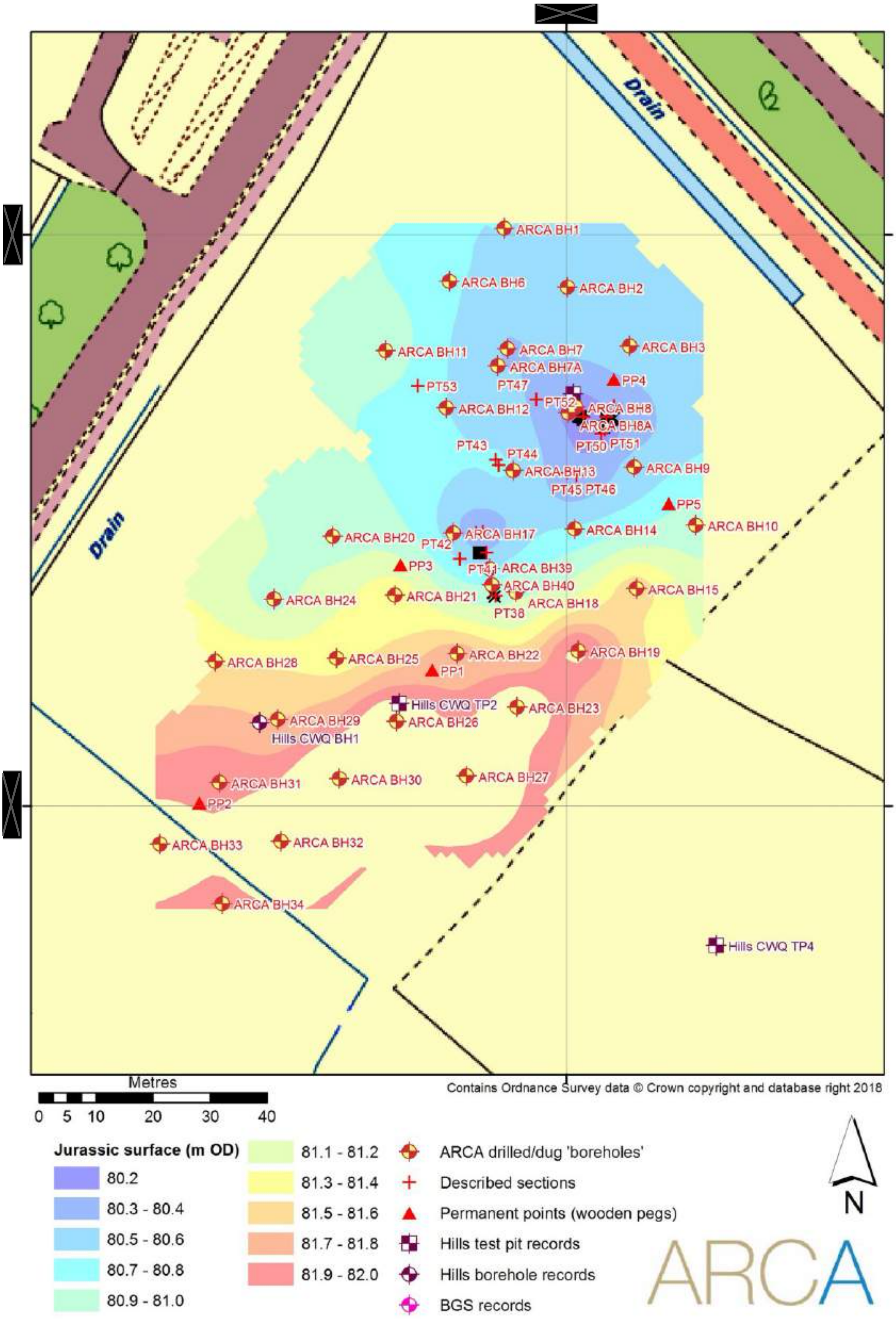


Figure 22. Modelled surface (using a kriging algorithm with eight nearest neighbours) of the Jurassic basement in the base of the [redacted] quarry on the basis of test pit and borehole data

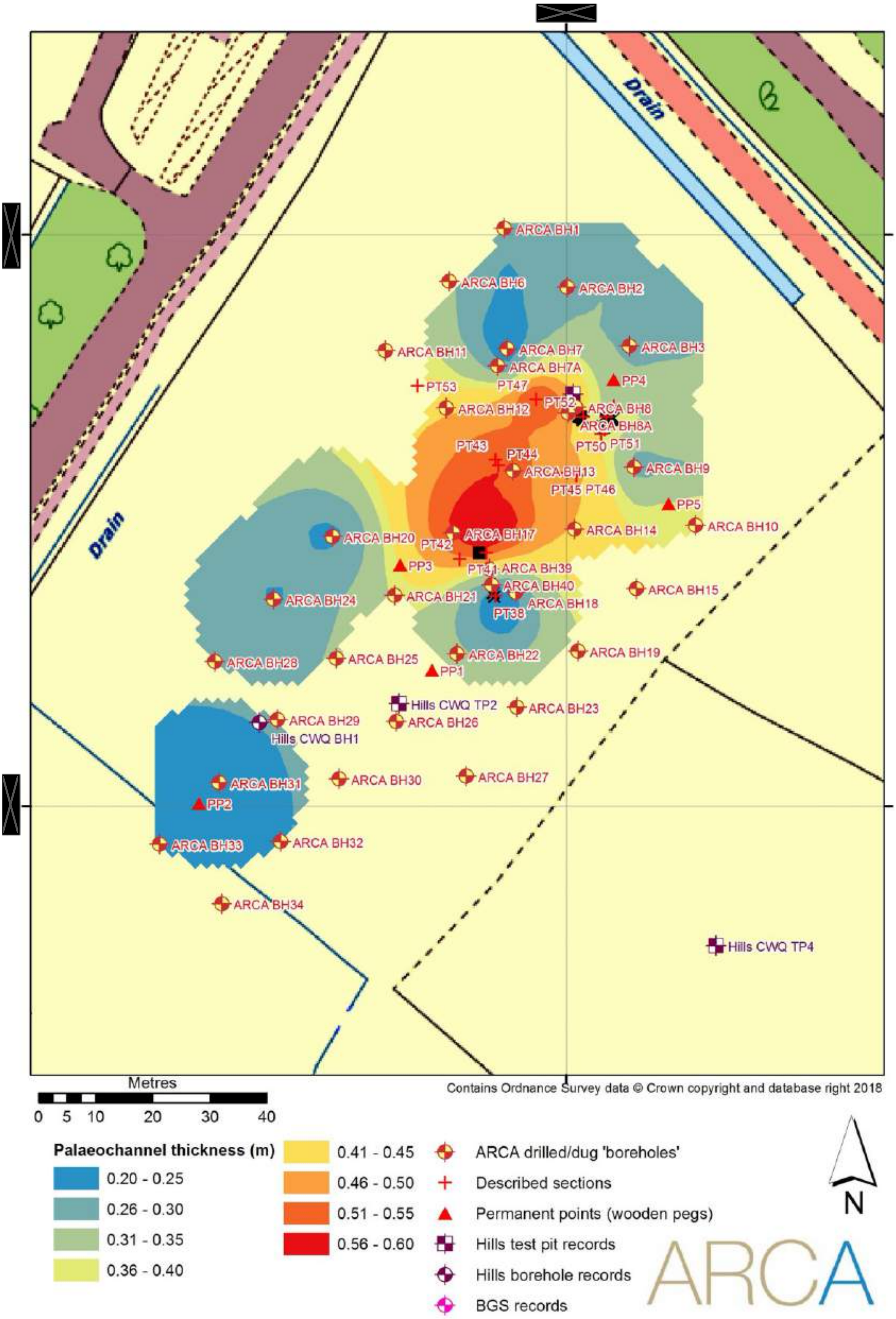


Figure 23. Modelled thickness (using a kriging algorithm with eight nearest neighbours) of palaeochannel deposits in the base of the [redacted] quarry on the basis of test pit and borehole data. Also shown is the location of the four archaeological test pits excavated during the Stage 4 works

Interpretation

The palaeochannel deposits are distinct from those of the overlying Northmoor Member on the basis of the finer-grained matrix of the gravel facies (medium–fine sands and silts) and colour (dark grey rather than strong brown), both of which are the result of accumulation of Oxford Clay particles in the former, but not the latter. Gravel particles in both units appear to have the same derivation, i.e. the Middle Jurassic limestone outcrop to the west and north. There are two possible reasons for Oxford Clay being deposited in the palaeochannel, but not in the Northmoor Member. Firstly, that flow passing through the palaeochannel was able to liberate particles of Oxford Clay or that a tributary stream did the same, while such source material was not available when the Northmoor Member was forming (i.e. the Oxford Clay-containing fold in the Kellaway Clay Member had been completely infilled by the palaeochannel sediments). The second possibility is that flow energies during the deposition of the Northmoor Member were sufficiently high to flush any Oxford Clay particles downstream before they could accrete within channels/on floodplains. In practice it is likely that a combination of both explanations applied. Further it is clear that the two sediment suites formed in very different flow regimes, with the Northmoor Member forming during very flashy discharge, while the palaeochannel deposits accreted in more gradational flow environment. Further, it is therefore probable that the Northmoor Member formed in colder climatic conditions than the palaeochannel fills, i.e. where there was a significant element of spring snow/ice melt. Nevertheless, it is still the case that the heterogeneity of the palaeochannel fills indicates varying flow velocity, with facies i–iii forming during high energy events (the finer particles forming the matrix are presumably interstitial fills accreting as flow ebbed), and facies iv at lower flow energies. The remaining facies probably accumulated in either very slow-moving water at the margin of the channel (facies v) or in shallow pools at the channel edge (facies vi), again both in ebb flow conditions. Facies i–iv dominate the palaeochannel sequence, particularly in the northern part of the site, while any palaeontological and archaeological remains found in such strata are likely reworked, present as lags in the case of cobble-sized or larger vertebrate remains or deposited as interstitial fill during ebb flow events in the case of Mollusca, Coleoptera and botanical remains). Facies v and in particular, vi, might, however, be expected to contain in situ/near in situ archaeological, palaeontological and palaeobotanical remains.

APPENDIX 3. STAGE 3 – LITHOSTRATIGRAPHIC DESCRIPTIONS

Test Pit 1	Dimensions: 3.7 x 2.3m	
	Reason for test pit: Record stratigraphic sequence of palaeochannel where handaxe and faunal remains had previously been recorded	
DV Unit	Description	LU
31001	Dumped deposits from palaeontological test pit (0.00-0.23m)	i
Link		
31002	2.5 Y 4/1 Dark grey clast and matrix-supported gravels of sub-rounded quartzitic limestone pebbles and granules in a medium-fine sand matrix. Homogeneous. Gravels orientated at a variety of angles. Bone at basal contact (0.46-0.66m)	iv
Link		
31003	5 Y 4/1 Dark grey compact silt/clay (0.82-0.90m).	vi
Link		
31004	2.5 Y 4/1 Dark grey matrix-supported gravel of sub-rounded and rounded pebbles and granular quartzitic limestone fine pebbles and granules in a fine-medium sand matrix. Clasts are parallel to the horizontal bedding plain. Moderately sorted (0.23-0.36m).	ii
Link		
31005	2.5 Y 3/1 Very dark grey clast and matrix-supported gravel of medium-fine sub-rounded and rounded quartzitic limestone pebbles in a medium-coarse sand and organic mud matrix. Clasts laid horizontally (0.36-0.46m):	iii
Link		
31006	2.5 Y 4/1 Dark grey fine-medium sand with moderate rounded and sub-rounded quartzitic limestone clasts. Frequent fine pebble and finer mollusc shell (*Bithynia* and *Pisidium*). Moderately sorted (0.66-0.82m)	v
Link		
	5 Y 3/1 Very dark grey thin and lenticularly bedded fine sand/silt with moderate sub-rounded and rounded fine pebble limestone clasts.	vii
	2.5 Y 4/1 Dark grey fine-medium well sorted sand with occasional cobble-sized patches of sub-rounded granular and fine pebble-sized limestone clasts. Occasional mollusc shell (*Valvata* sp.).	viii
	2.5 Y 4/1 Dark grey reverse bedded silt/fine sand (more fine sand upwards) with moderate granular-sized shell fragments. Occasional pebble-sized clasts (sub-rounded). Occasional organic lenses towards surface.	ix

Test Pit 2	Dimensions: 4.5 x 4m	
	Reason for test pit: Record stratigraphic sequence of palaeochannel	
DV Unit	Description	LU
25001	Tabular sets of gravel 0.05-0.10m thick. Lenticular bedded, but as sheets. Sets are clast and matrix-supported and comprise sub-rounded quartzitic limestone pebbles in medium-coarse sand and granular matrix.	J J1
Link		
	2.5 Y 4/1 Dark grey fine sand/silt with occasional sub-rounded quartzitic limestone pebbles. Occasional thin lenticular beds of 2.5 Y 5/1 Grey	K

Test Pit 2	Dimensions: 4.5 x 4m	
	Reason for test pit: Record stratigraphic sequence of palaeochannel	
DV Unit	Description	LU
	fine-medium sand. Occasional granular and coarse sand sized mollusc shell. Well sorted.	
25002	2.5 Y 4/1 Dark grey silt/clay with moderate sub-rounded limestone pebbles and granules (matrix-supported gravel). Occasional coarse sand and granular-sized mollusc shells.	K1
Link		
25003	2.5 Y 5/1 Grey fine sand with wavy, discontinuous, southward-dipping laminae of 5 Y 2.5/1 Black organic mud. Locally iron stained. Moderate coarse sand-sized mollusc shell. Well sorted.	K2
Link		
25004	2.5 Y 4/1 Dark grey fine sand/silt with occasional fine pebble-sized sub-rounded limestone clasts. Moderate coarse sand-sized mollusc shells.	K3
Link		
25005	2.5 Y 5/2 Greyish brown matrix-supported gravel of sub-rounded pebbles in a medium-coarse sand matrix. Poorly sorted. Normally bedded, i.e. gravels coarse at the base and fining upwards	K4
Link		
25006	10 YR 4/4 Dark yellowish brown clast- and matrix-supported gravel of sub-rounded quartzitic limestone pebbles in a granular to coarse sand matrix. Clasts dip just east of south. Localised imbrication. Sharp boundaries (sheet gravel - same as C, but lacking intensity of iron-staining). Lenticular, thin bed of 10 YR 3/2 Very dark greyish brown well sorted silt with moderate granular-size mollusc shell. Sharp boundaries. 10 YR 4/3 Brown well sorted medium-fine sand with frequent granular-sized mollusc shell (*Bithynia* sp.).	I I1 I2
Link		
25007	Grey clast and matrix-supported gravel of sub-rounded quartzite and quartzitic limestone pebbles in coarse sand and granular matrix. Moderate Bithynia shells. Moderately sorted.	B2
Link		
25008	White clast-supported gravel of sub-rounded quartzite, quartzitic limestone and other lithology pebbles in a granular and coarse sand matrix. Rare *Valvata* shells. Moderately sorted. Trough bedded.	B1
Link		
25009	5 Y 4/1 Dark grey well sorted silt/clay	A
Link		
25010	Clast-supported gravel of sub-rounded quartzitic limestone pebbles in a granular quartzitic limestone matrix. Localised imbrication. Lenticular bedded. Moderately sorted.	H
Link		
25011	10 YR 4/2 Dark greyish brown organic silt/clay with frequent granular and finer mollusc shell (*Bithynia*, Planorbidae), and moderate plant macrofossils (stem fragments). Thin and lenticular bedded.	G
Link		
25012	Thinly bedded, lenticular 2.5 Y Dark grey well-sorted silt with moderate granular-size mollusc shell fragments including *Bithynia* sp.	D

Test Pit 2	Dimensions: 4.5 x 4m	
	Reason for test pit: Record stratigraphic sequence of palaeochannel	
DV Unit	Description	LU
Link	[redacted]	

Test Pit 3	Dimensions: 8 x 1m	
	Reason for test pit: Record stratigraphic sequence of palaeochannel	
DV Unit	Description	LU
20001	7.5 YR 5/6 Strong brown clast and matrix-supported gravel of sub-rounded limestone pebbles and granules in a fine-medium sand matrix. Poorly sorted.	A
Link	[redacted]	
20002	2.5 Y 5/1 Grey fine to medium sand with moderate silt. Occasional stringers of sub-rounded limestone pebbles and granules. Normally bedded (silt content increases upwards).	B
Link	[redacted]	
20003	10 YR 5/2 Greyish brown fine sand/silt. Well sorted. Homogeneous.	C
Link	[redacted]	
20004	10 YR 6/4 Light yellowish brown fine-medium sand with moderate iron stains. Possible fine-medium wavy, parallel, discontinuous laminae of iron stains. Well sorted.	E
Link	[redacted]	
20005	Thinly bedded, alternating D and 10 YR 5/2 Greyish brown organic silt. Well sorted. Beds are discontinuous, but parallel. Occasional coarse sand-sized mollusc shell fragments.	F
Link	[redacted]	
20006	Tabular sets of gravel 0.05-0.10m thick. Lenticular bedded, but as sheets. Sets are clast and matrix-supported and comprise sub-rounded quartzitic limestone pebbles in medium-coarse sand and granular matrix. Same as 25001	I
Link	[redacted]	
20007	10 YR 6/3 Pale brown silt/fine sand with moderate iron stains. Well sorted. Possible medium, wavy, parallel, discontinuous laminate iron stains.	D
Link	[redacted]	
20008	2.5 Y 4/1 Dark grey matrix-supported gravel of sub-rounded quartzitic limestone pebbles and granules, and sub-angular to sub-rounded vertebrate bone boulders, in a fine sand/silt matrix. Occasional Unio valves. Moderately sorted.	BH38 0.15-0.25m
	[redacted]	
20009	Tabular sets of gravel 0.05-0.10m thick. Lenticular bedded, but as sheets. Sets are clast and matrix-supported and comprise sub-rounded quartzitic limestone pebbles in medium-coarse sand and granular matrix. Same as 25001	I
Link	[redacted]	
20010	Tabular sets of gravel 0.05-0.10m thick. Lenticular bedded, but as sheets. Sets are clast and matrix-supported and comprise sub-rounded	I

Test Pit 3	Dimensions: 8 x 1m	
	Reason for test pit: Record stratigraphic sequence of palaeochannel	
DV Unit	Description	LU
	quartzitic limestone pebbles in medium-coarse sand and granular matrix. Same as 25001	
Link		
20011	7.5 YR 5/6 Strong brown clast and matrix-supported gravel of sub-rounded limestone pebbles and granules in a fine-medium sand matrix. Poorly sorted.	A
Link		
20012	5 Y 5/1 Very dark grey clay/silt. Homogeneous. Well sorted.	H
Link		
20013	7.5 YR 4/4 Brown silt (some clay). Homogeneous. Well sorted.	G
Link		
20014	7.5 YR 4/6 Strong brown matrix-supported gravel of sub-rounded quartzitic limestone pebbles and granules in a silt-fine sand matrix. Fining upwards from fine pebbles at base. Poorly sorted.	BH38 0.00-0.15m
Link		
20015	2.5 Y 4/1 Dark grey silt/clay with frequent quartzitic limestone granular clasts and occasional pebbles. Homogeneous. Poorly sorted	BH38 0.25-0.56m
Link		

Test Pit 4	Dimensions: 1 x 1m	
	Reason for test pit: Explore potential for palaeochannel deposits to the southwest of the quarry	
DV Unit	Description	LU
14001	10 YR 4/6 Dark yellowish brown matrix-supported gravel. Clasts are modally sub-rounded and are of limestone and occasional angular flint. Matrix is of sand.	1
Link		
14002	5 Y 5/1 Grey matrix-supported gravel of sub-rounded limestone and occasional sub-angular flint in a siltsand matrix containing *Bithynia* sp. shell. Poorly sorted. 5 Y 5/1 Grey siltfine sand with isolated sub-rounded limestone clasts. Moderate shell fragments including *Bithynia* sp. focussed in thin beds. Moderately sorted.	2 3
Link		
14003	10 YR 4/6 Dark yellowish brown matrix-supported gravel.	3
Link		

Lithofacies	Description	BH/TP facies	Miall (1996) codes	Depositional setting
1	Dark yellow brown (Munsell 10 YR 5/6) clast and matrix-supported limestone sheet pebble gravels with a coarse sand matrix	n/a	Gmg, Gcm	High energy flow environment with each set representing a distinct flow event flow event.
2	Clast-supported, lenticular-bedded, imbricated limestone pebbles	i	Gt	High energy flow within a narrow channel leading to rapid deposition and burial (the latter preventing interstitial fill of fines
3	Dark grey (Munsell 2.5 Y 4/1) clast and matrix-supported, locally imbricated, normally bedded, sub-rounded limestone gravels	ii	Gmg, Gci	High energy fluvial flow followed by lower energy flow leading to interstitial fill.
4	Dark grey (Munsell 2 Y 4/1) to Grey (Munsell 5 Y 5/1) massive, poorly sorted sub-rounded limestone gravels in a fossiliferous (Bithynia sp. mollusc shell and occasional vertebrate fossils) silt/clay matrix	iii	Gmm	Either a sediment gravity flow, or a fluvial gravel lag with later interstitial fill during low energy flow events. The Bithynia sp. Mollusca are indicative of large, vegetated water bodies and are part of the interstitial fill – perhaps favouring the latter interpretation
5	Light yellowish brown (Munsell 10 YR 6/4) laminated fine-medium sand	n/a	Sl	Rhythmically deposited, but in higher energy levels than facies 8 and with no slack water deposition.
6	Dark grey (Munsell 2.5 Y 4/1) to greyish brown (Munsell 10 YR 5/2) normally- and massively-bedded silt-fine sand, containing occasional granular limestone clasts and freshwater (Lymnaea sp.) mollusc shell. Moderately sorted	iv	Sm	Moderate energy fluvial flow, or in scour hollows where energy levels are lower. Where massively bedded, the facies might have formed during a single event of uniform energy, but the lack of bedding might also be a product of diagenesis. The absence of deformation (e.g. as a result of loading), or indicators of bioturbation (root channels of burrows), indicates that the former interpretation is more likely to be correct. Where facies 6 is normally bedded, deposition was as previously stated, albeit that energy levels fell during deposition.
7	Grey (Munsell 5 Y 5/1) massively-bedded silt/clay, containing freshwater mollusc shell and occasional pebble-	v	Fsm	Low energy flow, most likely in a channel environment at ebb flow or following channel cut-off. The facies might also form more locally, in scour hollows.

Lithofacies	Description	BH/TP facies	Miall (1996) codes	Depositional setting
	granular clasts. Moderately sorted			
8	Thinly bedded to medium laminated, parallel bedded, grey (Munsell 2.5 Y 5/1) to pale brown (Munsell 10 YR 6/3) silt-fine sand and black (Munsell 2.5 Y 2.5/1) to greyish brown (Munsell 10 YR 5/2) organic muds	n/a	Fl	A rhymite indicating alternating deposition of silts and fine sands in a low energy fluvial environment (within a small channel), and then period of slack, shallow water during which organic muds form – possibly in vegetated conditions
9	Dark greyish brown (Munsell 10 YR 4/2) thin and lenticular-bedded, massive organic mud with mollusc shell (Bithynia, Planorbidae) and plant macrofossils	vi	Fm, C	Low energy or slack water deposition in vegetated water, e.g. in a cut-off channel or scour hollow.
10	Brown (Munsell 7.5 YR 4/4) massive silt	n/a	Fsm	A variation of facies 7 (on the base of its redder colour – possibly a diagenetic oxidation) – and is the result of fall out of silt particles from suspension in an abandoned palaeochannel

Table 5. Lithofacies of the archaeological test pits

APPENDIX 4. STAGE 3 – LITHOSTRATIGRAPHIC CORRELATIONS

Test Pit 1					
DV Unit	Geological Unit	Monolith Samples	Column Samples	Lithofacies	Interpretative Phase
31001	i			N/A	Modern Spoil
31002	iv	Monolith 4, 0.36-0.45 m [86]	Column I, 0-17 cm [9] Column I, 9-17 cm [10] Column II, 0-10 cm [52] Column II, 10-20 cm [53] Column II, 20-25 cm [54]	Facies 3	Phase 1
31003	vi			N/A	Oxford Clay
31004	ii	Monolith 4, 0.00-0.05 m [86]		Facies 3	Phase 1
31005	iii	Monolith 4, 0.05-0.10 m [86] Monolith 4, 0.10-0.17 m [86]		Facies 6	Phase 1
31006	v	Monolith 4, 0.45-0.50 m [86]	Column I, 17-30 cm [11] Column I, 30-35 cm [12] Column II, 25-30 cm [55] Column II, 30-35 cm [56]	Facies 6	Phase 1

Test Pit 2					
DV Unit	Geological Unit	Monolith Samples	Column Samples	Lithofacies	Interpretative Phase
25001	J		Column I, 0-10 cm [13]	Facies 1	Phase 3
25002	K1		Column I, 10-15 cm [14] Column I, 15-20 cm [15] Column I, 20-25 cm [16]	Facies 8	Phase 3
25003	K2		Column I, 25-30 cm [17] Column I, 30-35 cm [18]	Facies 8	Phase 3
25004	K3		Column I, 35-40 cm [19] Column I, 40-45 cm [20] Column I, 45-47 cm [21]	Facies 8	Phase 3
25005	K4		Column I, 47-52 cm [22]	Facies 8	Phase 3
25006	I, I1, I2 C E	Monolith 1, 0.00-0.06 m [84]	Column I, 52-62 cm [23]	Facies 1 Facies 2	Phase 3
25007	B2		Column I, 62-70 cm [24]	Facies 4	Phase 3
25008	B1		Column I, 70-75 cm [25] Column I, 75-80 cm [26] Column I, 80-85 cm [27] Column I, 85-90 cm [28] Column I, 90-95 cm [29] Column I, 95-100 cm [30]	Facies 2	Phase 1
25009	A	Monolith 1, 0.06-0.43 m [84] Monolith 1, 0.43-0.50 m [84]		Facies 7	Phase 1
25010	H			Facies 2	Phase 3
25011	G			Facies 2	Phase 3
25012	D			Facies 9	Phase 3

Test Pit 3					
DV Unit	Geological Unit	Monolith Samples	Column Samples	Lithofacies	Interpretative Phase
20001	A			Facies 1	Member or Modern Spoil
20002	B	Monolith 3, 0.00-0.08 m [82]	Column I, 10-18 cm [66]	Facies 6 Facies 9	Phase 4
20003	C	Monolith 3, 0.08-0.11 m [82]	Column I, 18-28 cm [67] Column I, 28-38 cm [68] Column I, 38-41 cm [69]	Facies 5 Facies 8	Phase 4
20004	E	Monolith 3, 0.11-0.28 [82] Monolith 3, 0.28-0.50 [82]	Column I, 41-49 cm [70]	Facies 5	Phase 4
20005	F	Monolith 2, 0.14-0.18 m [85] Monolith 2, 0.18-0.22 m [85] Monolith 2, 0.22-0.25 m [85] Monolith 2, 0.25-0.30 m [85] Monolith 2, 0.30-0.41 m [85]	Column II, 0-5 cm [71] Column II, 5-10 cm [72] Column II, 10-15 cm [73] Column II, 15-20 cm [74]	Facies 8	Phase 4
20006	I	Monolith 2, 0.41-0.50 m [85]		Facies 1	Phase 3
20007	D			Facies 5	Phase 4
20008	BH38 0.15-0.25m			Facies 4	Phase 1
20009	I			Facies 3	Phase 3
20010	I			Facies 3	Phase 3
20011	A			Facies 1	Phase 4
20012	H	Monolith 2, 0.00-0.11 m [85]		Facies 7	Phase 4
20013	G	Monolith 2, 0.11-0.14 m [85]		Facies 10	Phase 4
20014	BH38 0.00-0.15m			Facies 1	Member or Modern Spoil

Test Pit 3					
DV Unit	Geological Unit	Monolith Samples	Column Samples	Lithofacies	Interpretative Phase
20015	BH38 0.25-0.56m			N/A	Bedrock

Test Pit 4					
DV Unit	Geological Unit	Monolith Samples	Column Samples	Lithofacies	Interpretative Phase
14001	1			Facies 1	?Phase 3
14002	2 3			Facies 4 Facies 6 Facies 4	?Phase 3
14003	4			Facies 1	?Phase 3

APPENDIX 5. STAGE 3 – MONOLITH DESCRIPTIONS

Monolith 1

Depth (m)	Description	DV Unit
0.00-0.06	10 YR 5/6 Yellowish brown matrix-supported gravel of sub-rounded limestone pebbles in a fine sand to clay matrix. Poorly sorted. Sharp boundary to:	25006
0.06-0.43	5 Y 4/1 Grey silt/clay with granular sized iron stained mottling throughout. Occasional rounded and sub-rounded limestone fine pebbles and granules, decreasing upwards. Moderately sorted. Diffuse boundary to:	25009
0.43-0.50	2.5 Y 4/2 Dark greyish brown matrix-supported gravel of sub-angular and sub-rounded limestone, flint and fossil pebbles and granules in a silt/clay matrix. Poorly sorted.	25009

Figure 24. Photograph of Monolith 1

Monolith 2

Depth (m)	Description	DV Unit
0.00-0.11	2.5 Y 3/1 Very dark grey silt/fine sand with occasional sub-angular to sub-rounded limestone pebbles towards surface. Possible wavy, parallel, discontinuous lamina structure with darker sediment. Moderately sorted. Diffuse boundary to:	20012
0.11-0.14	10 YR 4/2 Dark greyish brown thinly bedded silt/clay. Well sorted. Sharp boundary to:	20013
0.14-0.18	10 YR 6/3 Pale brown fine-medium sand with frequent discontinuous parallel coarse laminations of 10 YR 3/2 Very dark greyish brown silt/clay. Well sorted within laminae. Diffuse boundary to:	20005
0.18-0.22	10 YR 4/2 Dark greyish brown silt/fine sand. Thinly bedded. Well sorted. Sharp boundary to:	20005
0.22-0.25	10 YR 7/2 Light grey fine to medium sand with frequent discontinuous, fine, wavy, parallel laminae of 10 YR 4/2 Dark greyish brown silt. Well sorted within laminae. Diffuse boundary to:	20005
0.25-0.30	10 YR 4/2 Dark greyish brown silt with occasional straight, fine, parallel laminae of 10 YR 7/2 Light grey fine to medium sand. Well sorted within laminae. Diffuse boundary to:	20005
0.30-0.41	10 YR 5/3 Brown fine sand with occasional to frequent laminae of iron stains above 0.35m. Laminae are fine, wavy, parallel and non-parallel, discontinuous. Occasional sub-rounded limestone granules below 0.37m. Well sorted. Sharp boundary to:	20005
0.41-0.50	Clast-supported gravel of sub-rounded limestone granules and fine pebbles, and occasional coarse in pebbles in a rare coarse sand matrix.	20006

Figure 25. Photograph of Monolith 2

Monolith 3

Depth (m)	Description	DV Unit
0.00-0.08	10 YR 5/4 Yellowish brown silt/fine sand with frequent straight, parallel, fine iron-stained laminae. Well sorted. Sharp boundary to:	20002
0.08-0.11	10 YR 5/2 Greyish brown well sorted fine sand. Possible thin, straight lamina structure of darker sediment and iron stains. Diffuse boundary to:	20003
0.11-0.28	10 YR 4/3 Brown silt (some fine sand) with occasional granular sub-rounded and sub-angular limestone clasts and occasional granular mollusc shell (*Bithynia* sp.). Rare coarse, discontinuous, wavy laminae of iron stains. Well sorted. Sharp boundary to:	20004
0.28-0.50	5 Y 4/1 Dark grey silt/clay to fine sand. Compact. Homogeneous. Well sorted.	20004

Figure 26. Photograph of Monolith 3

Monolith 4 – Sample No. 86

Depth (m)	Description	DV Unit
0.00-0.05	10 YR 4/2 Dark greyish brown clast and matrix-supported gravel of sub-rounded limestone granules and fine pebbles in a medium-coarse sand matrix. Poorly sorted. Sharp boundary to:	31004
0.05-0.10	2.5 Y 4/1 Dark grey fine sand with discontinuous, fine, parallel laminae of 2.5 Y 3/1 Very dark grey organic silt. Well to moderately sorted. Sharp boundary to:	31005
0.10-0.17	10 YR 4/2 Dark greyish brown clast and matrix-supported gravel of pebble and granular-sized sub-rounded limestone in a silt/clay to medium sand matrix. Poorly sorted.	31005
0.17-0.36	Void	
0.36-0.45	2.5 Y 4/2 Very dark greyish brown matrix-supported gravel of granular to fine pebble and moderate coarse pebble-sized sub-rounded limestone clasts in a coarse sand matrix. Poorly sorted. Sharp boundary to:	31002
0.45-0.50	2.5 Y 3/1 Very dark grey fine to medium sand with occasional sub-rounded granular and fine pebble-sized limestone clasts. Moderately sorted.	31006

Figure 27. Photograph of Monolith 4

APPENDIX 6. STAGE 3 – QUARRY WALL LITHOSTRATIGRAPHIC DESCRIPTIONS

LU	Description
1	10 YR 5/4 Yellowish brown massive humic sand silt/clay with occasional sub-rounded and sub-angular limestone and quartzite pebbles and frequent modern plant roots. Moderately sorted. Sharp boundary to:
2	10 YR 7/4 trending downwards to 10 YR 5/8 massive matrix-supported gravel of pebble-sized sub-rounded to sub-angular limestone, quartzite and sandstone clasts in a fine sand matrix. Powdery carbonate common in the upper part of the unit, while Fe stains and cement present in the lower part of the unit (approximately 0.2-0.3m below upper contact). Poorly sorted. Sharp contacts with Units 3 and 4.
2b	10 YR 7/4 trending downwards to 10 YR 5/8 normally bedded matrix-supported gravel of pebble-sized sub-rounded to sub-angular limestone, quartzite and sandstone clasts in a fine sand matrix. Powdery carbonate common in the upper part of the unit, while Fe stains and cement present in the lower part of the unit (approximately 0.2-0.3m below upper contact). Poorly sorted. Sharp contacts with Units 3 and 4.
3	Clast-supported, open framework, gravel of sub-rounded to rounded medium to fine limestone pebbles in massive, lenticular beds. Moderate modern plant roots. Well sorted.
4	Clast-supported gravel of sub-rounded and sub-angular fine to medium limestone pebbles of limestone, quartzite and sandstone in rare 10 YR 5/8 coarse sand matrix. Fe stained and cemented. Massively bedded. Well sorted (Gcm).
5	Clast- and matrix-supported gravel of fine-coarse pebbles of limestone, quartzite and sandstone in a medium-coarse sand matrix. Fe stained and cemented in places. Massively bedded. Sharp contact to Unit 6 (Gcm).
6	Clast-supported, open framework gravel of sub-rounded and sub-angular fine to medium limestone pebbles of limestone, quartzite and sandstone in 10 YR 5/8 coarse sand matrix. Fe stained and cemented. Massively bedded. Well sorted.
7	Clast-supported gravel of sub-angular medium and fine limestone, quartzite and sandstone pebbles in a sand-clay matrix. Fe stained clasts. Poorly sorted. Diffuse boundary to Unit 8.
8	7.5 YR 4/6 Strong brown matrix-supported gravel of sub-rounded and sub-angular limestone, quartzite and sandstone medium to coarse pebble-sized clasts in a silt/clay and occasional medium sand matrix.
9	Clast-supported gravel of fine to medium sub-rounded to rounded limestone, quartzite and sandstone clasts in a medium to coarse sand matrix. Fe stained. Massively bedded. Discontinuous and sharp upper and lower boundaries.
10	Indurated clayey sand and gravel organised as discontinuous spherical shapes. Poorly sorted.
11	10 YR 3/2 Dark olive grey massive clayey sand with occasional sub-rounded to sub-angular medium pebbles. Rare fragments of thick bivalve shells (pre-Quaternary). Poorly sorted.
12	7.5 YR Brown massive clayey sand with occasional angular pebble clasts and thick bivalve shells (pre-Quaternary). Rare Fe nodules. Sharp upper contact with Unit 7.
13	Clast-supported, open framework, gravel of sub-rounded to rounded coarse to fine limestone pebbles in massive, lenticular beds. Moderate modern plant roots. Well sorted.
14	10 YR 6/2 Light brownish grey matrix-supported gravels of fine pebble and granular sub-rounded limestone, quartzite and sandstone clasts covered in carbonate

LU	Description
	coatings and with a medium sand and carbonate powder matrix. Sharp contacts with surrounding units.
14b	10 YR 6/2 Light brownish grey matrix-supported gravels of fine pebble and granular sub-rounded limestone, quartzite and sandstone clasts covered in carbonate coatings and with a medium sand and carbonate powder matrix. Massively bedded. Sharp contacts with surrounding units (?Made Ground, i.e. berm).
15	Clast-supported, open framework, massively bedded gravel of sub-rounded to rounded coarse to fine limestone pebbles. Moderate modern plant roots. Well sorted.
16	Matrix-supported gravel of medium and coarse pebble-sized limestone, quartzite and sandstone clasts in a medium to coarse sand matrix. Lenticularly bedded . Fe stained.
17	Matrix- and clast-supported gravel of sub-rounded and sub-angular limestone, quartzite and sandstone pebbles and granular clasts in a fine to medium coarse sand matrix organised in discontinuous sets of clast- and matrix-support. Locally Fe stained, carbonate cemented and imbricated. Diffuse contacts with overlying and underlying units.
18	2.5 Y 7/2 Light grey matrix-supported gravel of fine pebble and granular sized limestone, quartzite and sandstone clasts in a medium sand matrix. Reverse bedded, carbonate cemented and lenticular. Diffuse upper and sharp lower contacts
19	2.5 Y 6/6 Dark yellow matrix-supported gravel of sub-rounded fine to coarse pebble and fine cobble limestone, quartzite and sandstone clasts in a fine to medium sand matrix. Massively bedded. Moderately sorted.
20	Clast-supported gravel of granular to fine cobble-sized rounded and sub-rounded limestone, quartzite and sandstone clasts in a fine sand matrix (Gcm).
21	Clast-supported, horizontally-bedded gravel of rounded limestone, quartzite and sandstone clasts in a medium to coarse sand matrix. Clasts are imbricated (Gcm).
22	Matrix-supported gravel of sub-rounded and rounded medium and fine pebble-sized limestone, quartzite and sandstone clasts in a medium to fine sand madrix.
23	Matrix-supported gravel of horizontally bedded sub-rounded granular to fine pebble sized limestone, quartzite and sandstone clasts in a medium to fine sand matrix. Normally bedded. Moderately sorted (Gmh)
24	Clast-supported gravel of granular to very fine pebble sized limestone, quartzite and sandstone clasts in a fine-medium sand matrix. Fe stained and carbonate cemented. Crudely horizontally bedded.
25	Clast-supported gravel of sub-rounded and sub-angular fine to medium limestone pebbles of limestone, quartzite and sandstone in rare 10 YR 5/8 coarse sand matrix. Fe stained and cemented. Massively bedded. Well sorted (Gcm).
26	Clast- and matrix-supported gravel of fine-coarse pebbles of limestone, quartzite and sandstone in a medium-coarse sand matrix. Fe stained, cemented and imbricated in places. Massively bedded (Gcm).
27	Coarse sand and granular gravel. Weakly normally and lenticularly bedded (Sg).
28	Massive coarse to medium sand with occasional pebble clasts.
29	Granular gravel and sands, trough cross-bedded with darker organic rich sediment.
30	Matrix- and clast-supported gravel of granular to fine pebble sized limestone, quartzite and sandstone clasts in a medium to fine matrix. Fe stained with mm scale intraclasts of 10 YR 6/4 Light yellowish brown granular-sized clay (Sl, Sm). Lenticular and crudely horizontally bedded.

LU	Description
31	10 YR 5/8 Yellowish brown coarse sand with occasional granular- and fine-pebble sized limestone, quartzite and sandstone clasts. Reverse bedded. Fe stained.
32	10 YR 5/8 Yellowish brown clast-supported gravel of granular and medium pebble sized sub-angular and sub-rounded limestone, quartzite and sandstone clasts in alternating sets of granular to fine pebble and fine to medium pebbles. Matrix is of medium sand. Sharp boundaries between sets. Beds are sub-horizontal and discontinuous
33	Clast-supported gravel of granular to medium pebble-sized limestone, quartzite and sandstone sub-rounded to sub-angular clasts in a medium sand matrix. Massive and weakly imbricated.
34	2.5 Y 6/4 Light yellowish brown medium sand laminated with clay. Sharp upper and lower contacts, but grades laterally into Unit 39.
35	10 YR 5/8 Yellowish brown coarse sand with occasional granular and pebble-sized sub-rounded to rounded limestone, quartzite and sandstone clasts. Sharp, undulating contact with Kellaway Clay below.
36	10 YR 4/4 Dark yellowish brown (clay and sand) and 2.5 Y 5/4 clay thinly bedded silt/clay and fine to medium sand and horizontal beds of 5-10mm thickness. Normally bedded, i.e. clay beds thicken upwards. Single 20mm thick bed of granular clasts in matrix of grey silt/clay.
36b	10 YR 4/4 Dark yellowish brown (clay and sand) and 2.5 Y 5/4 clay thinly bedded silt/clay and fine to medium sand and horizontal beds of 5-10mm thickness. Also contains massive, amorphous beds of organic fragments. Normally bedded, i.e. clay beds thicken upwards. Single 20mm thick bed of granular clasts in matrix of grey silt/clay.
39	2.5 Y 6/4 Light yellowish brown medium to coarse sand, crudely cross bedded with granular to coarse sands. Grading laterally from Unit 34.
40	10 YR 5/8 Yellowish brown clast-supported gravel of granular and fine pebble sized sub-angular and sub-rounded limestone, quartzite and sandstone clasts in alternating sets of granular and fine pebble clasts and matrix-supported granules in medium sand. Sharp boundaries between sets. Beds are sub-horizontal and discontinuous
41	Matrix-supported gravel of medium to coarse limestone, quartzite and sandstone sub-angular to sub-rounded pebbles in silt/clay matrix. Fe stained. Lenticularly bedded.
42	2.5 Y 7/4 Pale brown fine to medium sand. Massively bedded.
43	2.5 Y 5/3 Light olive brown silt/clay. Massively and thinly bedded. Forms drape over Units 45 and 46.
44	Clast- and matrix-supported gravel of granular to fine pebble sized limestone, quartzite and sandstone sub-rounded and sub-angular clasts, forming trough cross bedded structure with sets ranging from 10-30mm and comprising alternating fine-coarse open framework pebbles and matrix supported fine pebbles in a granular matrix. Fe stained throughout. Sharp boundaries.
45	Clast- and matrix-supported gravel of granular to fine pebble sized limestone in a coarse sand matrix. Horizontally bedded and with 20-100mm thick sets of matrix-supported granules in a coarse sand matrix and clast-supported granules and fine pebbles. Fe stained throughout.
46	Clast-supported gravel of granules in a medium to coarse sand matrix. Normally bedded.
47	Medium sand and clay forming climbing ripple cross beds.

LU	Description
48	Clast- and matrix-supported gravels of granular to medium pebble sized sub-rounded and sub-angular limestone, quartzite and sandstone in a medium to coarse sand matrix. Forming alternating sets of open framework clast-supported granules and fine pebbles and matrix-supported granules to medium pebbles in sand matrix. Well sorted.
49	Medium sand with occasional sub-rounded to rounded limestone, quartzite and sandstone granules forming cross-bedded structure. Truncated by Unit 50 bounding surface.
50	Matrix-supported gravel of granular limestone, quartzite and sandstone clasts in a medium sand matrix. Becomes increasingly clast rich towards the centre of the bed.
51	10 YR 7/4 trending downwards to 10 YR 5/8 massive matrix-supported gravel of pebble-sized sub-rounded to sub-angular limestone, quartzite and sandstone clasts in a fine sand matrix. Powdery carbonate common in the upper part of the unit. Fe stained throughout. Poorly sorted. Sharp contacts with Units 3 and 4.
52	Matrix-supported gravel of granuies to medium pebble sized limestone, quartzite and sandstone clasts in a medium sand matrix. Forming trough cross bedded structure together with discontinuous wavy lenticular beds of Units 3, 6 and 42.

APPENDIX 7. SAMPLE LIST

Sample No.	Test Pit	Field Code	Type	Quantity	DV Unit	Geological Unit
1-8	VOID					
9	1	Column I, 0-9 cm	Bulk	40L	31002	iv
10	1	Column I, 9-17 cm	Bulk	20L	31002	iv
11	1	Column I, 17-30 cm	Bulk	30L	31006	v
12	1	Column I, 30-35 cm	Bulk	10L	31006	v
13	2	Column, 0-10 cm	Bulk	20L	25001	J
14	2	Column, 10-15 cm	Bulk	20L	25002	K1
15	2	Column, 15-20 cm	Bulk	20L	25002	K1
16	2	Column, 20-25 cm	Bulk	20L	25002	K1
17	2	Column, 25-30 cm	Bulk	20L	25003	K2
18	2	Column, 30-35 cm	Bulk	20L	25003	K2
19	2	Column, 35-40 cm	Bulk	20L	25004	K3
20	2	Column, 40-45 cm	Bulk	20L	25004	K3
21	2	Column, 45-47 cm	Bulk	10L	25004	K3
22	2	Column, 47-52 cm	Bulk	30L	25005	K4
23	2	Column, 52-62 cm	Bulk	30L	25006	I
24	2	Column, 62-70 cm	Bulk	10L	25007	B2
25	2	Column, 70-75 cm	Bulk	30L	25008	B1
26	2	Column, 75-80 cm	Bulk	20L	25008	B1
27	2	Column, 80-85 cm	Bulk	20L	25008	B1
28	2	Column, 85-90 cm	Bulk	20L	25008	B1
29	2	Column, 90-95 cm	Bulk	20L	25008	B1
30	2	Column, 95-100 cm	Bulk	20L	25008	B1
31	1	1.1a	SedaDNA	/	31002	
32	1	1.1b	SedaDNA	/	31002	
33	1	1.2a	SedaDNA	/	31002	
34	1	1.2b	SedaDNA	/	31002	
35	1	1.3a	SedaDNA	/	31002	
36	1	1.3b	SedaDNA	/	31002	
37	2	2.1a	SedaDNA	/	25001	J1
38	2	2.1b	SedaDNA	/	25001	J1
39	2	2.2a	SedaDNA	/	25005	K4
40	2	2.2b	SedaDNA	/	25005	K4
41	2	2.3a	SedaDNA	/	25003	K2
42	2	2.3b	SedaDNA	/	25003	K2
43	2	2.4a	SedaDNA	/	25008	B1
44	2	2.4b	SedaDNA	/	25008	B1
45	2	2.5a	SedaDNA	/	25002	K1
46	2	2.5b	SedaDNA	/	25002	K1
47	3	3.1a	SedaDNA	/	20005	
48	3	3.1b	SedaDNA	/	20005	
49-50	VOID					
51	3	51	Spot sample	20L	20008	B1
52	1	Column II, 0-10 cm	Bulk	30L	31002	iv
53	1	Column II, 10-20 cm	Bulk	30L	31002	iv

Sample No.	Test Pit	Field Code	Type	Quantity	DV Unit	Geological Unit
54	1	Column II, 20-25 cm	Bulk	10L	31002	iv
55	1	Column II, 25-30 cm	Bulk	10L	31006	v
56	1	Column II, 30-35cm	Bulk	10L	31006	v
57	2	OSL 1a	OSL	/	25009	C
58	2	OSL 1b	OSL	/	25009	C
59	2	OSL 1c	OSL	/	25009	C
60	2	OSL 2a	OSL	/	25004	K2
61	2	OSL 2b	OSL	/	25004	K2
62	1	OSL 3a	OSL	/	31006	BH3 9V
63	1	OSL 3b	OSL	/	31006	BH3 9V
64	3	OSL 4a	OSL	/	20003	C
65	3	OSL 4b	OSL	/	20003	C
66	3	Column I, 10-18 cm	Bulk	10L	20002	B
67	3	Column I, 18-28 cm	Bulk	10L	20003	C
68	3	Column I, 28-38 cm	Bulk	10L	20003	C
69	3	Column I, 38-41 cm	Bulk	10L	20003	C
70	3	Column I, 41-49 cm	Bulk	10L	20004	D
71	3	Column II, 0-5 cm	Bulk	10L	20005	F
72	3	Column II, 5-10 cm	Bulk	10L	20005	F
73	3	Column II, 10-15 cm	Bulk	10L	20005	F
74	3	Column II, 15-20 cm	Bulk	10L	20005	F
75	3	75	Spot sample	10L	20012	H
76	Quarry Walls	OSL 5a	OSL	/	47001	49
77	Quarry Walls	OSL 5b	OSL	/	47001	49
78	Quarry Walls	OSL 6a	OSL	/	35001	28
79	Quarry Walls	OSL 6b	OSL	/	35001	28
80	Quarry Walls	OSL 7a	OSL	/	35002	28
81	Quarry Walls	OSL 7b	OSL	/	35002	28
82	3	Mono 3, 0.00-0.50 m	Monolith	50 x 10 x 10m	20002	B
					20003	C
					20003	D
					20004	E
83	VOID					
84	2	Mono 1, 0.00-0.50 m	Monolith	50 x 10 x 10m	25006	C
					25009	A
					25009	A
86	1	Mono 4, 0.00-0.50 m	Monolith	50 x 10 x 10m	31004	ii
					31005	iii
					31002	iv

Sample No.	Test Pit	Field Code	Type	Quantity	DV Unit	Geological Unit
					31006	v
85	3	Mono 2, 0.00-0.50 m	Monolith	50 x 10 x 10 m	20012	H
					20013	G
					20005	F
					20006	I

APPENDIX 8. PLANT MACROFOSSILS

Sample No.	SEEDS																
	Asteraceae	Betula	Brassicaceae	Carex	Chenopodiaceae	Cyperaceae	Empetrum	Epilobium	Juncaceae	Nymphaea cf	Polygonaceae	Potamogeton	Silene cf	Thalictrum cf	Budscales	Catkins	Unidentified stone fruits
9				1					59				4	3			
10				1	1	4					1	2					
11		1		5	1				71				7	1			
14									24	1			4	3			
18			2	2				3	33		1	2		4	1 (birch?)	1 (birch?)	
22				4					48				5	4			
26				6		2						1	3	1			2 (frag)
67	1			15	2			3	212				16	5			
69				5	2		2		37			2		3			

Sample No.	OTHER MACROFOSSILS									
	Characeae	Chironomids	Grasses	Insect frag	Leaves frag.	Mites	Moss	Ostracods	Roots/ woody material	Snails/shells
9	+ +	+	+ + +	+ +		+	+ + +	+ + +	+ + +	
10	+		+ + +	+			+ +		+ + +	+ +
11	+ + +	+ +	+ +	+ + +		+	+ +	+ + +		
14	+		+	+		+		+	+	+
18	+ + +	+ + +	+ + +	+ + +	+ (Ericaceae)	+ +	+ + +	+ + +		
22	+ + +	+ +	+ + +	+ +		+ +	+ +	+ +		
26	+ +		+ + +	+ +			+ +	+		
67	+ + +	+ +	+ + +	+ +		+ +	+ +	+ + +		
69	+ + +			+ + +		+	+ +	+ + +		+

Key; following Hughes and Barber, 2004).

+

+ +

+ + +

APPENDIX 9.MOLLUSCA

Location	TP1	TP1	TP1	TP2	TP2	TP2	TP2	TP3	TP3
Sample Number	9	10	11	14	18	22	26	67	69
Context Number									
Depth (cms)	0-9	9-17	17-25	10-15	30-35	47-52	75-80	18-28	38-41
Fraction	>500	>500	>500	>500	>500	>500	>500	>500	>500
Proportion fresh: subfossil shell	0:1	0:1	0:1	0:1	0:1	0:1	NA	0:1	0:1
MOLLUSCA: GASTROPODA									
Valvata spp.	++	++	+	+	+++	+		++	+++
Bithynia sp.									
Shell	+	+	++		++			++	++
Opercula	+	+			++	+		++	++
Radix auricularia		+	+		+				
Radix balthica	++	++	+		+	+		+	++
Planorbis planorbis					+				+
Hippeutis complanata									+
Acroloxus lacustris									+
Pupilla muscorum	+	+		+	+				
Vallonia spp.	+	+		+	+				
Limacidae sp.				+					
Trochulus sp.	+	+	+		+			+	+
MOLLUSCA: BIVALVIA									
Sphaerium sp.	+	+	+	+	+	+		+	+
Pisidium spp.	++	++	+	+	++			++	++

Key to estimated abundance: + = 1-10 items, ++ = 11-50 items, +++ = 51-100 items

APPENDIX 10.INSECTS AND OTHER INVERTEBRATES – SPECIES LIST

CLADOCERA (water fleas)
Daphnia magna group ephippia
Daphnia sp. ephippia

OSTRACODA (ostracods)
Ostracoda sp(p) carapaces

INSECTA:
DERMAPTERA (earwigs)
Dermaptera sp.

HEMIPTERA (bugs)
Heteroptera
Lygaeidae spp. [oa-p]
Corixidae sp(p). [oa-w]
Heteroptera sp. [u]
Homoptera
Auchenorhyncha sp. [oa-p]

TRICHOPTERA (caddis flies)
Trichoptera spp. (larval head fragments)

DIPTERA (flies)
Diptera spp.
Diptera spp. (puparia)

HYMENOPTERA (bees, wasps and ants)
Parasitica spp. (parasitic wasps)

COLEOPTERA (beetles)
Sphaeriusidae
?*Sphaerius acaroides* Waltl [oa-w]

Dytiscidae (diving beetles)
Colymbetes cf *fuscus* (Linnaeus) [oa-w]
Hydroporinae sp. [oa-w]

Carabidae (ground beetles)
?*Elaphrus* sp. [oa-d]
Loricera cf *pilicornis* (Fabricius) [oa]
Bembidion spp. [oa]
Pterostichus sp. [ob]
Chlaenius sp. [oa-d]
Calathus sp. [oa]
Carabidae spp. and sp. indet.[ob]

Helophoridae (grooved water scavengers)
Helophorus spp. [oa-w]

Georissidae
Georissus crenulatus (Rossi) [oa-w]

Hydrochidae
Hydrochus sp. [oa-w]

Hydrophilidae
Laccobius sp. [oa-w]
Hydrophilinae spp. [oa-w]
Sphaeridium sp. [rf]
Cercyon spp. [rt]
Cryptopleurum sp. [rf]

Histerinae (clown beetles)
Histerinae spp. [rt]

Hydraenidae (moss water beetles)
Ochthebius ?*bicolon* Germar [oa-w]
Ochthebius (*Asiobates*) sp. [oa-w]
Ochthebius minimus (Fabricius) [oa-w]
Ochthebius sp. [oa-w]

Ptiliidae (featherwing beetles)
Ptenidium sp. [rt]

Staphylinidae (rove beetles)
Micropeplus sp. [rt]
Tachinus sp. [u]
Tachyporus sp(p). [u]
Aleochariinae spp. [u]
Carpelimus spp. [u]
Platystethus cornutus group [oa-d]
Platystethus (?*Craetopycrus*) sp(p) [oa-d]
Anotylus rugosus (Fabricius) [rt]
Anotylus spp. [rt]
Oxytelinae sp. [u]
Stenus spp. [u]
Lathrobium spp. [u]
Paederinae sp. [u]
Xantholinini spp. [u]
Staphylininae spp. [u]

Geotrupidae (dor beetles)
?Geotrupinae sp. [oa-rf]

Scarabaeidae (dung beetles and chafers)
?*Euheptaulacus* sp. [oa-rf]
Aphodiinae spp. [ob-rf]

Byrrhidae (pill beetles)
Byrrhidae sp. [u]

Elmidae (riffle beetles)
Elmidae spp. [oa-w]

Elateridae (click beetles)
Elateridae spp. [ob]

Cantharidae (soldier beetles)
Cantharidae sp. [ob]

Latridiidae (mould beetles)
Corticariinae sp(p). [rt]

Salpingidae
?Salpingidae sp. [l]

Anthicidae
Anthicidae sp. [u]

Chrysosmelidae (leaf beetles)
Donacia sp. [oa-p-d]
Donaciinae sp(p) and sp. indet. [oa-p-d]
Chaetocnema arida group [oa-p]
Alticini spp. [oa-p]

Apionidae (apionid weevils)
Apionidae spp. [oa-p]

Erirhinidae (erirhinid weevils)
?*Notaris* sp. [oa-p-d]
Erirhinidae sp. [oa-p-d]

Curculionidae (curculionid weevils)
?Mecininae sp. [oa-p]
Ceutorhynchinae spp. [oa-p]
Sitona sp. [oa-p]
Entiminae sp. [oa-p]
Curculionidae spp. and spp. indet. [oa-p]

Coleoptera spp. and spp. indet. [u]

ARACHNIDA
Acarina spp. (mites)
Aranae sp. (spider)

BRYOZOA
Lophopus crystallinus (Pallas) statoblasts

NB: Identification has not been pressed to species level in many cases, and the list should be regarded as provisional. Ecological codes shown in square brackets are: d – damp ground/waterside, oa – 'outdoor' taxa not living in accumulations of decomposing organic matter or within buildings, ob – probable outdoor taxa, rf – foul decomposers, rt – eurytopic decomposers, u – uncoded, w - aquatic. Some taxa are uncoded pending closer identification. Nomenclature for Coleoptera follows Duff (2018)

APPENDIX 11. INSECTS AND OTHER INVERTEBRATES – ASSESSMENT DATA

Test pit	Depth	Sample	Sample volume	Paraffin flot volume	Est. no. beetles and bugs	State of preservation	Taxa noted during scanning. Please note that the lists are not exhaustive and identifications are provisional	Potential for analysis
TP1	0 - 9cm	<9>	5L	10ml	~50	Fragmentation moderate; chemical erosion moderate	CRUSTACEA: Daphnia ephippia P, Ostracoda P; HEMIPTERA: Corixidae +; COLEOPTERA: *Loricera pilicornis* +, Carabidae spp +, *Laccobius* +, ?Hydrophilinae +, *Cercyon* spp +, Histerinae +, *Ochthebius* +, *Tachyporus* +, ?*Tachinus* +, Aleocharinae spp, *Platystethus* +, *Anotylus rugosus* +, *Anotylus* spp +, *Stenus* +, Paederinae +, Staphylinidae spp ++, Aphodiinae spp ++, ?Elateridae +, Corticariinae +, *Donacia* +, Donaciinae indet +, Apionidae +, Entiminae +, Curculionidae spp +, Coleoptera spp and sp indet. ++; HYMENOPTERA: Hymenoptera Parasitica +; ARACHNIDA: Acari C	MODERATE
TP1	9 - 17cm	<10>	5L	10ml	<50	Fragmentation moderate; chemical erosion moderate	HEMIPTERA: Lygaeidae +, Corixidae +; COLEOPTERA: *?Elaphrus* +, *Pterostichus* +, Carabidae +, *Helophorus* spp +, Histerinae +, *Tachinus* +, Aleocharinae, *Anotylus* spp +, Xantholinini +, Staphylinidae +, Aphodiinae spp ++, Elateridae +, Corticariinae +, Alticinae +, Apionidae +, Curculionidae spp +, Coleoptera spp and sp indet. ++; DIPTERA: Diptera puparia +; HYMENOPTERA: Hymenoptera Parasitica +; ARACHNIDA: Acari P	MODERATE

Test pit	Depth	Sample	Sample volume	Paraffin flot volume	Est. no. beetles and bugs	State of preservation	Taxa noted during scanning. Please note that the lists are not exhaustive and identifications are provisional	Potential for analysis
TP1	17 - 25cm	<11>	5L	10ml	<50	Fragmentation moderate; chemical erosion moderate	CRUSTACEA: Ostracoda; HEMIPTERA: Corixidae +; COLEOPTERA: *Hydroporinae* +, Carabidae +, *Helophorus* spp +, *Cercyon* +, *Tachyporus* +, *Carpelimus* +, *Anotylus* +, *Stenus* +, Xantholinini +, Staphylinidae spp +, ?*Euheptaulacus* +, Aphodiinae spp ++, Elateridae +, Alticinae spp +, Apionidae +, Ceutorhynchinae +, Curculionidae spp +, Coleoptera spp and sp indet. ++; ARACHNIDA: Acari P	MODERATE
TP2	10 - 15cm	<14>	5L	10ml	~25	Fragmentation moderate; chemical erosion moderate	CRUSTACEA: Ostracoda; HEMIPTERA: Corixidae +; COLEOPTERA: Hydroporinae +, Carabidae spp +, *Helophorus* spp ++, *Micropeplus* +, Pselaphinae +, *Tachyporus* +, ?*Carpelimus* +, Aphodiinae spp +, Donaciinae +, Alticinae +, Apionidae +, *Sitona* +, Curculionidae spp +, Coleoptera spp and sp indet. ++; ARACHNIDA: Aranae P	LOW to MODERATE

Test pit	Depth	Sample	Sample volume	Paraffin flot volume	Est. no. beetles and bugs	State of preservation	Taxa noted during scanning. Please note that the lists are not exhaustive and identifications are provisional	Potential for analysis
TP2	30 - 35cm	<18>	5L	10ml	100-150	Fragmentation high; chemical erosion moderate	CRUSTACEA: Daphnia magna group ephippia P, Ostracoda C; DERMAPTERA: Dermaptera +; HEMIPTERA: Lygaeidae +, Corixidae +; Heteroptera +, Homoptera +; COLEOPTERA: *Colymbetes* cf *fuscus* +, *Hydroporinae* +, *Bembidion* +, *Calathus* +, *Chlaenius* +, Carabidae spp ++, *Helophorus* spp ++, Hydrophilinae +, *Sphaeridium* +, *Cercyon* spp +, *Cryptopleurum* +, Histerinae +, *Ochthebius* (*Asiobates*) +, *Ochthebius minimus* +, *Limnebius* +, *Ochthebius* +, *Ptenidium* +, *Tachyporus* +, Aleocharinae +, *Carpelimus* spp +, *Platystethus* +, *Anotylus* spp +, *Stenus* +, Staphylinidae spp ++, Aphodiinae spp ++, Elateridae spp +, Corticariinae +, ?Salpingidae +, Donaciinae +, *Chaetarthria arida* group +, Alticinae spp +, Apionidae +, Curculionidae spp +++, Coleoptera spp and sp indet. ++; HYMENOPTERA: Hymenoptera Parasitica +; TRICHOPTERA: Trichoptera spp larval head fragments +; ARACHNIDA: Acari C	GOOD
TP2	47 - 52cm	<22>	5L	5ml	~25	Fragmentation moderate; chemical erosion moderate, occasional	CRUSTACEA: Ostracoda C; HEMIPTERA: Corixidae +; COLEOPTERA: *?Sphaerius acaroides* +, Carabidae +, *Helophorus* +, Histerinae +, Oxytelinae +, Staphylinidae +, Aphodiinae +, *Chaetarthria arida* group +, Coleoptera spp and sp indet. ++; ARACHNIDA: Acari P; BRYOZOA: *Lophopus crystallinus* statoblasts P	LOW

Test pit	Depth	Sample	Sample volume	Paraffin flot volume	Est. no. beetles and bugs	State of preservation	Taxa noted during scanning. Please note that the lists are not exhaustive and identifications are provisional	Potential for analysis
						sclerites well-preserved		
TP2	75 - 80cm	<26>	5L	Washover 15ml	1	Fragmentation high	HEMIPTERA: Corixidae +; COLEOPTERA: traces Coleoptera cuticle	NONE
TP3	18 - 28cm	<67>	5L	10ml	~150	Fragmentation moderate; chemical erosion moderate to advanced	CRUSTACEA: Ostracoda C; HEMIPTERA: Heteroptera +; COLEOPTERA: *Colymbetes* cf *fuscus* +, Carabidae spp ++, *Helophorus* spp ++, *Georissus crenatus* +, *Hydrochus* +, Hydrophilinae +, *Sphaeridium* +, *Cercyon* spp +, Histerinae +, *Ochthebius* ?*bicolon* +, *Ptenidium* +, *Tachyporus* +, ?*Tachinus* +, Aleocharinae, *Carpelimus* spp +, *Platystethus cornutus* group +, *Platystethus* +, *Anotylus* +, *Lathrobium* +, Staphylinidae +, ?Geotrupinae +, Aphodiinae spp +++, ?Byrrhidae +, Elmidae spp +, Elateridae +, Anthicidae +, Donaciinae spp ++, *Chaetarthria arida* group +, Alticinae +, Apionidae +, ?*Notaris* +, Erirhinidae +, ?Mecininae +, Ceuthorhynchinae +, Curculionidae +++; Coleoptera spp and sp indet. ++; DIPTERA: Diptera +; Diptera puparia +; ARACHNIDA: Acari C; BRYOZOA: *Lophopus crystallinus* statoblasts P	GOOD

Test pit	Depth	Sample	Sample volume	Paraffin flot volume	Est. no. beetles and bugs	State of preservation	Taxa noted during scanning. Please note that the lists are not exhaustive and identifications are provisional	Potential for analysis
TP3	38 - 41cm	<69>	5L	Washover 20ml	~25	Fragmentation moderate; chemical erosion moderate to advanced, some sclerites pale with loss of surface texture; sclerites often flattened or otherwise distorted	CRUSTACEA: Ostracoda P; COLEOPTERA: Carabidae +, *Hydrochus* +, *Cercyon* +, Histerinae +, *Anotylus* +, Elmidae +, Cantharidae +, Donaciinae +, ?*Notaris* +, Ceuthorhynchinae +, Curculionidae ++; Coleoptera spp and sp indet. +	MODERATE

Ecological codes shown in square brackets are as follows: d- damp ground/waterside, oa- outdoor insects not found within buildings or in accumulations of decaying matter, ob - probable outdoor insects, p - plant-associated, rf - foul decomposers, rt - eurytopic decomposers,u - uncoded, w - aquatic. Many taxa are uncoded pending closer identification. Abundances of beetles (Coleoptera) and bugs (Hemiptera) were estimated semi-quantitatively as + (1 - 3 individuals), ++ (4 – 10), +++ (>10). Other invertebrate remains in the samples were recorded as present (P) or common (C).

APPENDIX 12. FAUNAL REMAINS

Test Pit	Context	Find No.	Element	Count	Side	Fragmentation (Dobney and Reilly 1988)	ID	Weight (g)	Condition	Burning	Butchery	Carnivore	Measurable	Ageable
1	31001	15	Vertebra - Atlas?	1	\	2	Mammalia cf. *Mammuthus*	95	3 - Medium	N	N	N	N	N
1	31001	16	Tarsal	1	\	85%	Mammuthus sp.	310	2 - Good	N	N	N	Y	N
1	31002	1	Mandible	1	R	3 6	*Mammuthus* sp.	419	3 - Medium	N	N	N	N	Y
1	31002	2	Rib	1	\	2	Mammalia cf. *Mammuthus*	325	3 - Medium	N	N	N	N	N
1	31002	3	Tusk[a]	-	-	-	Mammuthus sp.	-	-	-	-	-	-	-
1	31002	4	Unidentified	2	\	\	Mammalia	227	4 - Poor	N	N	N	N	N
1	31002	5	? Rib	1	\	\	Mammalia cf. *Mammuthus*	146	3 - Medium	N	N	N	N	N
1	31002	6	Thoracic vertebra	2	\	1 2 3 .	*Mammuthus* sp.	1338^	2 - Good	N	N	N	Y	N
1	31002	9	Rib	1	\	partial 1	*Mammuthus* sp.	190^	2 - Good	N	N	N	N	N
1	31002	10	Single lamella - tooth plate	3	\	Fragments	*Mammuthus* sp.	58	4 - Poor	N	N	N	N	N
2	25002	14	Unidentified[b]	1	-	-	Mammalia	-	-	-	-	-	-	-
3	20007	7	Unidentified	1	\	\	Mammalia	13	3 - Medium	N	N	N	N	N
3	20008	8	Tusk	60	\	\	*Mammuthus* sp.	168	5 - Awful	N	N	N	N	N
3	20008	12	Unidentified[b]	1	-	-	Mammalia	-	-	-	-	-	-	-

[a] *on-site conservation required prior to lifting and further conservation required before analysis*

[b] *retained with multiproxy column samples*

APPENDIX 13. OSL METHODOLOGY

Mechanisms and principles

Upon exposure to ionising radiation, electrons within the crystal lattice of insulating minerals are displaced from their atomic orbits. Whilst this dislocation is momentary for most electrons, a portion of charge is redistributed to meta-stable sites (traps) within the crystal lattice. In the absence of significant optical and thermal stimuli, this charge can be stored for extensive periods. The quantity of charge relocation and storage relates to the magnitude and period of irradiation. When the lattice is optically or thermally stimulated, charge is evicted from traps and may return to a vacant orbit position (hole). Upon recombination with a hole, an electron's energy can be dissipated in the form of light generating crystal luminescence providing a measure of dose absorption.

Herein, quartz is segregated for dating. The utility of this minerogenic dosimeter lies in the stability of its datable signal over the mid to late Quaternary period, predicted through isothermal decay studies (e.g. Smith et al., 1990; retention lifetime 630 Ma at 20°C) and evidenced by optical age estimates concordant with independent chronological controls (e.g. Murray and Olley, 2002). This stability is in contrast to the anomalous fading of comparable signals commonly observed for other ubiquitous sedimentary minerals such as feldspar and zircon (Wintle, 1973; Templer, 1985; Spooner, 1993).

Optical age estimates of sedimentation (Huntley et al., 1985) are premised upon reduction of the minerogenic time dependent signal (Optically Stimulated Luminescence, OSL) to zero through exposure to sunlight and, once buried, signal reformulation by absorption of litho- and cosmogenic radiation. The signal accumulated post burial acts as a dosimeter recording total dose absorption, converting to a chronometer by estimating the rate of dose absorption quantified through the assay of radioactivity in the surrounding lithology and streaming from the cosmos. Age is equal to the Mean Equivalent Dose (De, Gy) divided by Mean Dose Rate (Dr, Gy.ka-1). Aitken (1998) and Bøtter-Jensen et al. (2003) offer a detailed review of optical dating.

Sample Preparation

Six sediment samples were collected within opaque tubing and submitted for Optical dating. To preclude optical erosion of the datable signal prior to measurement, all samples were opened and prepared under controlled laboratory illumination provided by Encapsulite RB-10 (red) filters. To isolate that material potentially exposed to daylight during sampling, sediment located within 20 mm of each tube-end was removed.

The remaining sample was dried and then sieved. The fine sand fraction was segregated and subjected to acid and alkaline digestion (10% HCl, 15% H2O2) to attain removal of carbonate and organic components respectively. A further acid digestion in HF (40%, 60 mins) was used to etch the outer 10-15 μm layer affected by α radiation and degrade each samples' feldspar content. During HF treatment, continuous magnetic stirring was used to effect isotropic etching of grains. 10% HCl was then added to remove acid soluble fluorides. Each sample was dried, resieved and quartz isolated from the remaining heavy mineral fraction using a sodium polytungstate density separation at 2.68g.cm-3. Twelve 6 mm multi-grain aliquots (c. 3-6 mg) of quartz from each sample were then mounted on stainless steel cups for determination of De values.

All drying was conducted at 40°C to prevent thermal erosion of the signal. All acids and alkalis were Analar grade. All dilutions (removing toxic-corrosive and non-minerogenic luminescence-bearing substances) were conducted with distilled water to prevent signal contamination by extraneous particles.

Acquisition and accuracy of De value

All minerals naturally exhibit marked inter-sample variability in luminescence per unit dose (sensitivity). Therefore, the estimation of De acquired since burial requires calibration of the natural signal using known amounts of laboratory dose. De values were quantified using a single-aliquot regenerative-dose (SAR) protocol (Murray and Wintle 2000; 2003) facilitated by a Freiberg Instruments Lexsyg Smart irradiation-stimulation-detection system (Richter et al., 2015). Within this apparatus, optical signal stimulation is provided by an assembly of blue laser diodes, filtered to 445±3 nm conveying 80 mW.cm-2 using a 3 mm Schott GG420 and HC448/20 positioned in front of each laser diode. Infrared (IR) stimulation, provided by IR laser diodes stimulating at 850±3nm filtered by 3 mm RG 715 and delivering ~200 mW.cm-2, was used to indicate the presence of contaminant feldspars (Hütt et al., 1988). Stimulated photon emissions from quartz aliquots are in the ultraviolet (UV) range. These were divided from stimulating photons by 2.5 mm Hoya U-340 and 1mm NG4 glass filters, and a Delta BP 365/50 interference filter, then detected by a Hamamatsu UV-VIS (300-650 nm) bi-alkaline cathode photomultiplier. Aliquot irradiation was conducted using a 1.85 GBq 90Sr/90Y β source calibrated for multi-grain aliquots of 125-180 and 180-250 µm quartz against the 'Hotspot 800' 60Co γ source located at the National Physical Laboratory (NPL), UK.

SAR by definition evaluates De through measuring the natural signal (Fig. 1) of a single aliquot and then regenerating that aliquot's signal by using known laboratory doses to enable calibration. For each aliquot, five different regenerative-doses were administered so as to image dose response. De values for each aliquot were then interpolated, and associated counting and fitting errors calculated, by way of exponential plus linear regression (Fig. 1). Weighted (geometric) mean De values were calculated from 12 aliquots using the central age model outlined by Galbraith et al. (1999) and are quoted at 1σ confidence (Table 1). The accuracy with which De equates to total absorbed dose and that dose absorbed since burial was assessed. The former can be considered a function of laboratory factors, the latter, one of environmental issues. Diagnostics were deployed to estimate the influence of these factors and criteria instituted to optimise the accuracy of De values.

Laboratory Factors

<u>Feldspar contamination</u>

The propensity of feldspar signals to fade and underestimate age, coupled with their higher sensitivity relative to quartz makes it imperative to quantify feldspar contamination. At room temperature, feldspars generate a signal (IRSL; Fig. 1) upon exposure to IR whereas quartz does not. The signal from feldspars contributing to OSL can be depleted by prior exposure to IR. For all aliquots the contribution of any remaining feldspars was estimated from the OSL IR depletion ratio (Duller, 2003). The influence of IR depletion on the OSL signal can be illustrated by comparing the regenerated post-IR OSL De with the applied regenerative-dose. If the addition to OSL by feldspars is insignificant, then the repeat dose ratio of OSL to post-IR OSL should be statistically consistent with unity (Table 1). If any aliquots do not fulfil this criterion, then the sample age estimate should be accepted tentatively. The source of feldspar contamination is rarely rooted in sample preparation; it predominantly results from the occurrence of feldspars as inclusions within quartz.

Preheating

Preheating aliquots between irradiation and optical stimulation is necessary to ensure comparability between natural and laboratory-induced signals. However, the multiple irradiation and preheating steps that are required to define single-aliquot regenerative-dose response leads to signal sensitisation, rendering calibration of the natural signal inaccurate. The SAR protocol (Murray and Wintle, 2000; 2003) enables this sensitisation to be monitored and corrected using a test dose, here set at 5 Gy preheated to 160°C for 10s, to track signal sensitivity between irradiation-preheat steps. However, the accuracy of sensitisation correction for both natural and laboratory signals can be preheat dependent.

The Dose Recovery test was used to assess the optimal preheat temperature for accurate correction and calibration of the time dependent signal. Dose Recovery (Fig. 2) attempts to quantify the combined effects of thermal transfer and sensitisation on the natural signal, using a precise lab dose to simulate natural dose. The ratio between the applied dose and recovered De value should be statistically concordant with unity. For this diagnostic, 6 aliquots were each assigned a 10 s preheat between 140°C and 240°C.

That preheat treatment fulfilling the criterion of accuracy within the Dose Recovery test was selected to generate the final De value from a further 12 aliquots. Further thermal treatments, prescribed by Murray and Wintle (2000; 2003), were applied to optimise accuracy and precision. Optical stimulation occurred at 105°C in order to minimise effects associated with photo-transferred thermoluminescence and maximise signal to noise ratios. Inter-cycle optical stimulation was conducted at 240°C to minimise recuperation.

Irradiation

For all samples having De values in excess of 100 Gy, matters of signal saturation and laboratory irradiation effects are of concern. With regards the former, the rate of signal accumulation generally adheres to a saturating exponential form and it is this that limits the precision and accuracy of De values for samples having absorbed large doses. For such samples, the functional range of De interpolation by SAR has been verified up to 600 Gy by Pawley et al. (2010). Age estimates based on De values exceeding this value should be accepted tentatively.

Internal consistency

Abanico plots (Dietze et al., 2016) are used to illustrate inter-aliquot De variability (Fig. 3). De values are standardised relative to the central De value for natural signals and are described as overdispersed when >5% lie beyond ± 2σ of the standardising value; resulting from a heterogeneous absorption of burial dose and/or response to the SAR protocol. For multi-grain aliquots, overdispersion of natural signals does not necessarily imply inaccuracy. However where overdispersion is observed for regenerated signals, the efficacy of sensitivity correction may be problematic. Murray and Wintle (2000; 2003) suggest repeat dose ratios (Table 1) offer a measure of SAR protocol success, whereby ratios ranging across 0.9-1.1 represent effective sensitivity correction. However, this variation of repeat dose ratios in the high-dose region can have a significant impact on De interpolation.

Environmental factors

Incomplete zeroing

Post-burial OSL signals residual of pre-burial dose absorption can result where pre-burial sunlight exposure is limited in spectrum, intensity and/or period, leading to age overestimation. This effect is particularly acute for material eroded and redeposited subaqueously (Olley et al., 1998, 1999; Wallinga, 2002) and exposed to a burial dose of <20 Gy (e.g. Olley et al., 2004), has some influence in sub-aerial contexts but is rarely of consequence where aerial transport has occurred. Within single-aliquot regenerative-dose optical dating there are two diagnostics of partial resetting (or bleaching); signal analysis (Agersnap-Larsen et al., 2000; Bailey et al., 2003) and inter-aliquot De distribution studies (Murray et al., 1995).

Within this study, signal analysis was used to quantify the change in De value with respect to optical stimulation time for multi-grain aliquots. This exploits the existence of traps within minerogenic dosimeters that bleach with different efficiency for a given wavelength of light to verify partial bleaching. De (t) plots (Fig. 4; Bailey et al., 2003) are constructed from separate integrals of signal decay as laboratory optical stimulation progresses. A statistically significant increase in natural De (t) is indicative of partial bleaching assuming three conditions are fulfilled. Firstly, that a statistically significant increase in De (t) is observed when partial bleaching is simulated within the laboratory. Secondly, that there is no significant rise in De (t) when full bleaching is simulated. Finally, there should be no significant augmentation in De (t) when zero dose is simulated. Where partial bleaching is detected, the age derived from the sample should be considered a maximum estimate only. However, the utility of signal analysis is strongly dependent upon a samples pre-burial experience of sunlight's spectrum and its residual to post-burial signal ratio. Given in the majority of cases, the spectral exposure history of a deposit is uncertain, the absence of an increase in natural De (t) does not necessarily testify to the absence of partial bleaching.

Where requested and feasible, the insensitivities of multi-grain single-aliquot signal analysis may be circumvented by inter-aliquot De distribution studies. This analysis uses aliquots of single sand grains to quantify inter-grain De distribution. At present, it is contended that asymmetric inter-grain De distributions are symptomatic of partial bleaching and/or pedoturbation (Murray et al., 1995; Olley et al., 1999; Olley et al., 2004; Bateman et al., 2003). For partial bleaching at least, it is further contended that the De acquired during burial is located in the minimum region of such ranges. The mean and breadth of this minimum region is the subject of current debate, as it is additionally influenced by heterogeneity in microdosimetry, variable inter-grain response to SAR and residual to post-burial signal ratios.

<u>Turbation</u>
As noted in section 3.1.1, the accuracy of sedimentation ages can further be controlled by post-burial trans-strata grain movements forced by pedo- or cryoturbation. Berger (2003) contends pedogenesis prompts a reduction in the apparent sedimentation age of parent material through bioturbation and illuviation of younger material from above and/or by biological recycling and resetting of the datable signal of surface material. Berger (2003) proposes that the chronological products of this remobilisation are A-horizon age estimates reflecting the cessation of pedogenic activity, Bc/C-horizon ages delimiting the maximum age for the initiation of pedogenesis with estimates obtained from Bt-horizons providing an intermediate age 'close to the age of cessation of soil development'. Singhvi et al. (2001), in contrast, suggest that B and C-horizons closely approximate the age of the parent material, the A-horizon, that of the 'soil forming episode'. Recent analyses of inter-aliquot De distributions have reinforced this complexity of interpreting burial age from pedoturbated deposits (Lombard et al., 2011; Gliganic et al., 2015; Jacobs et al., 2008; Bateman et al., 2007; Gliganic et al., 2016). At present there is no definitive post-sampling mechanism for the direct detection of and correction for post-burial sediment remobilisation. However, intervals of palaeosol evolution can be delimited by a maximum age derived from parent material and a minimum age obtained from a unit overlying the palaeosol. Inaccuracy forced by cryoturbation

may be bidirectional, heaving older material upwards or drawing younger material downwards into the level to be dated. Cryogenic deformation of matrix-supported material is, typically, visible; sampling of such cryogenically-disturbed sediments can be avoided.

Acquisition and accuracy of Dr value

Lithogenic Dr values were defined through measurement of U, Th and K radionuclide concentration and conversion of these quantities into β and γ Dr values (Table 1). β contributions were estimated from sub-samples by laboratory-based γ spectrometry using an Ortec GEM-S high purity Ge coaxial detector system, calibrated using certified reference materials supplied by CANMET. γ dose rates can be estimated from in situ NaI gamma spectrometry or, where direct measurements are unavailable as in the present case, from laboratory-based Ge γ spectrometry. In situ measurements reduce uncertainty relating to potential heterogeneity in the γ dose field surrounding each sample. The level of U disequilibrium was estimated by laboratory-based Ge γ spectrometry. Estimates of radionuclide concentration were converted into Dr values (Adamiec and Aitken, 1998), accounting for Dr modulation forced by grain size (Mejdahl, 1979) and present moisture content (Zimmerman, 1971). Cosmogenic Dr values were calculated on the basis of sample depth, geographical position and matrix density (Prescott and Hutton, 1994).

The spatiotemporal validity of Dr values can be considered a function of five variables. Firstly, age estimates devoid of in situ γ spectrometry data should be accepted tentatively if the sampled unit is heterogeneous in texture or if the sample is located within 300 mm of strata consisting of differing texture and/or mineralogy. However, where samples are obtained throughout a vertical profile, consistent values of γ Dr based solely on laboratory measurements may evidence the homogeneity of the γ field and hence accuracy of γ Dr values. Secondly, disequilibrium can force temporal instability in U and Th emissions. The impact of this infrequent phenomenon (Olley et al., 1996) upon age estimates is usually insignificant given their associated margins of error. However, for samples where this effect is pronounced (>50% disequilibrium between 238U and 226Ra; Fig. 5), the resulting age estimates should be accepted tentatively. Thirdly, pedogenically-induced variations in matrix composition of B and C-horizons, such as radionuclide and/or mineral remobilisation, may alter the rate of energy emission and/or absorption. If Dr is invariant through a dated profile and samples encompass primary parent material, then element mobility is likely limited in effect. Fourthly, spatiotemporal detractions from present moisture content are difficult to assess directly, requiring knowledge of the magnitude and timing of differing contents. However, the maximum influence of moisture content variations can be delimited by recalculating Dr for minimum (zero) and maximum (saturation) content. Finally, temporal alteration in the thickness of overburden alters cosmic Dr values. Cosmic Dr often forms a negligible portion of total Dr. It is possible to quantify the maximum influence of overburden flux by recalculating Dr for minimum (zero) and maximum (surface sample) cosmic Dr.

Estimation of Age

Ages reported in Table 1 provide an estimate of sediment burial period based on mean De and Dr values and their associated analytical uncertainties. Uncertainty in age estimates is reported as a product of systematic and experimental errors, with the magnitude of experimental errors alone shown in parenthesis (Table 1). Cumulative frequency plots indicate the inter-aliquot variability in age (Fig. 6). The maximum influence of temporal variations in Dr forced by minima-maxima in moisture content and overburden thickness is also illustrated in Fig. 6. Where uncertainty in these parameters exists this age range may prove instructive, however the combined extremes represented should not be construed as preferred age estimates. The analytical validity of each sample is presented in Table 2.

Analytical uncertainty

All errors are based upon analytical uncertainty and quoted at 1σ confidence. Error calculations account for the propagation of systematic and/or experimental (random) errors associated with De and Dr values.

For De values, systematic errors are confined to laboratory β source calibration. Uncertainty in this respect is that combined from the delivery of the calibrating γ dose (1.2%; NPL, pers. comm.), the conversion of this dose for SiO2 using the respective mass energy-absorption coefficient (2%; Hubbell, 1982) and experimental error, totalling 2.4%. Mass attenuation and bremsstrahlung losses during γ dose delivery are considered negligible. Experimental errors relate to De interpolation using sensitisation corrected dose responses. Natural and regenerated sensitisation corrected dose points (Si) were quantified by,

Eq. 1: $$Si = (Di - x.Li) / (di - x.Li)$$

Where:
Di = Natural or regenerated OSL, initial 0.2 s
Li = Background natural or regenerated OSL, final 5 s
di = Test dose OSL, initial 0.2 s
x = Scaling factor, 0.08 10

The error on each signal parameter is based on counting statistics, reflected by the square-root of measured values. The propagation of these errors within Eq. 1 generating σSi follows the general formula given in Eq. 2. σSi were then used to define fitting and interpolation errors within exponential plus linear regressions.

For Dr values, systematic errors accommodate uncertainty in radionuclide conversion factors (5%), β attenuation coefficients (5%), matrix density (0.20 g.cm-3), vertical thickness of sampled section (specific to sample collection device), saturation moisture content (3%), moisture content attenuation (2%) and burial moisture content (25% relative, unless direct evidence exists of the magnitude and period of differing content). Experimental errors are associated with radionuclide quantification for each sample by Ge gamma spectrometry. The propagation of these errors through to age calculation was quantified using the expression,

Eq.2 $$\sigma y\ (\delta y/\delta x) = (\Sigma\ ((\delta y/\delta xn).\sigma xn)2)1/2$$

Where y is a value equivalent to that function comprising terms xn and where σy and σxn are associated uncertainties.

Errors on age estimates are presented as combined systematic and experimental errors and experimental errors alone. The former (combined) error should be considered when comparing luminescence ages herein with independent chronometric controls. The latter assumes systematic errors are common to luminescence age estimates generated by means identical to those detailed herein and enable direct comparison with those estimates.

Fig. 1 Signal Calibration

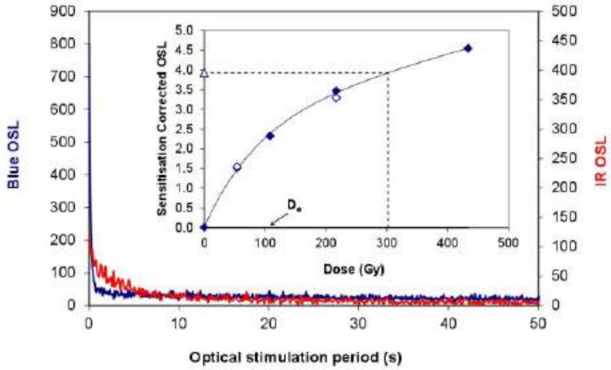


Fig. 2 Dose Recovery

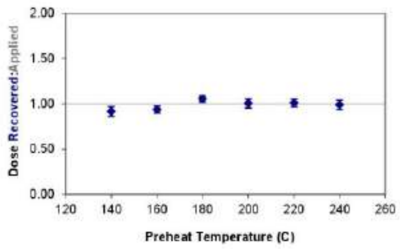


Fig. 3 Inter-aliquot D_e distribution

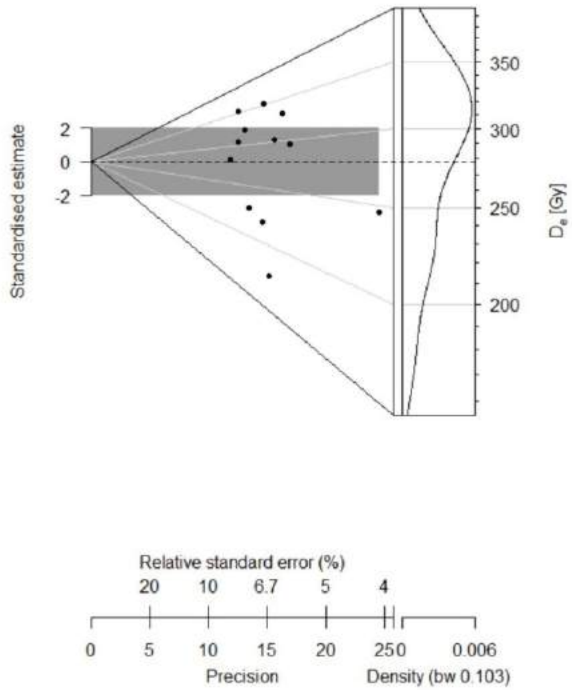


Fig. 4 Signal Analysis

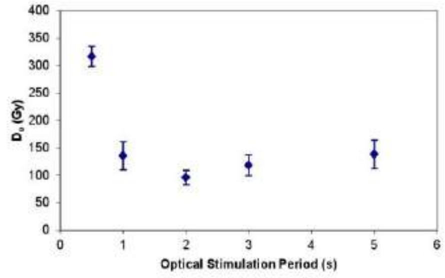


Fig. 5 U Decay Activity

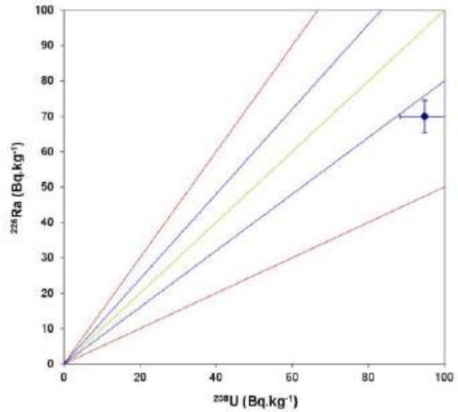


Fig. 6 Age Range

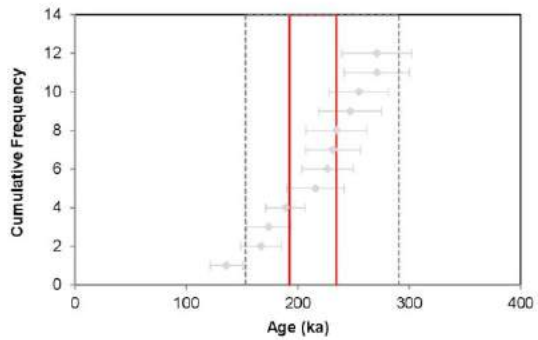


Fig. 1 Signal Calibration Natural blue and laboratory-induced infrared (IR) OSL signals. Detectable IR signal decays are diagnostic of feldspar contamination. Inset, the natural blue OSL signal (open triangle) of each aliquot is calibrated against known laboratory doses to yield equivalent dose (D_e) values. Repeats of low and high doses (open diamonds) illustrate the success of sensitivity correction.

Fig. 2 Dose Recovery The acquisition of D_e values is necessarily predicated upon thermal treatment of aliquots succeeding environmental and laboratory irradiation. The Dose Recovery test quantifies the combined effects of thermal transfer and sensitisation on the natural signal using a precise lab dose to simulate natural dose. Based on this an appropriate thermal treatment is selected to generate the final D_e value.

Fig. 3 Inter-aliquot D_e distribution Abanico plot of inter-aliquot statistical concordance in D_e values derived from natural irradiation. Discordant data (those points lying beyond ±2 standardised ln D_e) reflect heterogeneous dose absorption and/or inaccuracies in calibration.

Fig. 4 Signal Analysis Statistically significant increase in natural D_e value with signal stimulation period is indicative of a partially-bleached signal, provided a significant increase in D_e results from simulated partial bleaching followed by insignificant adjustment in D_e for simulated zero and full bleach conditions. Ages from such samples are considered maximum estimates. In the absence of a significant rise in D_e with stimulation time, simulated partial bleaching and zero/full bleach tests are not assessed.

Fig. 5 U Activity Statistical concordance (equilibrium) in the activities of the daughter radioisotope ^{226}Ra with its parent ^{238}U may signify the temporal stability of D_r emissions from these chains. Significant differences (disequilibrium; >50%) in activity indicate addition or removal of isotopes creating a time-dependent shift in D_r values and increased uncertainty in the accuracy of age estimates. A 20% disequilibrium marker is also shown.

Fig. 6 Age Range The Cumulative frequency plot indicates the inter-aliquot variability in age. It also shows the mean age range; an estimate of sediment burial period based on mean D_e and D_r values with associated analytical uncertainties. The maximum influence of temporal variations in D_r forced by minima-maxima variation in moisture content and overburden thickness is outlined and may prove instructive where there is uncertainty in these parameters. However the combined extremes represented should not be construed as preferred age estimates.

Sample: GL19029

Fig. 1 Signal Calibration

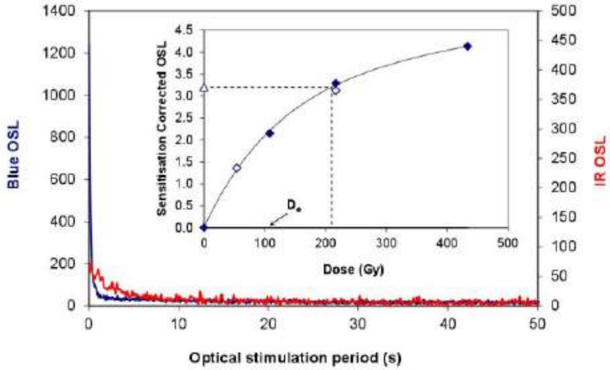


Fig. 2 Dose Recovery

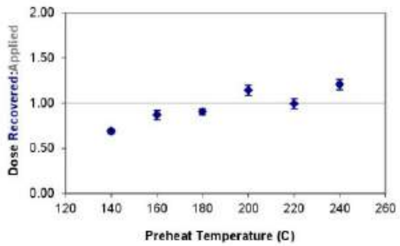


Fig. 3 Inter-aliquot D_e distribution

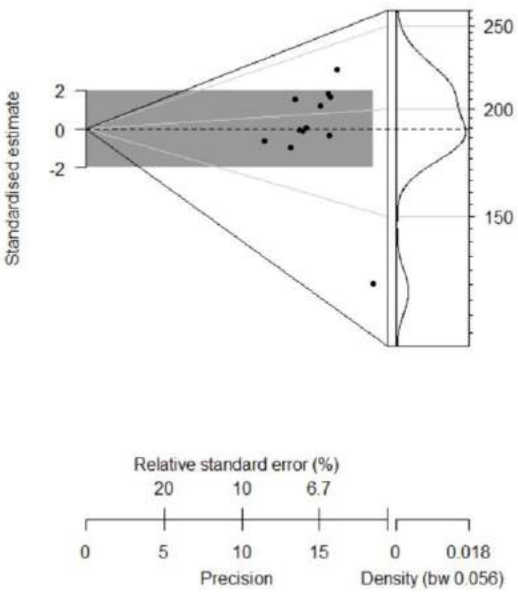


Fig. 4 Signal Analysis

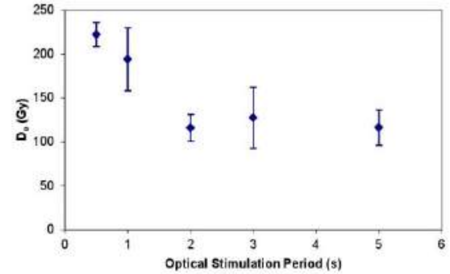


Fig. 5 U Decay Activity

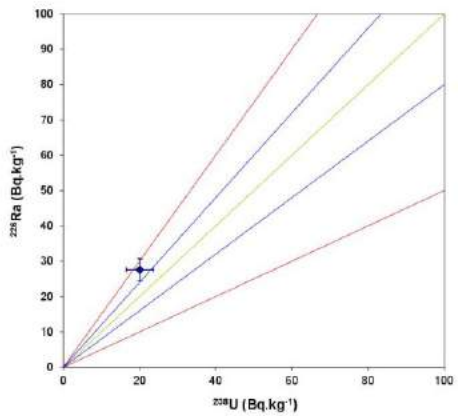


Fig. 6 Age Range

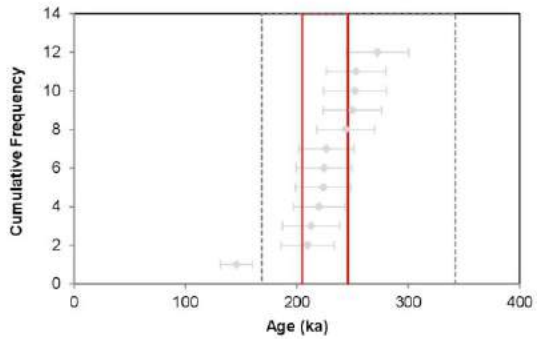


Fig. 1 Signal Calibration Natural blue and laboratory-induced infrared (IR) OSL signals. Detectable IR signal decays are diagnostic of feldspar contamination. Inset, the natural blue OSL signal (open triangle) of each aliquot is calibrated against known laboratory doses to yield equivalent dose (D_e) values. Repeats of low and high doses (open diamonds) illustrate the success of sensitivity correction.

Fig. 2 Dose Recovery The acquisition of D_e values is necessarily predicated upon thermal treatment of aliquots succeeding environmental and laboratory irradiation. The Dose Recovery test quantifies the combined effects of thermal transfer and sensitisation on the natural signal using a precise lab dose to simulate natural dose. Based on this an appropriate thermal treatment is selected to generate the final D_e value.

Fig. 3 Inter-aliquot D_e distribution Abanico plot of inter-aliquot statistical concordance in D_e values derived from natural irradiation. Discordant data (those points lying beyond ±2 standardised in D_e) reflect heterogeneous dose absorption and/or inaccuracies in calibration.

Fig. 4 Signal Analysis Statistically significant increase in natural D_e value with signal stimulation period is indicative of a partially-bleached signal, provided a significant increase in D_e results from simulated partial bleaching followed by insignificant adjustment in D_e for simulated zero and full bleach conditions. Ages from such samples are considered maximum estimates. In the absence of a significant rise in D_e with stimulation time, simulated partial bleaching and zero/full bleach tests are not assessed.

Fig. 5 U Activity Statistical concordance (equilibrium) in the activities of the daughter radioisotope ^{226}Ra with its parent ^{238}U may signify the temporal stability of D_r emissions from these chains. Significant differences (disequilibrium; >50%) in activity indicate addition or removal of isotopes creating a time-dependent shift in D_r values and increased uncertainty in the accuracy of age estimates. A 20% disequilibrium marker is also shown.

Fig. 6 Age Range The Cumulative frequency plot indicates the inter-aliquot variability in age. It also shows the mean age range; an estimate of sediment burial period based on mean D_e and D_r values with associated analytical uncertainties. The maximum influence of temporal variations in D_r forced by minima-maxima variation in moisture content and overburden thickness is outlined and may prove instructive where there is uncertainty in these parameters. However the combined extremes represented should not be construed as preferred age estimates.

Sample: GL19030

Fig. 1 Signal Calibration

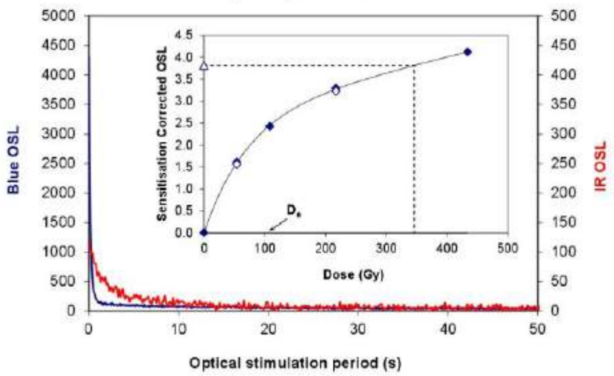


Fig. 2 Dose Recovery

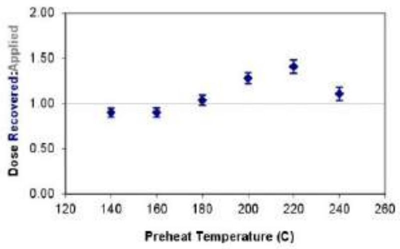


Fig. 3 Inter-aliquot D_e distribution

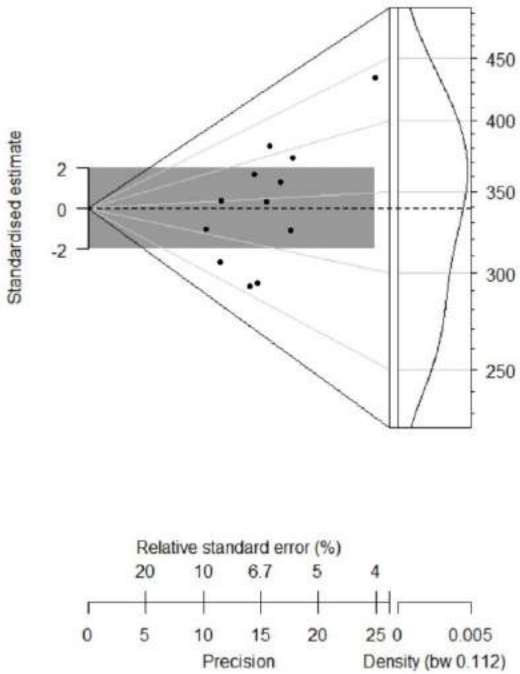


Fig. 4 Signal Analysis

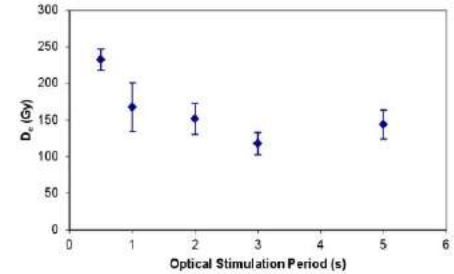


Fig. 5 U Decay Activity

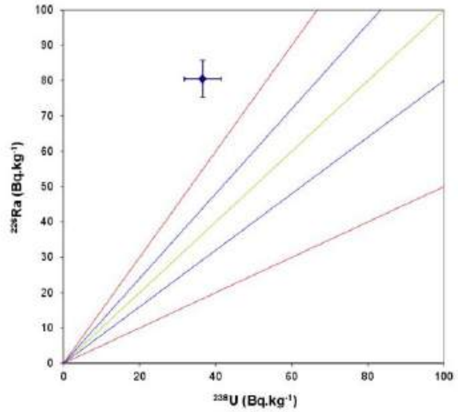


Fig. 6 Age Range

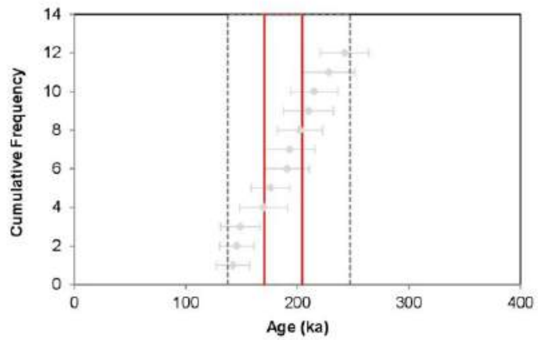


Fig. 1 Signal Calibration Natural blue and laboratory-induced infrared (IR) OSL signals. Detectable IR signal decays are diagnostic of feldspar contamination. Inset, the natural blue OSL signal (open triangle) of each aliquot is calibrated against known laboratory doses to yield equivalent dose (D_e) values. Repeats of low and high doses (open diamonds) illustrate the success of sensitivity correction.

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Fig. 3 Inter-aliquot D_e distribution Abanico plot of inter-aliquot statistical concordance in D_e values derived from natural irradiation. Discordant data (those points lying beyond ±2 standardised ln D_e) reflect heterogeneous dose absorption and/or inaccuracies in calibration.

Fig. 4 Signal Analysis Statistically significant increase in natural D_e value with signal stimulation period is indicative of a partially-bleached signal, provided a significant increase in D_e results from simulated partial bleaching followed by insignificant adjustment in D_e for simulated zero and full bleach conditions. Ages from such samples are considered maximum estimates. In the absence of a significant rise in D_e with stimulation time, simulated partial bleaching and zero/full bleach tests are not assessed.

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Fig. 6 Age Range The Cumulative frequency plot indicates the inter-aliquot variability in age. It also shows the mean age range; an estimate of sediment burial period based on mean D_e and D_r values with associated analytical uncertainties. The maximum influence of temporal variations in D_r forced by minima-maxima variation in moisture content and overburden thickness is outlined and may prove instructive where there is uncertainty in these parameters. However the combined extremes represented should not be construed as preferred age estimates.

Sample: GL19031

Fig. 1 Signal Calibration

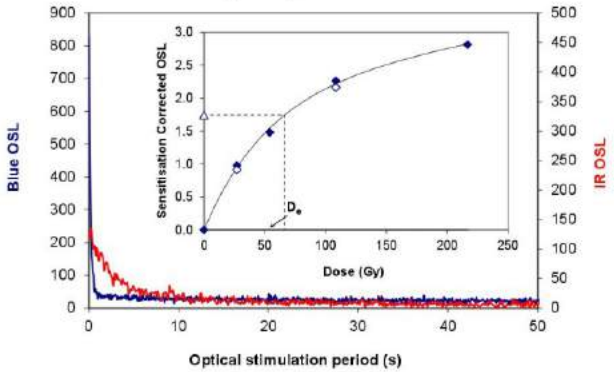

Fig. 2 Dose Recovery

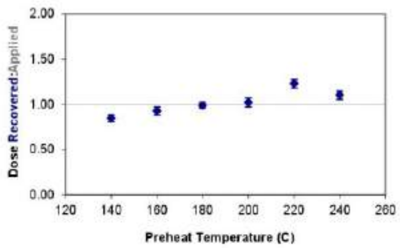

Fig. 3 Inter-aliquot D_e distribution

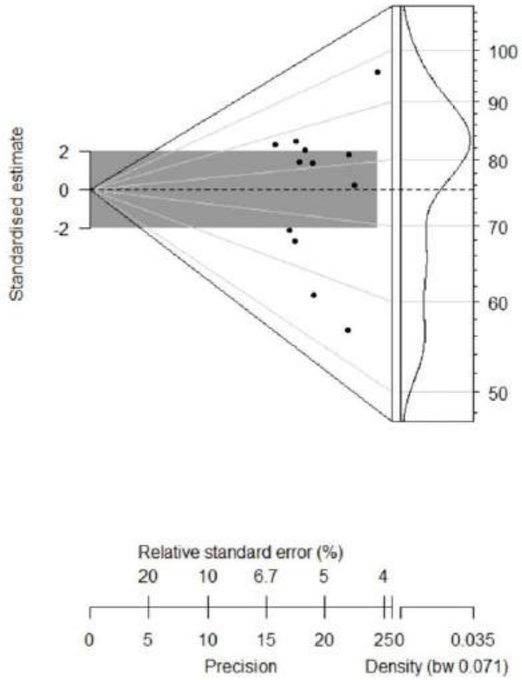

Fig. 4 Signal Analysis

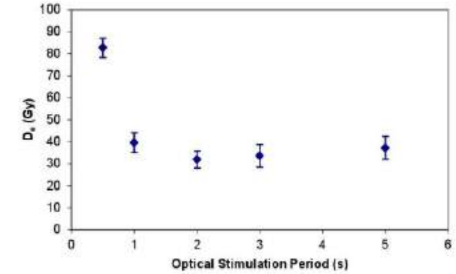

Fig. 5 U Decay Activity

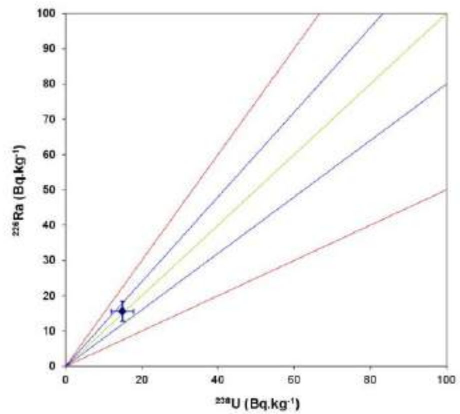

Fig. 6 Age Range

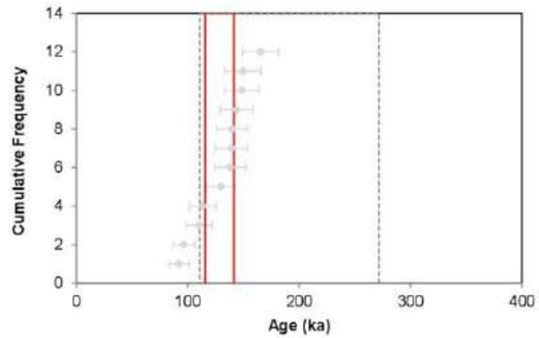

Fig. 1 Signal Calibration Natural blue and laboratory-induced infrared (IR) OSL signals. Detectable IR signal decays are diagnostic of feldspar contamination. Inset, the natural blue OSL signal (open triangle) of each aliquot is calibrated against known laboratory doses to yield equivalent dose (D_e) values. Repeats of low and high doses (open diamonds) illustrate the success of sensitivity correction.

Fig. 2 Dose Recovery The acquisition of D_e values is necessarily predicated upon thermal treatment of aliquots succeeding environmental and laboratory irradiation. The Dose Recovery test quantifies the combined effects of thermal transfer and sensitisation on the natural signal using a precise lab dose to simulate natural dose. Based on this an appropriate thermal treatment is selected to generate the final D_e value.

Fig. 3 Inter-aliquot D_e distribution Abanico plot of inter-aliquot statistical concordance in D_e values derived from **natural** irradiation. Discordant data (those points lying beyond ±2 standardised ln D_e) reflect heterogeneous dose absorption and/or inaccuracies in calibration.

Fig. 4 Signal Analysis Statistically significant increase in **natural** D_e value with signal stimulation period is indicative of a partially-bleached signal, provided a significant increase in D_e results from **simulated partial bleaching** followed by insignificant adjustment in D_e for simulated **zero** and **full bleach** conditions. Ages from such samples are considered maximum estimates. In the absence of a significant rise in D_e with stimulation time, simulated partial bleaching and zero/full bleach tests are not assessed.

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Fig. 6 Age Range The Cumulative frequency plot indicates the inter-aliquot variability in age. It also shows the **mean age range**; an estimate of sediment burial period based on mean D_e and D_r values with associated analytical uncertainties. The maximum influence of temporal variations in D_r forced by minima-maxima variation in moisture content and overburden thickness is outlined and may prove instructive where there is uncertainty in these parameters. However the combined extremes represented should not be construed as preferred age estimates.

Sample: GL19032

Fig. 1 Signal Calibration

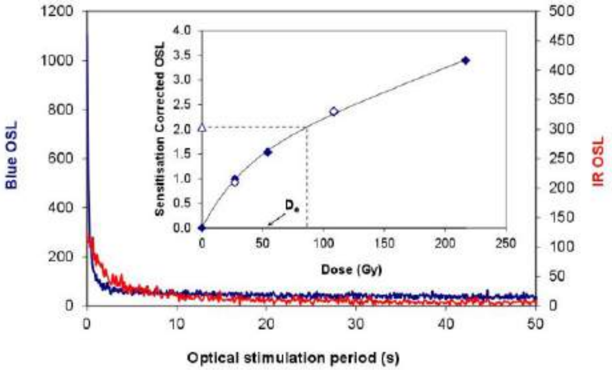

Fig. 1 Signal Calibration Natural blue and laboratory-induced infrared (IR) OSL signals. Detectable IR signal decays are diagnostic of feldspar contamination. Inset, the natural blue OSL signal (open triangle) of each aliquot is calibrated against known laboratory doses to yield equivalent dose (D_e) values. Repeats of low and high doses (open diamonds) illustrate the success of sensitivity correction.

Fig. 2 Dose Recovery The acquisition of D_e values is necessarily predicated upon thermal treatment of aliquots succeeding environmental and laboratory irradiation. The Dose Recovery test quantifies the combined effects of thermal transfer and sensitisation on the natural signal using a precise lab dose to simulate natural dose. Based on this an appropriate thermal treatment is selected to generate the final D_e value.

Fig. 3 Inter-aliquot D_e distribution Abanico plot of inter-aliquot statistical concordance in D_e values derived from natural irradiation. Discordant data (those points lying beyond ±2 standardised ln D_e) reflect heterogeneous dose absorption and/or inaccuracies in calibration.

Fig. 4 Signal Analysis Statistically significant increase in natural D_e value with signal stimulation period is indicative of a partially-bleached signal, provided a significant increase in D_e results from simulated partial bleaching followed by insignificant adjustment in D_e for simulated zero and full bleach conditions. Ages from such samples are considered maximum estimates. In the absence of a significant rise in D_e with stimulation time, simulated partial bleaching and zero/full bleach tests are not assessed.

Fig. 5 U Activity Statistical concordance (equilibrium) in the activities of the daughter radioisotope ^{226}Ra with its parent ^{238}U may signify the temporal stability of D_r emissions from these chains. Significant differences (disequilibrium; >50%) in activity indicate addition or removal of isotopes creating a time-dependent shift in D_r values and increased uncertainty in the accuracy of age estimates. A 20% disequilibrium marker is also shown.

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Fig. 2 Dose Recovery

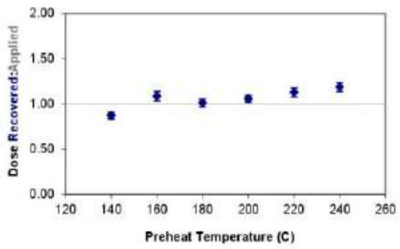
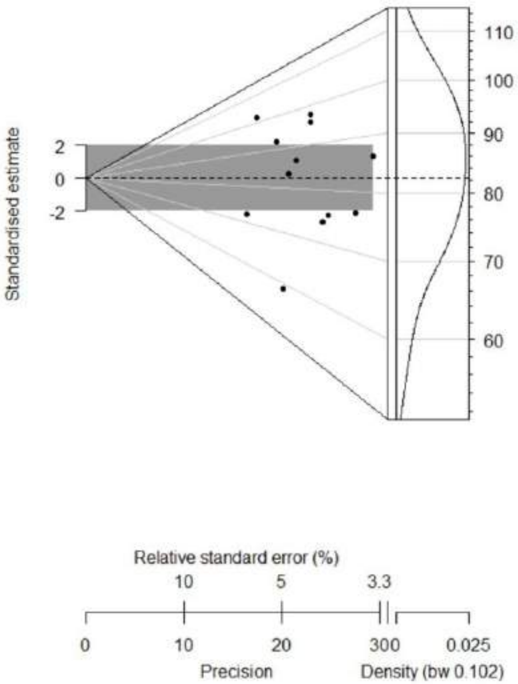


Fig. 3 Inter-aliquot D_e distribution



Sample: GL19037

Fig. 4 Signal Analysis

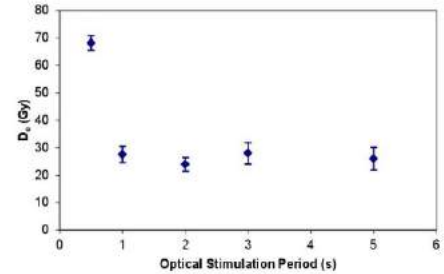


Fig. 5 U Decay Activity

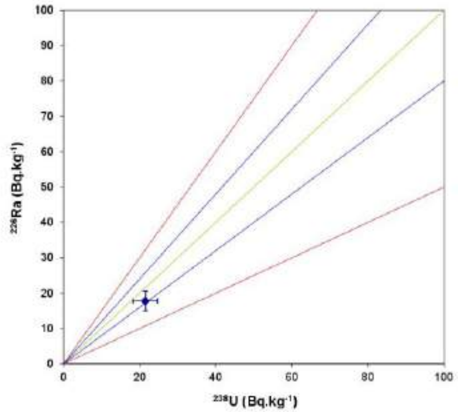
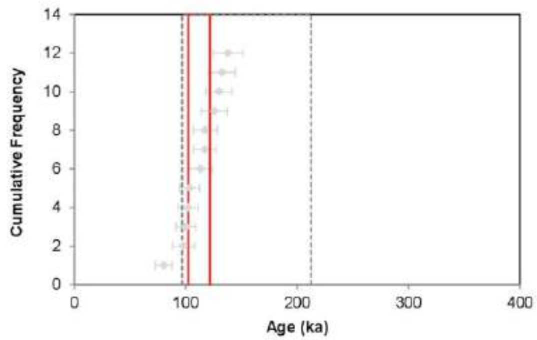


Fig. 6 Age Range



APPENDIX 15 UPDATED PROJECT DESIGN (BOUND UNDER SEPARATE COVER)