global environmental solutions

The Butter Cross, Market Place, Newport, Shropshire

(NGR SJ 7451 1914)

Archaeological Investigations

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Telford & Wrekin COUNCIL

REGISTERED ORGANISATION IfA

FAME Federation of Archaeological Managers & Employers

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Report prepared by
Tim Malim and George Nash, SLR Consulting Ltd 2011 (Revised 2012)
Fieldwork undertaken in 2010 by
Adam Stanford (Aerial Cam) and
Tom Wellicome (Archaeological Landscape Investigation)
with the assistance of volunteers from the Newport History Society

1.0 NON-TECHNICAL SUMMARY

This report outlines the history and recent archaeological investigations around the Butter Cross (or Puleston Cross) (NGR SJ 74522 19146), located in High Street, Newport, Shropshire. The Butter Cross has been designated a Scheduled Monument (Ref: 151). Investigations included an archaeological watching brief in advance and during groundworks and improvements to the High Street. A method statement outlining an archaeological programme of works was prepared by SLR Consulting Ltd on behalf of Telford & Wrekin Council and English Heritage.

The aim of the watching brief was to record any surviving archaeology which was present within the area of the development area. As a result the watching brief uncovered a number of significant features including levelling episodes for construction or repair of the cross, a layer of burnt material, demolition deposits, the foundations of the former Butter Market building, commercial and domestic buildings that formed the northern terrace to Middle Row (an early post-medieval development within this part of the High Street) and an array of artefacts that date from the post-medieval period.

A buried soil beneath the cross base has been dated by Optically Stimulated Luminescence methods to AD 1095 (AD 916 – 1205), and a disturbance event probably detected dated to around 1635 (AD 1577 - 1698).

2.0 INTRODUCTION

This report was prepared by SLR Consulting Ltd on behalf of Telford & Wrekin Council. This document relates to a proposed scheme of archaeological works that included a watching brief for the immediate area surrounding the Butter Cross, a [medieval] Grade II Listed Building (LBS 255412) and Scheduled Monument (Ref: 151) that is located on the eastern side of High Street, approximately 15m south of the St Nicholas Churchyard precinct. The Butter Cross is incorporated into a recently re-designed pedestrian area that included ornamental block-paving, works that are designed to enhance the setting and better protect the monument. Although the block-paving was not within the Scheduled area, the deposits underlying it are.

Scheduling notes suggest that the Butter Cross is a good example of a medieval market [commemorative] cross and is believed to have remained in its original position, within the centre of the medieval town since the late 13th century.

The watching brief had been requested by English Heritage and was required as mitigation works to offset the impact of development on exposed archaeological remains. The scope of the watching brief was based on the archaeological and historic sensitivity of the immediate area, which is located within the medieval town form, centred on High Street, the main north-south thoroughfare of the town.

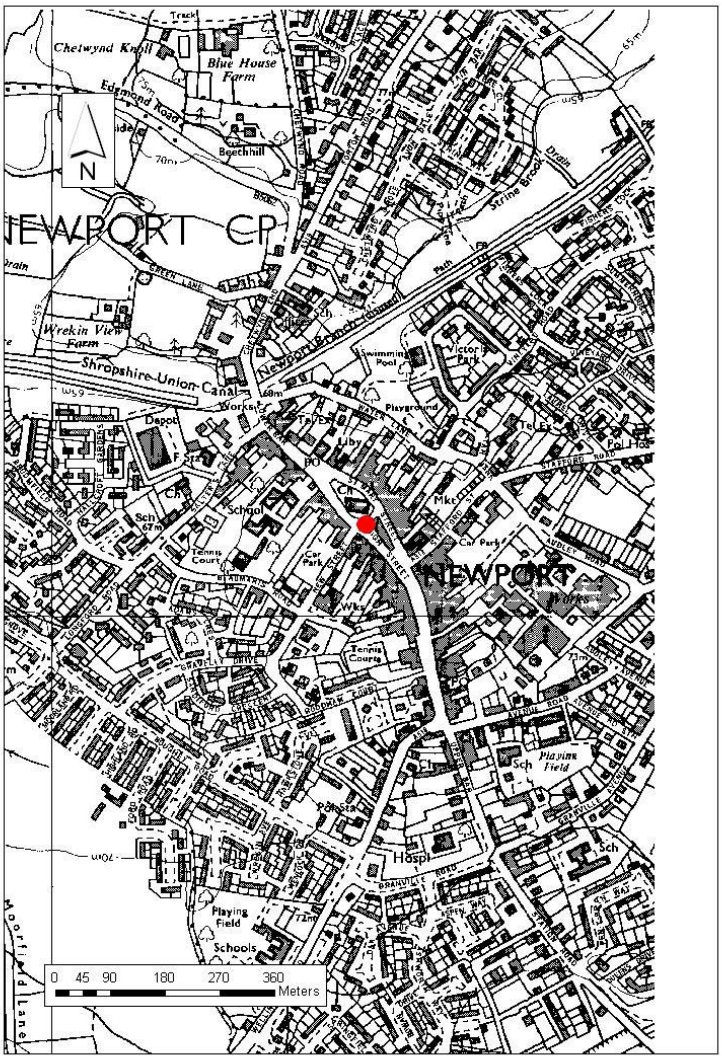
The works were undertaken in accordance with IfA document *Standard and Guidance for Archaeological Watching Brief* (2008) and particular guidelines set within PPS 5 (2010). SLR is a Registered Organisation (RO) with the Institute for Archaeologists, and a member of the Federation of Archaeological Managers and Employers. SLR undertakes work to the highest professional standards.

SLR operates a quality management system to help ensure all projects are managed in a professional and transparent manner, which enables it to qualify for ISO 9001.

3.0 SITE LOCATION, ARCHAEOLOGY & HISTORY

The Butter Cross is located at 73.8m AOD and stands within the High Street, a north-south main thoroughfare that runs through the town (Figure 1). To the north of the cross is the 12th century church of St Nicholas and associated churchyard. The extent of the churchyard precinct is delineated by the eastern line of High Street and the western line of St Mary's Street; both streets at this point would have formed an open market place south of the church. During the 19th century two rows of terrace dwellings and the town hall occupied the southern extent, between the church and the former Corn Exchange, known as Middle Row (formerly Rotten Row). The terrace and their subsequent footprints probably date to the late medieval or early post-medieval periods and are the result of building colonisation following the demise of a weekly market.

Figure 1: Site Location



The cross (also known as the Puleston Cross) is one of around 12,000 free- standing stone crosses in England. It currently stands in Market Place, High Street, within the

southern area of a former medieval open market area (NGR SJ 7451 1914) (Figure 1). However, there has been a suggestion that the stone has been moved; its original precise location unknown. The cross could have been moved in 1633, following the construction of a market hall (built by William Adams[1]). Around this time a butter (and cheese) market (or 'house') building (not the building shown in Plate 10) was constructed within the vicinity of the cross by Richard Barnefield.[2] The cross may have been rebuilt within this building in 1665 by [Lord of the Manor] Thomas Talbot of Longford House. Based on the archaeological evidence in the form of the surviving brick foundations (Plates 4, 5 & 6) this 17th century Butter Market building appears to have been rebuilt several times before being demolished in 1866 when it fell out of use and was replaced by a general market hall, located south of Middle Row. Despite the demolition of the Butter Market building, the cross was spared and has remained in its present position since this time.

The Butter Cross, Scheduled in 1952[3] is constructed of a five-course Old Red Sandstone stylobate block base, and is believed to have been erected in 1286, as a memorial to Roger de Pyvelesdon (hence the name *Puleston* Cross). During and after the English Civil War the cross was severely vandalised resulting in the upper section of the cross being removed.[4]

Based on documentary evidence Roger de Pyvelesdon in his role as Sheriff witnessed a number of important documents included a Charter to Haughmond Abbey and a local act at Vivary fish farm, Aqualate (near Newport). Within the documentation Roger de Pyvelesdon ensured that the burgesses could trade fish outside the county.

Despite the historic vandalism, an octagonal-plan base plinth with four stepped sandstone ashlar block sections supporting a weathered hexagonal stone socket and a part-section of a fluted cross-shaft survive. The base is c. 3m in diameter and stands 1.1m in height. The socket stone measuring 0.95m in diameter is cut from a single block with chamfered edging and contains a large socket-hole (for the shaft). Large groves are carved into several sides, which it has been postulated is the result of knife sharpening (Plate 15). The broken headless shaft, standing over 2m in height has ornamental angle rolls and worn triangular fillets. It is possible though that the present cross-shaft is not the original shaft and that it may originate from the medieval nave from within St Nicholas's Church prior to the rebuild/refurbishment phases of 1883 and 1890.[5]

Certainly over the past 150 years the cross has evoked much interest, being the focus a numerous historic photographs and postcards of Newport. In addition, a bronze plaque, attached to the cross bass sometime during the late 20th century reads: *The Market or "Butter" Cross of which this is the shaft and base, was originally set up in 1286 in memory of Roger de Pyvelesdon, and hence is also known as "The Puleston Cross". It was probably mutilated during the Civil War. The cross is*

[1] Adams left money for the Butter Market to be moved.

[2] The Newport History Society suggests that a Butter Market existed before the mid-17th century and was located to the south of the town. However, following the Great Fire of Newport in 1665, Barnefield's Butter Market was destroyed. This building was probably located within the eastern or southern part of the town where the fire centred.

[3] 28th April 1952

[4] The upper sections of many crosses were usually the target of destruction by *Iconoclasts* during the 16th and 17th centuries. English Heritage considers that only 2000 crosses with or without their cross-heads survive in England.

[5] The granular qualities of the sandstone cross-shaft are much finer than the sandstone blocks that form the base.

protected as a monument of National Importance under the Ancient Monuments Act 1913-1953.

As far as SLR Consulting are aware no archaeological investigations have been undertaken in or around the site. In 1995, Buteux (Worcestershire County Council) compiled the Central Marches Historic Towns Survey which included Newport. This desk-based document assessed the archaeological and historic heritage assets of the town.[6] More recently, an extensive pictorial study has been undertaken by the Newport History Society (supported by the former Local Heritage Initiative [LHI]).

[6] Very little is mentioned concerning the history of the Butter Cross and its immediate area.

4.0 HISTORICAL DEVELOPMENT AND MAP REGRESSION

The historic market town of Newport is located in eastern Shropshire and stands within an area that is associated with the birth of the Industrial Revolution. The original settlement dates to the Norman period. At this time the settlement was known as 'Novoburgo' and later became Newborough and finally Newport around 1221-22.[7] It appears that the Latin and later the anglicised names co-existed until the 14th century (Gelling 1990).

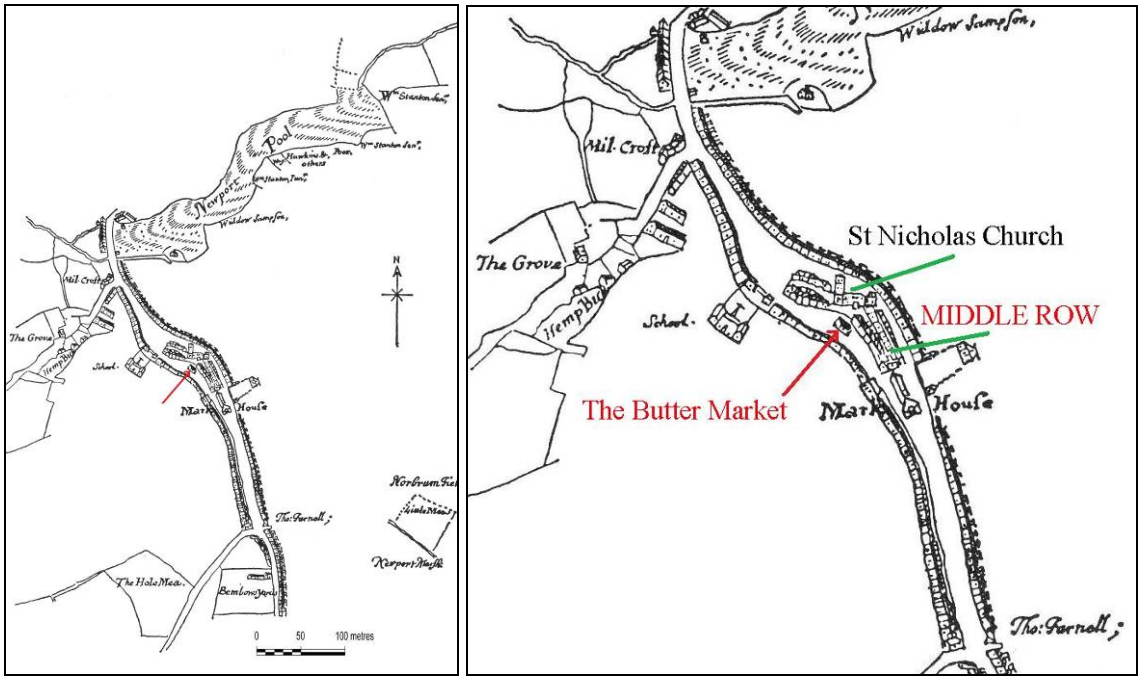
Newport was initially a planned Norman town and later a medieval 'new town'; the latter founded by Henry I between 1163 and 1166. The site of the town lay within his royal manor estate of Edgmond. By 1316-17 the town had prospered with up to 81 burgages occupying the main street, many of which are shown on a map of Newport dated to 1681 (Figure 2). With such a fast growing town, water supply became a problem and in 1309 Richard Attenbruggehend (of Newport) allowed a line of wooden pipes to be laid underground from his spring to the High Street (Prentice 1986, 22).

During this time the town appears to have developed along a single main street which widened around St Nicholas' church, probably purposely designed in order to hold a weekly market.

At some time prior to the 1681 map the market area around the 13th century parish church of St Nicholas Church was colonised by commercial and domestic buildings including Middle Row.

Figure 2
Map of Newport dated 1681

(showing the location of the Butter Market)



[7] The earliest documents referring to Newport date to 1136-39.

To the north and south of the town centre, ribbon development appears to have taken place with little expansion running either side of High Street. During the early post-medieval period many small industries such as the manufacture of cloth (linen and silk), fur, food stuffs and leather were produced within the various suburbs of the town.

Figure 3 1st Edition 1881 OS showing the location of the Butter Cross (in red)
Figure 4 2nd Edition 1902 OS showing the location of the Butter Cross (in red)

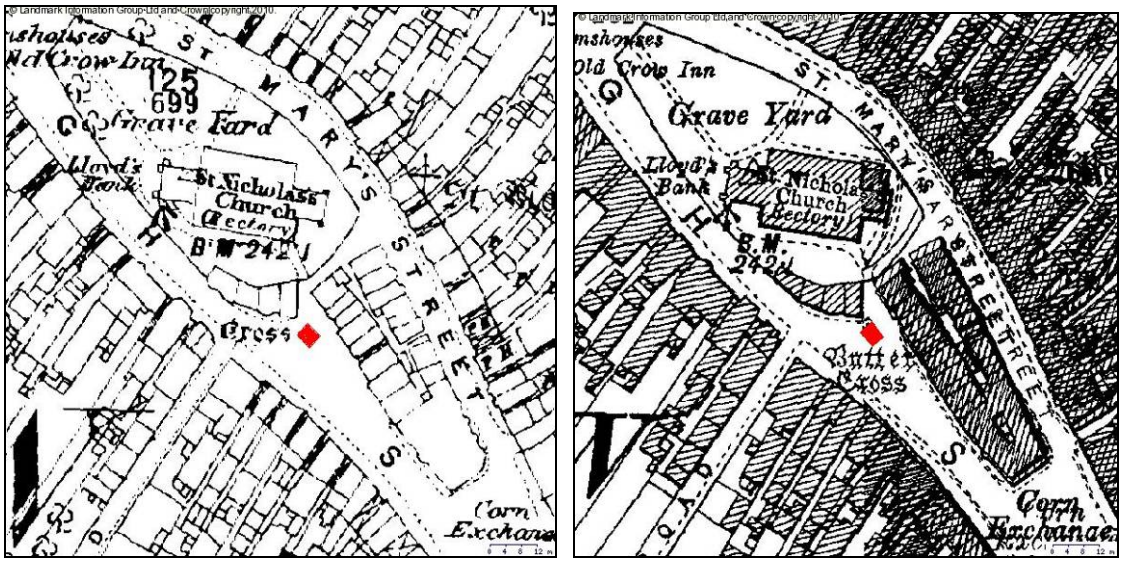
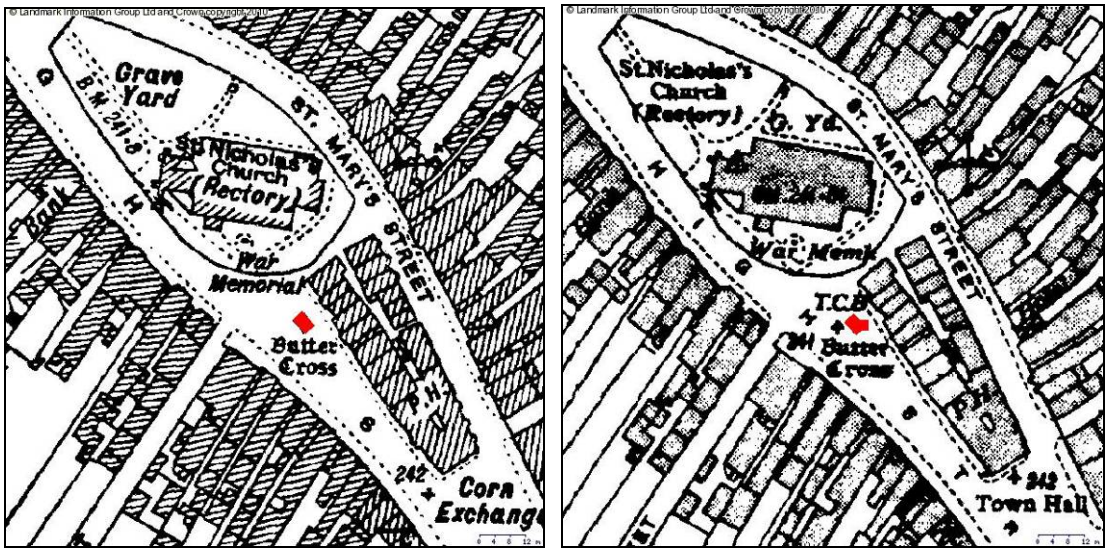


Figure 5 3rd Edition 1924-6 OS showing the location of the Butter Cross (in red)
Figure 6 4th Edition 1937 OS showing the location of the Butter Cross (in red)



The Ordnance survey map of 1881, and subsequent maps thereafter place the cross in its current location (i.e. approximately 20m SE of the churchyard precinct of St Nicholas's Church (Figure 3). To the north and east of the cross are several terraces, known as Middle Row that includes mainly commercial properties. The northern terrace comprising four buildings of varying footprint size appear to have been demolished between the publication of the 1902 and 1924-6 Ordnance Survey

maps. The foundations of these buildings, apparently constructed of 18th century brick were revealed during the watching brief. The footprints of buildings that form the double row (back-to-back) terrace located east and south-east of the Butter Cross appear to remain intact. Inspection of several of these buildings, especially those fronting St Mary's Street possesses timber-framing elements that clearly date the row to the late medieval or early post-medieval periods. Apart from the demolition of the northern terrace there appears to have been little change to the immediate area (Figures 4, 5 & 6). The 1st edition Ordnance Survey map of 1881 shows the Butter Cross standing in isolation. However, according to pictorial evidence, the cross was housed within a building known as the [Old] Butter Market which was demolished in 1866 and would not have featured on any early OS mapping (see Plate 10).

This open-sided civic building comprised twelve stone columns (arranged into five along each elevation and an additional column on each gable) that sat on a brick plinth and supported a pitched roof. The brick plinth is known through SLR'S recent archaeological investigations. It is probable and based on archaeological evidence that the surface within the Butter Market comprised a cobblestone floor; however, the photograph of the building suggests a flagged floor may be visible (Plate 10). The cross was probably located at the northern end of this structure (shown as a dark vertical shadow within the photograph of 1860 [Plate 10]).

Based on the historic photographic archive, the surfaces around the cross have changed a number of times since c. 1860. Since this date the desired surfaces have ranged from large cobble sets in 1860 to small cement-set pebbles during the early part of the 20th century. The current surface was probable laid between 1950 and 1970 and comprises of large grey stone set blocks laid in pointed cement, sitting on a bitumen surface – Context (101). This stabilising deposit is in-turn laid over natural sands – Context (135).

5.0 THE WATCHING BRIEF

5.1 Scope of the project

As part of the regeneration programme for the centre of Newport, a groundworks programme was required in order to replace an existing street surface and furniture. The street surface prior to the groundworks phase comprised uniform-sized angular grey stone sets laid on sand and bonded with a bitumen film. These surfaces surrounded the cross and extended across much of the site. The same stone sets will be re-laid to form a pedestrian area around the cross.

This civil engineering project included ground disturbance around the immediate area of the Butter Cross; a designated Scheduled Monument. Due to the groundworks programme English Heritage requested that a watching brief would be required during this phase of work and was to extend to the pavement line immediately north to the churchyard of St Nicholas and south to No. 64 High Street where the street space converges with the road surface of High Street.

The Sub-contractor – Fitzgerald Contractors Ltd. were instructed to restrict excavation to a depth of 400 mm below the level of the existing ground surface, within an area of c. 20 square metres around the cross (see Figure 7). SLR Consulting advised that all deposits immediately surrounding the monument should be carefully removed by hand excavation, following the removal of the stone sets (the former street surface). Much of the upper stratigraphy (directly below the block paving) comprised sandy deposition (Context 135), or in some places foundation debris and cobblestones. These upper deposits were clearly all of post-medieval and modern origin.

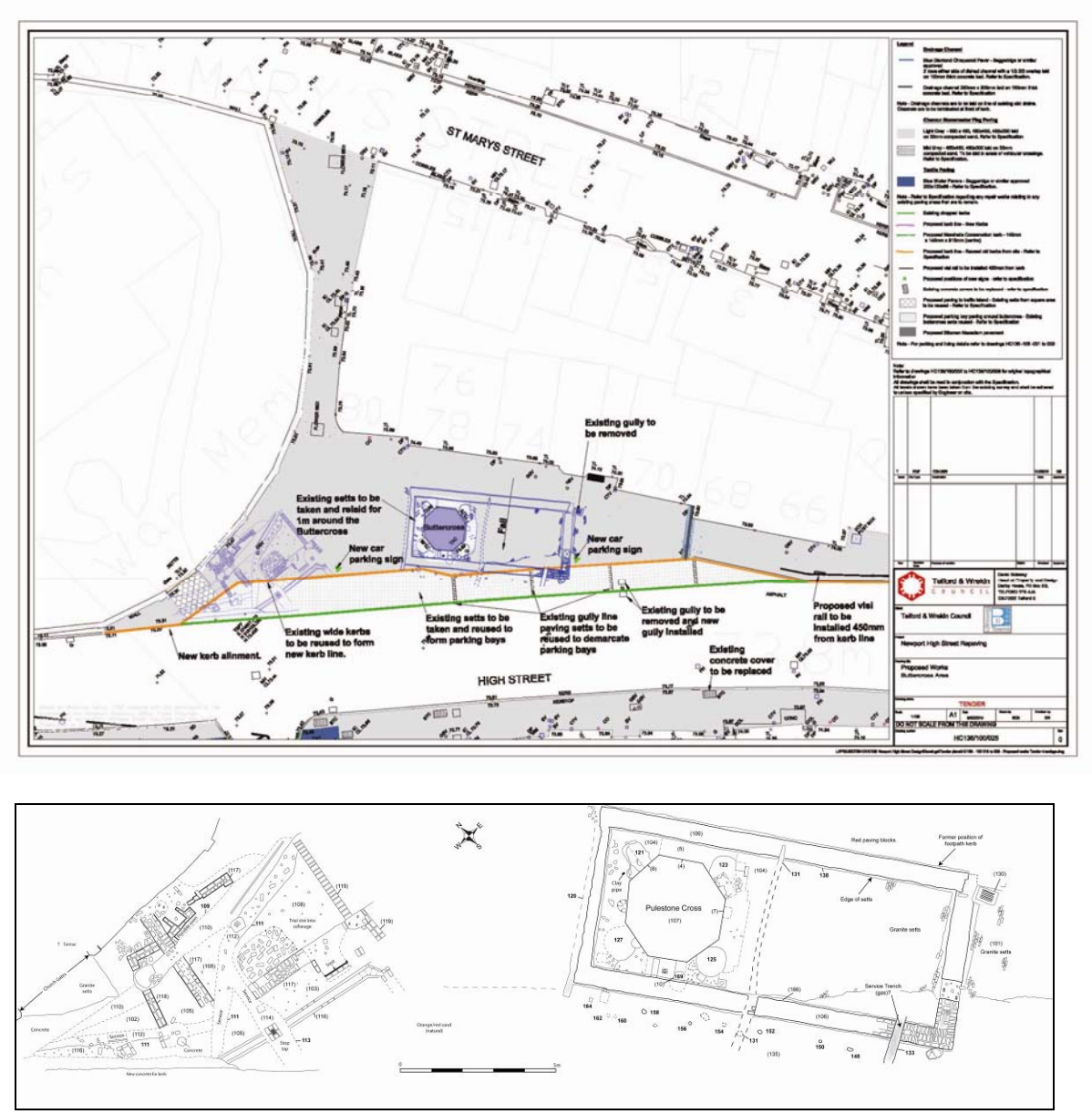
5.2 Fieldwork

The watching brief revealed up to 67 archaeological contexts (101 – 167) that included surface deposits and features, a series of surfaces that abutted and extended underneath the cross, foundation structures relating to the former Butter Market, deposits, features and structures associated with terracing north of the cross and a tightly compacted natural [sandy] soil deposit – (Context 135) - encountered across much of the site. Much of the stratigraphy, features and structures lay within or were cut into this deposit.

The area where archaeology was encountered measured approximately 35 x 9.5m (Figure 7). Three areas of significant archaeology were uncovered within the boundary of the site: the immediate area around the Butter Cross - Context (107), the exposure of the Butter Market – Context (106) and the area north of the Butter Cross where a terrace of four buildings once stood – Contexts (108) to (119) (referred to as the *northern terrace* – see Maps 5 & 6). The archaeology uncovered within these three areas was supported by reliable documentary and historic photographic evidence (see Plates 2, 3 & 10).[8]

[8] SLR Consulting would like to thank the Newport History Society for supplying invaluable documentary archive material including a set of prints that date from 1866.

Figure 7 General plan of archaeological excavation area



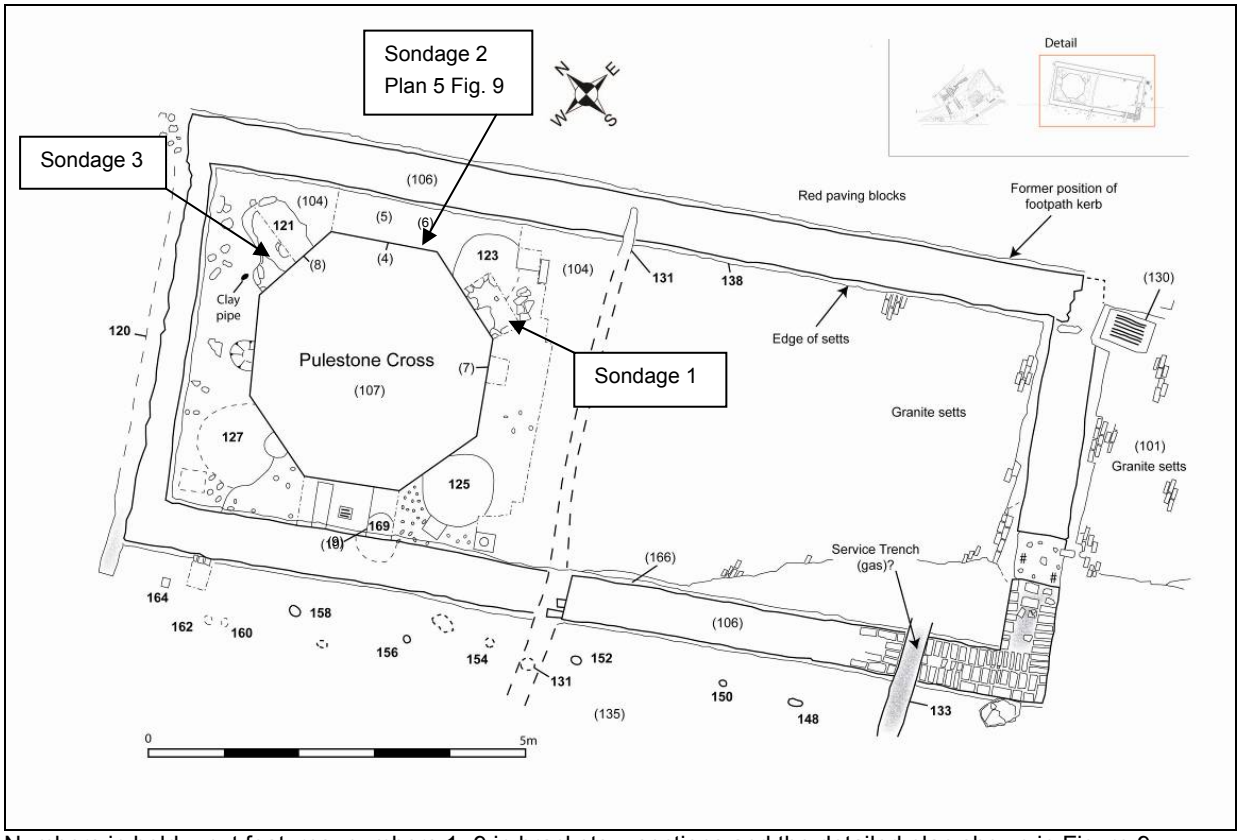
5.3 The Butter Market

The Butter Cross appears to have been in its current position since at least the early to mid 17th century. Documentary and photographic evidence suggests the cross was covered in an open-sided building until mid to late 19th century (see Plate 10). The date of when this structure was erected though is unclear, however it is probable that a Butter Market building stood around the Butter Cross by 1681 where a rectangular building is clearly marked on a plan of the town (see Figure 2). However, targeted excavation revealed the extent of this building. The foundations on which this structure stood comprised three courses of unfrogged brick surviving sub-surface (Context 106) (Figure 8) laid as two rows of header on its side, with a stretcher course on top. This rectangular-shaped structure represented the extent of the former Butter Market building which stood up until 1866. The remains of this structure measured 12.30 x 5.80m (c.40 x 19 feet, or 13.5 x 6.3yds) (see Figure 8 and Plate 10) and extended 0.3 – 0.4m below the present ground level. The

historically recorded dimensions for the Butter Market building were 14 x 6 yards, so the archaeological evidence would seem to confirm the historical record[9] The unfrogged brick, probably locally made, was bonded using a lime-mortared cement and each brick measured 240 x 110 x 70mm (see Plates 6, 7 & 8). These measurements are broadly consistent with the dimensions stipulated in a charter of 1571 that bricks should be 9 x 4.5 x 2.5 inches (230 x 115 x 57mm), whereas by the late 18th century bricks were almost twice as thick[10]. In addition, a construction cut for the foundations, measuring 0.75m wide, was recorded in places on either side of the brick foundations (Context **138**). This cut extended around most of the building foundations and had been filled with a loosely compacted silty sand (Context 166).

Truncating this structure and the associated cut for the foundation trench were several 20th century service trenches, each one running from the Middle Row properties, westwards into the High Street (Contexts [131] and [133]. Further service trenching ran alongside the northern extent of the Butter Market foundations, partially cutting into the surviving brickwork - Context [120]. To the west of this structure were a series of post/stake holes that probably represent localised post-medieval activity, e.g. the erection of signage – Contexts (**148**) to (**164**).

Figure 8
Composite plan of Butter Market building and associated deposits



Numbers in bold = cut features; numbers 1- 9 in brackets = sections and the detailed plan shown in Figure 9

[9] Transactions of the Shropshire Archaeological Society Vol. III, Historical Records of Newport, "The Burgesses" p.161

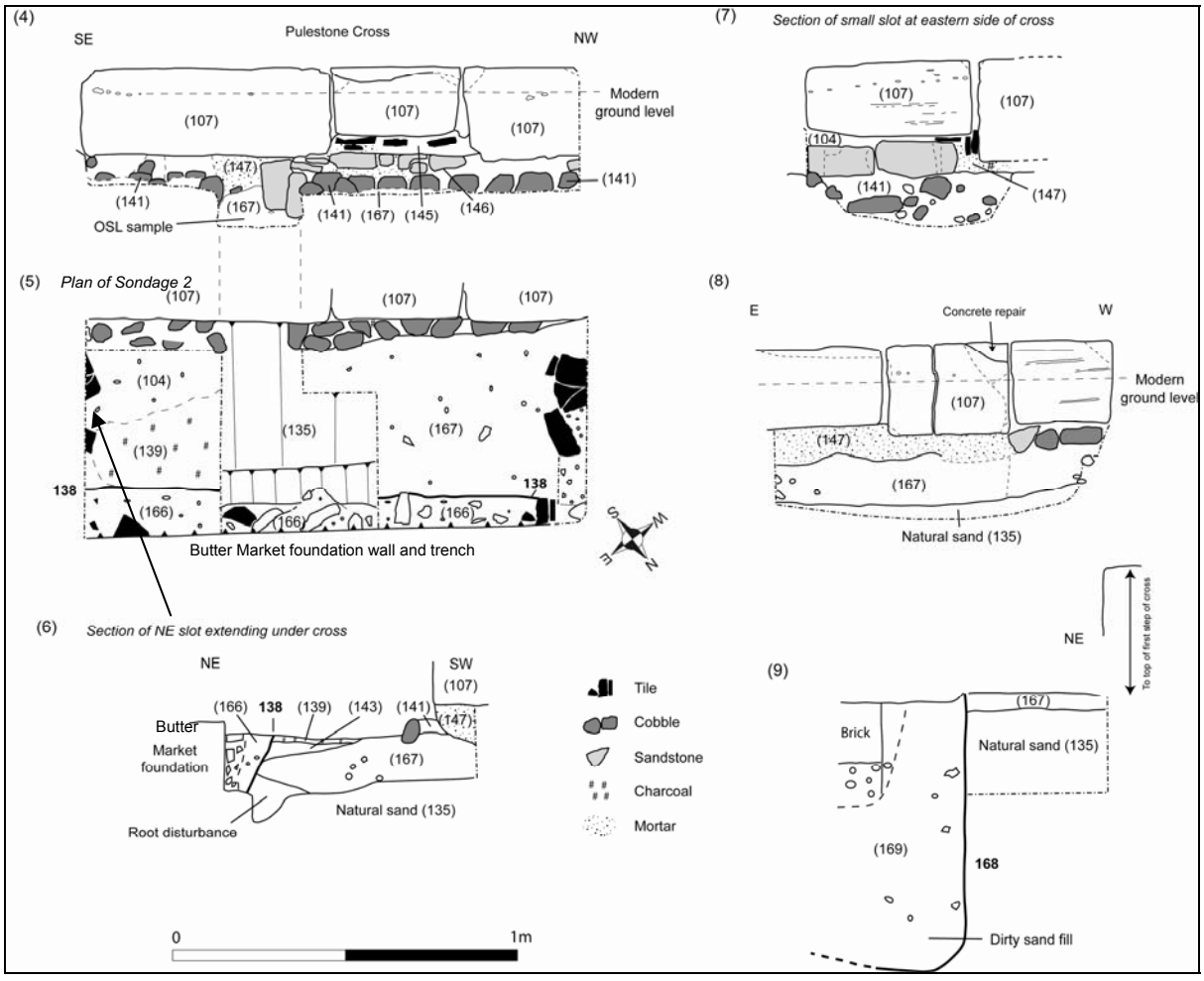
[10] Hammond 1981 Bricks and Brickmaking p.30

5.4 The Butter Cross

Within the northern part of the foundation of the Butter Market and present on a mid 19th century photograph is the Butter Cross (Plate 10). It has undergone a number of repairs both above and below the present ground level (Context 145). The cross may have been incorporated into a building that stood there in 1681 (see Figure 2), but equally it is possible that it has remained within its original location and that cobblestones beneath it on its east side may be a consequence of levelling activity.

Several investigative areas were excavated around and underneath the Butter Cross (Figures 8 and 9). These revealed successive deposits with a buried soil (Context 167, a loosely compacted sandy-silt) forming the earliest cultural deposit above the natural sand (Context 135). The main investigations comprised Sondages 1 – 3.

Figure 9 Section drawings, plans and photographs Sondages 1 & 2 of sandstone blocks forming plinth base and deposits beneath Cross



Sondages 1 and 2 shown on left and note demolition deposit 104, overlying ash and charcoal layer 139, and cobbles 141. In the right hand photograph these deposits are shown after removal of 104 in Sondage 2 (compare to plan 5 in Figure 9 above)

Beneath the Cross and above the buried soil Context 167, a layer of cobblestones was found (Context 141) which did not extend far beyond the Cross (Plate 5 and Figure 9). A layer of mortared and unmortared sandstone blocks and smaller fragments (Contexts 146 and 147) was found between the cobbles and the plinth, probably resulting from working the plinth when it was positioned in place beneath the cross (see sections 4, 6, 7 and 8 in Figure 9). A small area of 146 was overlain by a dark sandy deposit with bones in it (Context 145), and tile debris above which formed additional material to level the underneath of the plinth.

Perhaps contemporary with this foundation activity but located away from the Cross to the north-east in Sondage 2, a loosely compacted sandy deposit was found (Context 143) which contained 17 very small sherds of pottery, probably of early 17th century date. This deposit had been used to level up the ground surface where the buried soil (Context 167) dipped to the north-east. The deposit was sealed beneath a layer of ash and charcoal (Context 139 see Figure 9: plan 5, section 6), and both of these had been cut by the foundations of the Butter Market building (Context **138**).

Overlying Contexts 139, 141 and 167, and also found infilling between 146 and the plinth of the Cross, was a thin deposit of loose sandy-silt with a large amount of brick and tile, and artefacts included within it (Context 104 (see Appendix 2)). Some of the ceramics were clearly of 18th and 19th century date, and this deposit is interpreted as associated with demolition of the Butter Market in 1866 (see photographs above).

Four small areas of disturbance were identified to north, south, west and east of the Cross (Contexts **121**, **123**, **125** and **127**) cutting through the demolition spread (Context 104). These pits would seem to be the locations of four ornamental trees planted in the *c.* late 19th century when the cross was protected by iron railings (as seen on early 20th century imagery - see Plate 2). A large post-hole (**168**) and its fill (169) found on the south-western side of the Cross (Figures 8 and 9 section (9)) may also relate to this phase of Victorian management, perhaps to hold railings in place.

5.5 Artefactual evidence

The investigations recovered a range of material evidence, presumed to represent discarded items which have been broken up and incorporated into levelling episodes and infill of cut features such as pits. Pottery and tile, clay pipe fragments, glass and metalwork, as well as animal bone, were included (see Appendix 2).

As much of this material was re-deposited it cannot always be used for close dating of individual features or events, but can contribute to an understanding of the general chronological development of the site. There is sufficient, however, to identify some of the key phases.

A sample of the buried soil (context 167) beneath the plinth of the Cross was retrieved for OSL dating purposes (see below), and as part of this small-scale excavation three sherds of pottery and two mortar fragments were recovered, of probable post-medieval date. Contexts 141 and 147 appear to have formed a foundation deposit (made-up ground) for constructing the Cross on a level surface. These deposits contained little to help with dating them, whereas Context 143 included a large number of small fragments of animal bone and teeth, lumps of mortar, iron nails, clay-pipe fragments and an assemblage of ceramic material. In particular this included 17 very small sherds of pottery, many of 17th century date, and some probably pre-1620.
Within the area excavated on the north-eastern side of the Cross a thin deposit of black ash and charcoal (Context 139) was found overlying Context 143. This ash layer had been sealed by Context 104, interpreted as a deposit from demolition of the Butter Market in 1866. It contained a large number of animal bone fragments and teeth, some bronze metalwork, over 30 pot sherds, ceramic tile fragments, window and vessel glass, and clay-pipe fragments. The pottery was of 18th – 19th century date, and a bowl from a clay pipe was of probable 18th century date.

5.6 OSL dating results

The detailed results of the dates derived from the sediment sampling (buried soil Context 167) are contained in Appendix 3. In summary these show that the predominant cluster of dates which would represent the main period of soil formation have a date range around AD 1095 (AD 916 – 1205). There is also an indication that a secondary period of disturbance which occurred around AD 1635 (AD 1577 – 1698). OSL dating of the underlying sand (the natural deposit undisturbed by human activity) confirmed that this was deposited at least 116,000 years ago.

5.7 The northern terrace

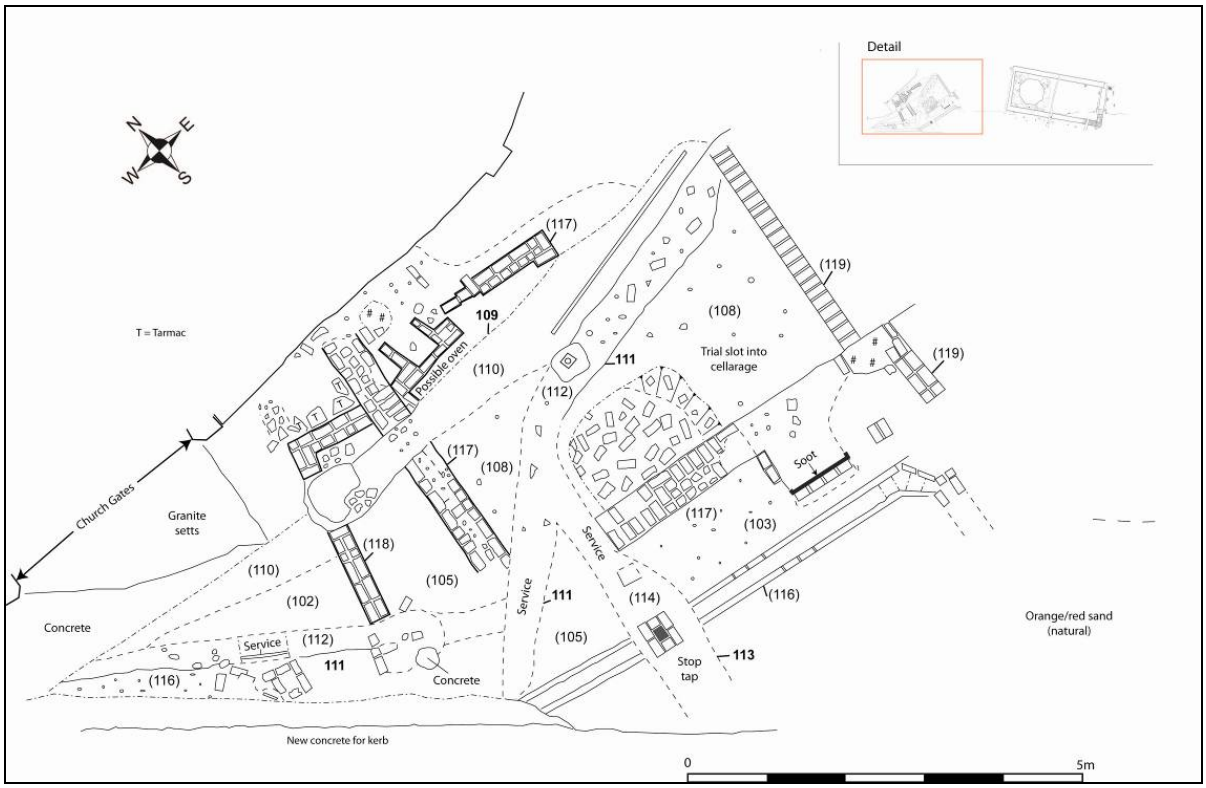
Located north of the Butter Cross and Butter Market, within the vicinity of the southern part of the churchyard precinct, are the foundations of one or two connected buildings (Figure 10), referred to in this report as the *northern terrace*. However, on the 1st edition Ordnance Survey, four buildings are present (Figure 3). Based on supportive photographic evidence this building range was standing until c.1900 (Plate 14), but it was probably originally contemporary with the neighbouring Middle Row. Both would have been the result of the infilling of this area during the late medieval and/or early post-medieval periods.

Up to twelve contexts were revealed during the limited archaeological investigations undertaken by SLR Consulting, many associated with the early 20th century demolition of the buildings - e.g. Context (108) (Figure 9). This deposit clearly indicated the presence of (infilled) cellarage; infilling included post-medieval CBM,

mortar fragments and stone. In addition to infilling and levelling, the surviving sub-surface structures were truncated by 20th century service trenching (e.g. Contexts **109**, **111** and **131**). The scope of work was to make a plan of the upper-most remains, but not to excavate to depth as the remains were not threatened.

The surviving mortared unfrogged brick foundations - Contexts (117), (118) and (119) clearly indicate the presence of several 18th century buildings, probably replacing the footprint of an earlier building range (as witnessed with the building terrace that form Middle Row). The exposed brickwork revealed successive repair and modification; not uncommon with commercial properties of this age and provenance.

Figure 10 Composite plan of Northern Terrace foundations



The mortared brick wall, located within the southern part of this area of the site is present on a number of 19th century postcards (e.g. Plate 14). The surviving wall section, measuring 3.60 x 0.50m, represents the SW elevation of one of the central buildings of the northern terrace and is cut by later service trenching **109** and **111**. On the surviving elevations there was plaster (internal) and cement render (external). Brickwork appeared to extend some distance below the current land surface suggesting associated cellarage. To the rear of this property were the remains of a small oven. A further substantial bonded brick wall, measuring 2.50 by 0.23m and orientated north-east – south-west, west of Wall (117) may represent the eastern elevation of a north-west building. This structural element is constructed differently to other wall sections within the northern terrace and is truncated by later service trenching – Contexts **111** and **113**. Context 119 is a north-south wall located at the eastern end of the northern terrace, which is probably too thin to represent an external gable wall, measuring 3.10 x 0.24m. The plan recovered is probably therefore, that of the penultimate easterly house in the terrace.

6.0 DISCUSSION

Although free-standing medieval crosses are frequent, usually constructed for preaching, public proclamation, penance and rights of sanctuary, the Butter Cross is considered rare in that it acts as a memorial, honouring Roger de Pyvelesdon, appointed Sheriff of Shropshire in 1241. In 1285 the son of Roger de Pyvelesdon (of the same name) signed a deed which refers to *"The Cross set up for the soul of Roger de Pyvelesdon who died in 1272".*

Market crosses were erected as the symbol of a borough's right to trade, usually located in the centre of the town where the main streets crossed. Symbolically they are also referred to as the *omphalos*, a Greek word meaning "navel" i.e. the centre of the community. They were thus closely associated with the prosperity of that community and it is therefore no co-incidence that the church at Newport is dedicated to St. Nicholas, who was the patron saint of merchants and traders, as well as many other groups such as sailors and fishermen. The existence of Newport Pool and the documentary evidence that the town supplied fish to the king's court, may have been another reason for this dedication (Buteux 1995).

The recent investigations around the Butter Cross are the first archaeological excavations within this historic town. They have demonstrated the survival of archaeological deposits and features at a shallow depth below the existing ground surface and thus illustrate the great potential the town has for containing a wealth of archaeological information. The results from this investigation have revealed the presence of a largely forgotten building, the Butter Market, in which the Cross was contained, and a deposit sequence that corroborates the historical record of Cross, Butter Market, Great Fire, reconstruction, and demolition. The excavations also revealed the foundations for terraced houses set against the churchyard precinct.

It has revealed that there is a rich sequence of deposits and activities associated with the erection of the cross and subsequent alterations to its surroundings. OSL dating has established that the cross was built upon a buried soil of probable 12th century date, which is perhaps a century before the cross was erected, with subsequent activity in the 17th century including a deposit of ash and charcoal. OSL and artefactual evidence also appears to exist for later disturbance, perhaps repairs or the possible movement of the cross, during the 17th century. It is unsurprising that artefacts earlier than the 17th century were not recovered due to the very minimal investigation beneath the Cross plinth that was possible during this watching brief, so virtually all finds have come from the disturbed area surrounding the plinth. It is probable that the artefactual finds are associated with the construction of the Butter Market and related contemporary maintenance works to the Cross. Although the possibility still exists that the cross could have been moved to its present location in 1633 by William Adams, such a hypothesis is unlikely because without the protection of the cross, the buried soil beneath would have been disturbed and exposed to light and therefore would not have produced a much earlier OSL date. In addition this location within the market square adjacent to the church, would be the expected position in which a medieval market cross should be found.

Further work remains to be undertaken into understanding more about the nature of the cross itself, whether the shaft is a reused piece of masonry perhaps from the original medieval church, as well as establishing a firm chronology through scientific dating for the erection of the monument. Such research could also stimulate a wider study into the archaeological, documentary and historic landscape evidence for the development of the planned town at Newport.

7.0 ACKNOWLEDGEMENTS

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8.0 REFERENCES

Buteux, V. (ed.) 1995. *Newport. Central Marches Historic Towns Survey*, Worcestershire County Council.

Draper, J. 2001 Post-Medieval Pottery, 1650 – 1800 *Shire Books No. 40*

Gelling, M. 1990. *The place-names of Shropshire, 1: The major names of Shropshire*, Nottingham.

Hammond, M. 1981 Bricks and Brickmaking *Shire Books No. 75*

McCarthy, M.R., and Brooks, C.M. 1988 *Medieval Pottery in Britain AD 900 – 1600* Leicester University Press

Prentice, R, 1986 *A history of Newport*, Chichester: Phillimore.

Rowley, T. 1972. *The Shropshire Landscape*, London.

White, S.D. 2004 The Dynamics of Regionalisation and Trade: Yorkshire Clay Tobacco Pipes c.1600 – 1800 *British Archaeological Reports British Series 374*

Cartography

Map of Newport dated 1681

1st Edition 1881 Ordnance Survey map; Scale 1:2500

2nd Edition 1902 Ordnance Survey map; Scale 1:2500

3rd Edition 1924-6 Ordnance Survey map; Scale 1:2500

4th Edition 1937 Ordnance Survey map; Scale 1:2500

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PLATES

Plate 1. Detail of the base coursing and the bronze plaque, looking east

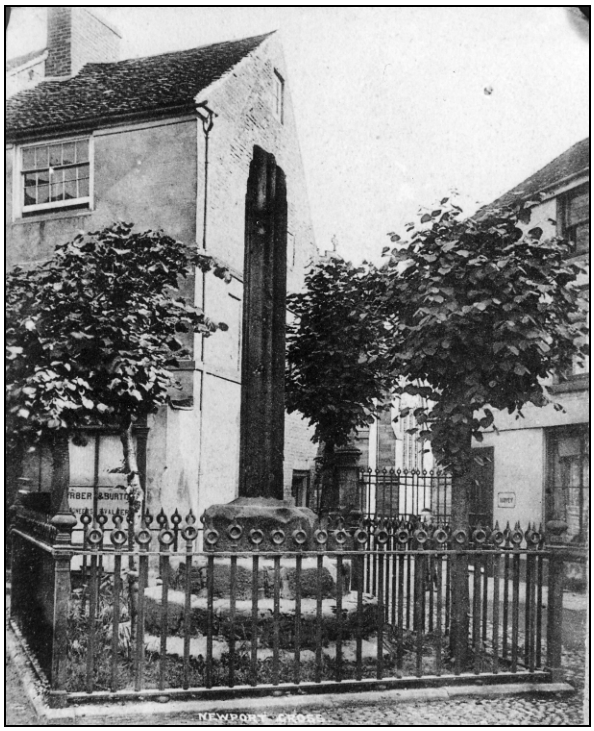

Plate 2. The Butter Cross enclosed by iron rails and trees at cardinal points, dated c. 1910 (*Courtesy of the Newport History Society SNAP Project)*

Plate 3. The Butter Cross with lower plinth partly buried by stone sets, dated c.1975

(*Courtesy of the Newport History Society SNAP Project)*

Plate 4. Archaeological excavation around the Butter Cross exposing the foundations of the 16th century Butter Market (Context 106)

Plate 5. Exploratory slot exposing cobblestones Context 141 in Sondage 1

Plate 6. SLR Archaeologist and two members of the Newport History Society exposing the western wall of the Butter Market (Context 106), looking north

Plate 7. Exposing the 16th century brick foundations of the Butter Market, looking north
Plate 8. Small slot exposing the depth of the foundations of the former Butter Market building

Plate 9. Aerial view of site showing the cross and the footprint of the former Butter Cross Market building (demolished in 1866)

Plate 10. A mid to late 19th century view of the Butter Market [enclosing the Butter Cross at the northern end] (*Courtesy of the Newport History Society SNAP Project)*

Plate 11. One of 12 stone columns belonging to the Butter Market (see Plate 10), now forming part of an archway to Castle House School, Newport

Plate 12. Cleaned area to the north of the Butter Cross showing the foundations of the northern terrace of Middle Row (demolished c. 1900)

Plate 13. Aerial view of the northern section of the site showing the brick foundations of the northern terrace

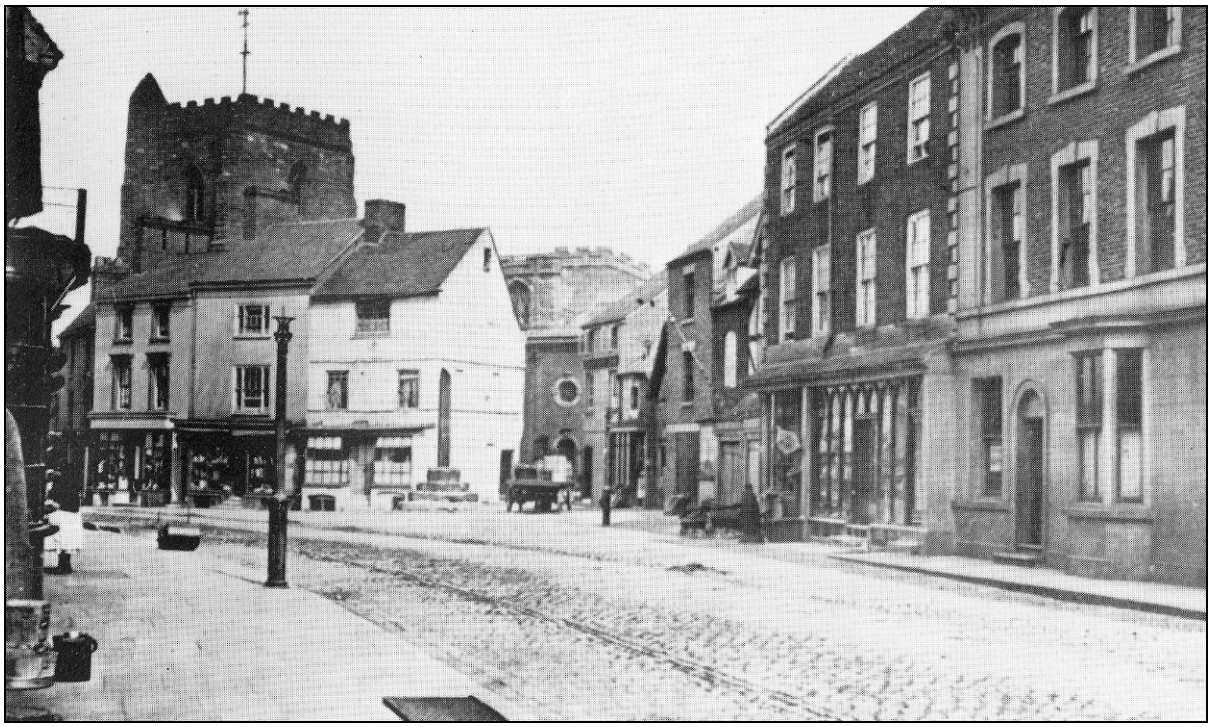

Plate 14. View of High Street and Middle Row looking north, dated c. 1900 (*Courtesy of the Newport History Society SNAP Project)*

Plate 15. View of socket stone for Cross shaft, chamfered and with grooves evident

APPENDIX 1
Context descriptions

Context No.	Description
101	Stone sets extending across the surface of the site, laid and set in sand and bitumen around the latter part of the 20th century.
102	Tarmacdam surface located around the southern gate area of St Nicholas church.
103	Underlying contexts (101) and (102) was a bedding material comprising gravel.
104	Loosely compacted deposit of silt and building debris associated with demolition of the Butter Market in 1866, underlies Contexts (123), (125), (127), (129), (131) & (133).
105	Post-medieval demolition deposit – similar to Context 104, associated with former buildings to the north of the site.
106	Rectangular-shaped brick foundation representing the former Butter Market building, measuring 12.30 x 5.50 m (see Plate 10). This structure, extending c. 0.42m below the present ground level comprises three courses of unfrogged 19th century bonded brick (brick dimensions 0.24 x 0.11 x 0.07m). See Plates 6, 7 & 8.
107	The Butter Cross.
	THE NORTHERN TERRACE AREA
108	20th century demolition deposit, forming a cellar infill of a building within the northern range of Middle Row. The building debris appears to have originated from several properties and comprises CBM, mortar fragments and stone; underlies Context (105) and overlies (117).
109	Early to mid 20th century linear cut for [town] gas service pipe, located within the northern section of the sit, truncating through one of the buildings within the northern terrace.
110	Loosely compacted material forming the fill of the gas service trench (109).
111	[town?] Gas main cutting through the southern building of the northern terrace, located west of (109).
112	Loosely compacted material forming the fill (containing CBM rubble) of the gas service trench (112).
113	Cut for water service trench, orientated E-W with brick-lined cavity for stop tap and servicing former buildings of the northern terrace.
114	Fill of water services trench that includes frequent quantities of CBM and stone cobbles.
115	Brick-lined mortared culvert and associated drain and the northern terrace of buildings, structure cut by Context [113].
116	Fill of culvert (115) comprising CBM and building debris. This deposit may represent the infilling of a robber trench, the debris from which originated from the northwest building of the northern terrace.
117	Mortared brick wall measuring 3.60 x 0.50m, representing the SW elevation of the central building of the northern terrace, cut by later trenches [109] and [111]. On the surviving elevation sections is plaster and cement render. Brickwork appears to extend some distance below the current land surface suggesting cellarage. Remnants of cellarage may exist in the other two identified buildings within this terrace. Brick measurements: 25 x 11.5 x 6 cm & 23 x 11 x 6.5 cm [bricks probably originate from local kilns].
118	Brick wall, measuring 2.50 by 0.23m and orientated NE-SW, west of Wall (117) may represent the eastern elevation of the NW building. This structural element is constructed differently to other wall sections within the northern terrace. Truncated by later cuts [119] and [111].
119	N-S wall located at the eastern end of the northern terrace, representing a possible external gable wall, measuring 3.10 x 0.24m. Brick measurement: 24.5 x 10.5 x 0.06 m.
	AREA AROUND THE BUTTERCROSS
120	Cut of an E-W linear concrete-lined service trench, running along the northern foundations of the Butter Market (106).
121	Four oval features each measuring 1.0 x 0.75m, representing a former trench for an ornamental tree (see Plate 2). Trees were planted around the cross c. 1900. These

	features cut into Context (104).
122	Fill of tree 'bowls' comprising a dark brown loamy soil with occasional CBM fragments, pottery sherds and animal bone.
123	Cut, same as (121), filled by (124) [same as (122)].
124	Fill, same as (122), within cut [125]), same as [121]
125	Cut, same as (121), filled by (126), same as (122).
126	Fill, same as (122), within cut [125], same as [121].
127	Cut, same as [121], filled with (128), same as (122).
128	Fill, same as (122), within cut [127], same as (121).
129	Concrete-lined cut for modern drain, measuring 12 x 0.20m and located east of the Butter Market foundations, cutting into Context (104) (not on plan).
130	Fill of modern drain cut [129].
131	Modern cut into Context (104) and the eastern and western foundation walls of the Butter Market (106), measuring c. 9 x 0.40m and forming a modern service trench.
132	Fill of service trench [131] comprising loosely compacted sand and CBM rubble.
133	Modern cut for service trench measuring c. 2.2 x 0.40m, cutting into (104) and the SW section of the Butter Market foundations (106).
134	Fill of service trench [133] comprising loosely compacted sand and CBM rubble.
135	Naturally deposited sand with no inclusions and sporadic lens, extending across the site.
136	**Unused Context number**
137	Compacted hard standing located outside the street doorway leading to the central building belonging to the northern terrace; deposit measuring 1.50 x 1.1m.
138	Cut for laying the late 18th / 19th century foundations of the Butter market (identified within an excavated slot, located within the NE section of the site but probably extending around the inner and outer wall sections of the Butter Market (12.30 x 5.50 m by 0.75m wide); filled by Context (166) and covered by (104).
139	Thin deposit. Comprising loosely compacted black ash and charcoal representing an isolated burning event; deposit measuring 1.50 x 0.45m; covered by (104), overlying (143) and cut by [138].
140	**Unused Context number**
141	Probable remains of a cobblestone street surface that extends to areas around the cross (see Plate 5).
142	Re-deposited sand, possibly associated with the levelling of the surface in and around the Butter Cross.
143	Underlying Context (139) was a further foundation layer associated with the levelling of the Butter Cross.
144	**Unused Context number**
145	Repair and support episode to the lower section (sub-surface) of the Butter Cross that includes the insertion of stone and tile underneath the first stone blocking course of the cross base.
146	Foundation material for the base of the cross that includes soil and sandstone rubble - possibly associated with Context (147).
147	Probable foundation material for the cross, 17th century in date. Foundation material includes mortared bonded stone. Evidence of later successive repairs, prior to modern burial of the lower base with abutting stone sets etc.
148	(Late post-medieval) cut of a small circular stake hole, measuring 0.20m in depth. This feature has been truncated by recent road works activity. This stake hole is one of a number that are located on the western side of the site; measuring c. 0.10m in diameter.
149	Fill of the circular stake hole.
150	Late post-medieval stake hole, same as Context (148) and measuring c. 0.10m in diameter.
151	Fill of the circular stake hole, same as Context (149).
152	Late post-medieval stake hole, same as Context (148), and measuring c. 0.15m in diameter.
153	Fill of the circular stake hole, same as Context (149).
154	Late post-medieval stake hole, same as Context (148), and measuring c. 0.10m in

	diameter.
155	Fill of the circular stake hole, same as Context (149).
156	Late post-medieval stake hole, same as Context (148), and measuring c. 0.10m in diameter. Heavily disturbed by recent road development.
157	Fill of the circular stake hole, same as Context (149).
158	Late post-medieval circular stake hole, same as Context (148), and measuring c. 0.25m in diameter. Heavily disturbed by recent road development.
159	Fill of the circular stake hole, same as Context (149).
160	Late post-medieval sub-circular stake hole, same as Context (148), and measuring c. 0.25m in diameter and having a depth of c. 0.10m. Heavily disturbed by recent road development.
161	Fill of the sub-circular stake hole, same as Context (149).
162	Late post-medieval sub-circular pit, measuring c. 0.20 by 0.20 m and having a depth of c. 0.10m. Heavily disturbed by recent road development.
163	Fill of the circular stake hole, same as Context (149).
164	Late post-medieval angular stake hole, same as Context (148), and measuring c. 0.10m in diameter and having a depth of c. 0.08m. Heavily disturbed by recent road development.
165	Fill of the post hole/pit.
166	Fill of foundation cut [138], associated with the foundations of the Butter Market (106), containing frequent quantities of CBM and building debris.
167	This heavily truncated surface (deposit) appears to extend underneath the Butter Cross. Based on the limited artefact evidence within its matrix, this deposit appears to date from the mid 17th century. OSL dating with confirm this.

APPENDIX 2
Finds Catalogue

CONTEXT	DESCRIPTION (see photographs)
104 Demolition of Buttermarket in 1866 19th century (Draper 2001)	1 unidentifiable thin clay (?) tube, 5 glass fragments from vessels – 1 of which has evidence of the terminus of a spout or handle, 2 window glass fragments,16 clay pipe stem frags,1 clay pipe bowl (probable spur type, decorated with ring and dot on either side of spur: 18th century (see White 2004 Fig. 6.8)), 26 animal bone fragments, 13 animal teeth, 1 oyster shell, 32 sherds of pot, mostly 18th – 19th century Staffordshire earthenwares, brown and cream decorated glazed ware, including 3 rims, a handle, handle terminus, 3 base sherds and 5 blue and white china sherds. 6 iron nails (?) 2 mortar frags, 9 brick/tile fragments, 1 small iron ring, 1 bronze pin, 1 bronze ring fragment, 3 stone (?) blade tools (?) (look like flints in shape), 1 clay ball fragment, 3 glass objects/fragments. 5 large pieces of roof tile including 2? Pantiles and 1 or 2 flat tiles.  **104** 

105 Demolition deposit Probably 17th Century	5 x clear window glass fragments 2mm thick, 1 ceramic rim fragment glazed blue and white, 1 fragment modern (?) white wall tile, 1 fragment ceramic vessel (salt-glazed stoneware?), 1 near complete base of yellow glazed vessel approx 3cm diameter (mid 17th century Midland yellow ware, lead glaze?), 1 clay pipe bowl (probably 17th century but not convincingly identified), 1 clay pipe stem fragment (see photo below) 
108	1 unidentified fragment (turquoise glass?), 3 fragments yellow/brown (window?) glass 1mm thick, 1 animal bone fragment, 1 animal tooth, 1 brown glazed rim sherd, 1 clay pipe bowl (height 33mm, width 16mm) with indistinct stamp on base (probable heel type dating to 1580 – 1610 (see White 2004 Fig. 6.1 No.6 for parallel)), 1 clay pipe stem fragment
122	4 fragments glass, 4 fragments glazed pot (2 of which glazed orange and brown), 3 animal teeth, 8 animal bone fragments, 9 iron nails, 2 iron cleats (?), 18 brick/tile fragments, 1 ceramic vessel body sherd – orange outside, white inside - inscribed 6V – wheel turned

126	1 glass fragment from vessel, 1 unidentified iron object, 6 animal bone fragments including 3 teeth, 1 ceramic rim sherd, 1 fragment glazed floor tile (see photograph above under 105)
139 Sondage 2: black ash & charcoal thin deposit	1 brick/tile fragment, 4 animal bone fragments, 1 base of clay pipe bowl fragment (unidentifiable) (see photograph below after 143)
140	1 oxidized glass fragment, 3 fragments ceramic vessel bases, 1 iron object, 2 animal teeth, 2 oyster shell fragments
141 cobblestones surface around Cross	2 iron glazed stoneware fragments
143 Foundation deposit for Cross Pottery 17th century, probably pre-1620 (McCarthy & Brooks 1988, p.474)	70 animal bone fragments inc 2 teeth, 17 very small pot fragments including 1 red stoneware rim sherd (3mm thick) and 4 very small sherds glazed Staffordshire ware orange with yellow decoration, 10 iron-glazed wares, 1 Midland Purple ware (ribbed 5mm thick x 2cm), 1 white sherd, 2 clay pipe stems, 2 iron nails, 2 brick/tile fragments, 2 mortar fragments (see photograph below) 

147 Foundation deposit for Cross	7 animal bone fragments including 1 tooth, 1 unglazed oxidised ceramic body sherd (3mm thick x 1.5cm),1 lump mortar (see photograph above under 105). 7 large lumps of mortar (bigger than fist size) not photographed.
167 (OSL dosimetry hole) from beneath Cross, probably 17th century (Draper 2001)	3 hard-fired ceramic fragments of which: 1 rim sherd glazed yellow and orange, 1 body sherd with black/dark brown shiny glaze on one side and red slip on external face; 1 body sherd with black/dark brown on one side – not shiny. 2 soft mortar fragments that join together  **167**
169	3 ceramic frags, 4 unidentified iron objects, 1 brick/tile frag
Unstratified (not photographed)	16 fragments mortar, 11 fragments brick/tile, 1 iron nail, 1 iron object, 2 clay pipe stems, 20 fragments white glazed vessel, 27 fragments animal bone several with evidence of burning, 10 animal teeth. *Photographed* – 6 fragments pottery of which: 3 black burnished (including 1 rim sherd), 2 fragments glazed orange and yellow (including 1 base fragment), 1 not glazed with ribbed decoration of 2 horizontal bands. 3 metal objects of which: 1 copper decorative staple/mount 3.3cmx9mm, 1 copper decorative mount (hook fastener?) 2.8cm long, 1 cylindrical lead weight tapered at the ends 5cm long, 1.3cm in the middle
Sondage 1 (not photographed)	1 iron unidentified object

APPENDIX 2
Optically Stimulated Luminescence Dating Report by Jean-Luc Schwenninger

Section 1: Project Summary – P507 Butter Cross, Newport

Contact	**Timothy Malim**
Nature of samples	Sediment sample for luminescence dating
Number of samples analysed	2
Location of site	Butter Cross, Newport.
Period of interest	Holocene

Table 1
summary of OSL dating results

Field code	*Laboratory code*	**Depth** (m)	*Palaeodose* (Gy)	*Dose rate* (Gy/ka)	*Age estimate* (years before 2010)
NPC10-01 Sample from context 167 (buried soil)	*X5044*	*0.33*	*1.535 ± 0.599*	*1.81 ± 0.12*	*845 ± 335*
NPC10-02 Sample from natural sands	*X5045*	*0.52*	*178.45 ± 66.59*	*1.51 ± 0.10*	*[116000 ± 44000*

Table 1 Summary of the optically stimulated luminescence (OSL) dating results. The results are based on luminescence measurements of sand-sized quartz (180-255μm) using the weighted mean of repeat measurements performed on multiple aliquots. All samples were measured using a SAR post-IR blue OSL protocol (Murray and Wintle 2000, Banerjee et al. 2001). Dose rate calculations are based on the concentration of radioactive elements (potassium, thorium and uranium) derived from elemental analysis by ICP-MS using a fusion sample preparation technique. The external gamma-dose rate was derived from in-situ measurements made with a portable gamma-ray spectrometer. The final OSL age estimates include an additional 2 % systematic error to account for uncertainties in source calibration. Dose rate calculations are based on Aitken (1985). These incorporated beta attenuation factors (Mejdahl 1979), dose rate conversion factors (Adamiec and Aitken 1998) and an absorption coefficient for the water content (Zimmerman 1971). The contribution of cosmic radiation to the total dose rate was calculated as a function of latitude, altitude, burial depth and average over-burden density based on data by Prescott and Hutton (1994). Further details regarding individual samples may be found in Appendix 3.1.

Section 2: Comments on the results

Two samples were collected by David Peat on the 5th of October 2010 at the location of the Butter Cross monument on Market Place in Newport. Sample NPC10-01 [X5044] was taken from a dark buried soil horizon [context 167] located underneath a cobblestone surface which forms the base of the monument. An additional sample [X5045] was secured from the underlying sand deposit which represents the parent material of the buried soil horizon. This latter sample was taken in order to assess potential problems related to partial bleaching and it was agreed that any analyses on this sample would be carried out free of charge. In-situ radioactivity measurements were made using a portable gamma-ray spectrometer (Ortec micronomad) equipped with a 3 inch NaI detector calibrated against the Oxford concrete blocks (Rhodes and Schwenninger 2007). Sample preparation and optically stimulated luminescence (OSL) measurements were performed at the luminescence dating laboratory at the Research Laboratory for Archaeology and the History of Art, University of Oxford. Initial results were communicated directly to T. Malim by telephone in January 2011 and this report contains the full details of the OSL dating programme.

The quartz OSL signal characteristics were determined to be good, featuring good signal intensity, negligible recuperation and good recycling ratios. No aliquots showed any signs of an infrared stimulated signal (IRSL) thus confirming the absence of contaminant feldspar mineral grains.

The dating results reveal very clearly that the depositional age of the parent material is substantially older than that of the overlying buried soil horizon. Unfortunately, no reliable age estimate could be obtained for the natural sand deposit. Repeat measurements on multiple aliquots show a considerable degree of scatter among palaeodose estimates. This may be due to the intrusion of mineral grains from the overlying sedimentary unit associated with the buried land surface. The inclusion of younger material could have been caused by physical disturbance associated with the building phase of the monument or as a result of post-depositional bioturbation by earthworm activity or through rooting. The calculated OSL age estimate of 116ka for the natural sand should therefore be considered to represent a minimum date and the true age of this unit may be considerably higher.

The dating of the buried soil horizon [sample X5044] provides an OSL age estimate of 845±335 years before 2010. The associated error is larger than expected mainly due to the degree of scatter between individual palaeodose estimates. The distribution of De estimates suggegsts the possible contribution of younger grains which could be related to a later archaeological event. Although, the calculated OSL date appears to fit reasonably well with an expected medieval date for the erection of the standing stone cross, the variability between measurements and the presence of a small number of lower estimates may hint towards a younger building or rebuilding event around AD 1635 [AD 1577-1698]. If this is the case, then the predominant cluster of higher palaeodse values could be interpreted as representing the main period of soil formation around AD 1095 [AD 916-1205]. More sophisticated analyses using single grain measurements by means of a focused green laser beam may in future help provide further clarification.

Section 3: The physical basis of luminescence dating

When ionising radiation (predominantly alpha, beta or gamma radiation) interacts with an insulating crystal lattice (such as quartz or feldspar), a net redistribution of electronic charge takes place. Electrons are stripped from the outer shells of atoms and though most return immediately, a proportion escape and become trapped at meta-stable sites within the lattice. This charge redistribution continues for the duration of the radiation exposure and the amount of trapped charge is therefore related to both the duration and intensity of radiation exposure.

Even though trapped at meta-stable sites, electrons become 'free' once again under certain conditions (e.g. if the crystal is heated and/or illuminated). Once liberated a free electron may become trapped once again or may return to a vacant position caused by the absence of a previously displaced electron (a 'hole'). This latter occurrence is termed 'recombination' and the location of the hole is described as the 'recombination centre'. As recombination occurs, a proportion of the energy of the electron is dissipated. Depending upon the nature of the centre where recombination occurs, this energy is expelled as heat and/or light. When the crystal grain is either heated or illuminated following irradiation (the 'dose') the total amount of light emitted (luminescence) is therefore directly related to the number of liberated electrons and available recombination sites. This is the fundamental principle upon which luminescence dating is based.

In cases where the duration of dosing is not known (as is the case for dating), estimates can be made from laboratory measurements. The response (the sensitivity) of the sample to radiation dose (i.e. the amount of light observed for a given amount of laboratory radiation, usually β-radiation) must be established. From this relationship the equivalent radiation exposure required to produce the same amount of light as that observed following the environmental dose can be determined, and is termed the 'equivalent dose' (D_e). The D_e (measured in Gy) is therefore an estimate of the total dose absorbed during the irradiation period. When the dose rate (the amount of radiation per unit time, measured in μGy/a) is measured (or calculated from measured concentrations of radionuclides), the duration of the dosing period can be calculated using the equation:

$$\text{Duration of dosing period} = D_e / \text{dose rate.}$$

The technique of optical dating was first applied to quartz by Huntley *et al*. (1985), and methodological details were further developed by Smith *et al.* (1986) and Rhodes (1988). The technique was demonstrated to work well for aeolian samples by Smith et al. (1990), and has further proved to provide useful age estimates for a range of sedimentary contexts ranging from aeolian to glacial contexts. Further developmental research has introduced D_e measurement protocols that use a 'single aliquot regenerative-dose' (SAR) protocol. These protocols have the potential to provide increased precision in the luminescence measurements, and may in some cases provide an indication of incomplete zeroing of the luminescence signal at the time of deposition.

Section 4: The Single Aliquot Regenerative-Dose (SAR) protocol

The SAR method is a regeneration procedure where the light level of the natural signal is converted into Gy via an interpolation between regenerated (i.e. known dose) points. The natural and regenerated signals are measured using the same aliquot. Sensitivity change commonly observed in quartz TL/OSL has previously precluded meaningful results being obtained this way. A key development reported by Murray and Wintle (2000) is that sample (aliquot) sensitivity is monitored following each OSL measurement (L_i) using the OSL response to a common test dose (S_i). Plots of $OSL1_i/OSL2_i$ provide the necessary (sensitivity change corrected) data for interpolation. The procedure is further outlined below, in Figure 4.1.

Murray and Wintle (2000) have introduced two further steps in to the measurement procedure. The first is the re-measurement of the first regenerated data point (indicated by the box in the explanatory Figure 4.1 below). The ratio of the two points (the "recycling ratio") provides an assessment of the efficacy of the sensitivity correction and the accuracy of the technique (large differences being suggestive of an ineffective technique). The second additional step is a measurement of the regenerated OSL due to zero dose. This value gives a measure of the degree of thermal transfer (to the trap(s) responsible for OSL) during preheating. The ratio of this value to the natural OSL value (both corrected for sensitivity change) gives the "thermal transfer ratio" and this is typically in the range of 0.005-0.020. The "recycling ratio" (ideally unity) is typically in the range 0.95-1.05.

Section 5: Measurement procedures / conditions

Luminescence measurements are made using automated Risø luminescence measurement equipment. There are currently three different systems that can be used for routine dating. The major difference between them being the optical stimulation sources. In the first two systems, optical excitation is provided by filtered blue diodes (emitting ~410-510nm), and in the third a filtered Halogen lamp (emitting ~420-560nm) is used. In all three systems, infrared stimulation is also possible using either an array of IR diodes or a single IR laser diode (depending on the measurement system). Luminescence is detected in the UV region on all systems, using EMI 9635Q bialkali photomultiplier tubes, filtered with Hoya U340 glass filters. Sample irradiation is provided in all cases by sealed ^{90}Sr sources at a rates of 1.5-3 Gy/minute depending on the system used.

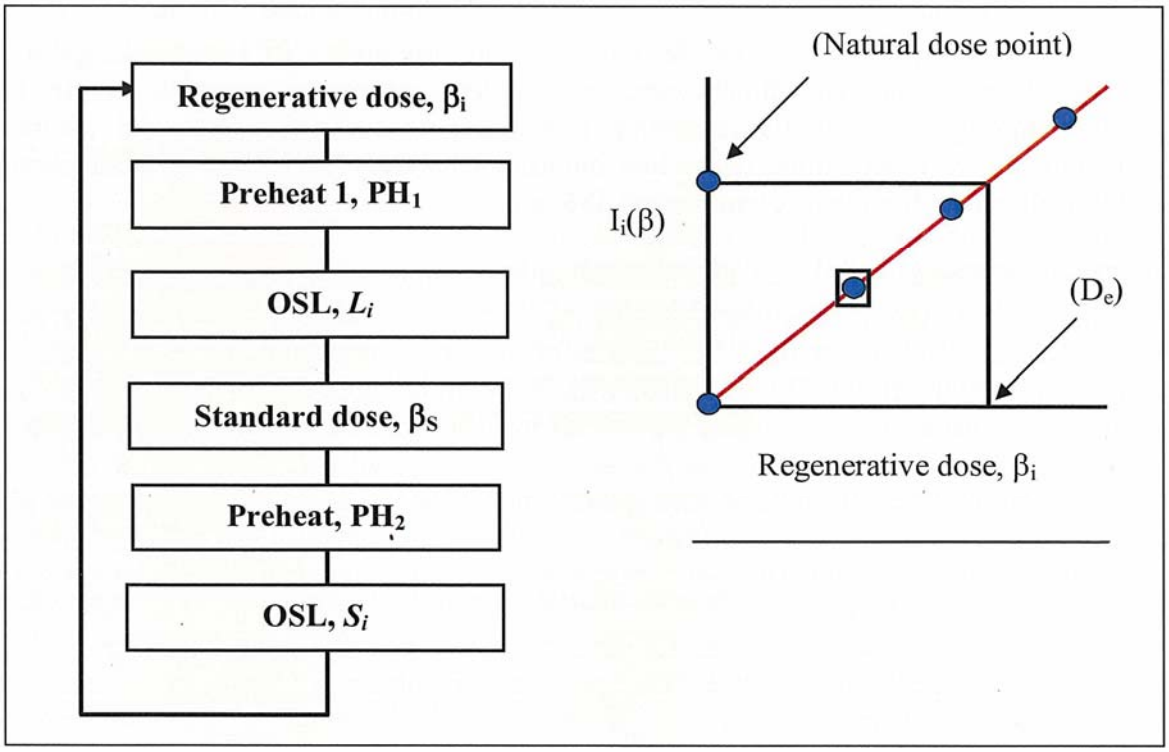

Figure 4.1 Steps 1-6 are repeated n times in order to produce the data points required for interpolation (the first dose β_1 being zero, to give a measure of the natural signal). Typically n=7 (i.e. the natural plus 6 regeneration points, including one zero dose point and one repeat point). PH_1 and PH_2 are usually different although Murray and Wintle (2000) report no dependence of D_e on either (over the range of 200-280°C). The OSL signal is integrated over the initial part of the decay (to ~10% of initial intensity) and the background is taken as the light level measured at the end of the OSL measurement.

In most cases the mean D_e for each sample is obtained from 6-12 aliquots (see Section 4 for details of calculations). All OSL measurements are made at 125°C (to ensure no re-trapping of charge to the 110°C TL trap during measurement) for 100s. The signal in the first 2s (with the stable background count rate from the last 24s subtracted) is normalized using the OSL signal regenerated by a subsequent beta dose (β_s). To ensure removal of unstable OSL components, removal of dose quenching effects and re-trapping necessary to ensure meaningful comparison between naturally and laboratory irradiated signals, 'preheating' is performed prior to each OSL measurement. A preheat (PH_1) at 240°C for 10s was used following the natural and regenerative dose (β_i), and a preheat (PH_2) of 220°C for 10s was used following each test dose (β_s). See Section 3 for further details of the SAR method.

Section 6: Sample preparation

The laboratory procedures were designed to yield pure quartz, of a particular grain size range, from the natural sediment samples. In order to obtain this material, samples were taken through a standard preparation procedure, as outlined below. All laboratory treatments were performed under low intensity laboratory safe-lighting, from purpose-built filtered sodium lamps (emitting at 588 nm).

The sample was wet-sieved to a resolution of ~50μm, and the modal grain size was retained for further processing. Typically the grain sizes used for dating are 90-125μm or 180-250μm (see Appendix 3.1 for details of specific samples). For both samples, the chosen fraction (180-255) was treated with hydrochloric acid (HCl) to remove carbonate and then treated in concentrated HF (48%) for 100 minutes. This treatment serves two purposes: (i) to dissolve feldspar grains, and (ii) to remove (etch) the outer surface of quartz grains (the only part of each quartz grain exposed during burial to natural alpha radiation). Any heavy minerals present were subsequently removed by gravity separation using a sodium polytungstate solution at 2.68 $g.cm^{-3}$. Finally, each sample was re-sieved to remove heavily etched grains. The order of the heavy liquid separation and second sieving are on occasion reversed for practical reasons, and for samples with extremely low yields, either or both of

these treatments may be omitted after careful consideration. The prepared quartz samples were mounted on 1cm diameter aluminium discs for luminescence measurement using viscous silicone oil.

Various tests for sample purity are made. Sub-samples of the prepared material are examined using optical microscopy and the sample is exposed (within the Risø measurement system) to infrared (IR) light. Quartz generally does not produce measurable IR luminescence at room temperature whereas feldspar, which can suffer from anomalous fading of the IRSL and OSL signals, or may be less rapidly bleached in some environments, produces an intense luminescence when stimulated with IR. The presence of a strong infra-red stimulated luminescence (IRSL) signal is therefore used as an indication for the presence of feldspar contaminants and is a criterion for rejection. In the rare cases where samples are rejected due to presence of high levels of IRSL, the prepared sediment sample is treated for ~ 2 weeks in concentrated H_2SiF_6 (silica-saturated HF) which effectively dissolves non-quartz material. If following this treatment, IRSL persists then the sample is subjected to a further two week H_2SiF_6 acid treatment before proceeding to the dating phase (luminescence measurement) and the results are interpreted with caution and the possible contamination of the sample will be discussed. No such extended acid preparation was required for the samples submitted for analysis.

Section 7: Dose rate determination

Radiation dose is described in units of Gray (Gy), the standard SI units of absorbed dose (1 Gy = 1 Joule/kg). The measurement of annual dose rate can be made using a variety of different methods. For most samples, the majority of the environmental dose rate is due to the radioactive decay of unstable isotopes of uranium (U), thorium (Th) and potassium (K). It is therefore necessary to measure the concentrations of each of these elements in each dating sample. An estimation of U, Th and K content can be made using a variety of different methods. These methods are described briefly below.

7.1 Field-based gamma-spectrometry

A portable spectrometer is taken to the sampling site. The probe (housing an NaI scintillator crystal) is inserted in to the cavity left behind following extraction of the sample. Measurements typically take up to one hour and result in direct estimation of the total in-situ gamma radiation field. The spectra are also used to estimate contributions from U, Th and K individually. Through comparison to known concentration standards, quantitative estimates of U, Th and K concentrations are made.

7.2 ICP-MS analysis

A representative sub-sample (typically 10-20g, though as little as a few mg may be used with specialised procedures) of the OSL sample is sent for commercial analysis by fusion ICP-MS to an accredited laboratory in Canada. The fusion ensures that the entire sample is dissolved. It is only with this attack that major oxides including SiO2, REE and other high field strength elements are put into solution. The sample is first crushed to a nominal minus 10 mesh (1.7 mm), mechanically split (riffle) to obtain a representative sample and then pulverized to at least 95% minus 150 mesh (106 microns). Samples are prepared and analyzed in a batch system. Each batch contains a method reagent blank, certified reference material and 17% replicates. Samples are mixed with a flux of lithium metaborate and lithium tetraborate and fused in an induction furnace. The molten melt is immediately poured into a solution of 5% nitric acid containing an internal standard, and mixed continuously until completely dissolved (~30 minutes). The samples are run for major oxides and selected trace elements on a combination simultaneous/sequential Thermo Jarrell-Ash ENVIRO II ICP or a Spectro Cirros ICP. Calibration is performed using 7 prepared USGS and CANMET certified reference materials. One of the 7 standards is used during the analysis for every group of ten samples. Totals should be between 98.5% and 101%. If results come out lower, samples are scanned for base metals. Low reported totals may indicate sulphate being present or other elements like Li which won't normally be scanned for. Samples with low totals however are automatically refused and re-analyzed. The measurement of K and Th are usually precise, though samples with low levels of U may be below the detection limit for this element, depending on the interferences from other isotopes.

7.3 Alpha-counting and flame photometry

A sub-sample of sediment (typically 3g) is dried and crushed to a fine powder (<34μm). The powder is then placed in a shallow container that holds a zinc-sulphide α-scintillator screen directly beneath the sample. The α emissions of U and Th (during radioactive decay) are then counted, giving a measure of total uranium/thorium concentration. The potassium concentration is estimated using standard flame-photometry methods.

The estimates of U, Th and K concentration are converted to estimates of radiation dose rate (mGy/a) using the standard conversion factors of Adamiec and Aitken (1998) (see Appendix A).

Other factors that influence the annual dose rate, and hence require calculation/measurement, are described below.

7.4 Moisture content of the sample

Moisture within the pore spaces of sediments absorbs α, β and γ-radiation. As a result, less radiation is absorbed by the mineral grains. It is therefore important to assess the present day water content of the sediment and to make some assessment of the variability of moisture throughout the burial period of the sample. The moisture correction factors of Aitken (1985) are used in the age calculation (Appendix A).

7.5 Cosmic dose rate

The contribution of cosmic radiation to the total dose rate is calculated as a function of (geomagnetic) latitude, altitude, burial depth and average over-burden density, according to the formulae of Prescott and Hutton (1994).

7.6 Radiation attenuation factors

For coarse grains, the portion of the sample that receives an α-dose is removed by HF etching. Therefore, no consideration of the α-dose is made during the age calculation. β-particles (electrons) are significantly attenuated (i.e. a large fraction of the energy is absorbed) as the β-particle passes through a grain. Account of this effect is needed in order to correctly estimate to dose received by the 'average' grain. The so-called 'attenuation factors' are taken from the empirical work of Mejdahl (1979).

The γ-dose is assumed to be unaffected by attenuation as the penetration of gamma-rays through sediments is several orders of magnitude greater than (~10^5 times) the size of individual grains. Consequently, no attenuation factors are applied to the γ-dose.

Results for the U, Th (ppm) and K (%) concentration of each sample, together with the other parameters used in the age calculation, are given in Appendix A.

Section 8: Statistics and error calculation

The calculated age depends on the estimate of total absorbed dose (D_e) and the annual dose rate (D_R). Both of these estimates have uncertainties associated with them. This section gives general details of how the 'error' (the statistical uncertainty) is calculated for each term and combined with the errors on other terms to give an overall estimate of uncertainty on the estimate of age.

8.1 D_e or palaeodose estimation

As described in a previous section (Figure 4.1), individual estimates of D_e are obtained from each of the aliquot (sub-samples) measured, using the SAR technique. The value (D_e) is obtained by interpolating between the points of the dose response curve. Statistical uncertainties are calculated for each of the individual points and also on the interpolated value of De. Typically, 12 aliquots are measured for each sample.

Each of the points on the growth curve is defined as

$$I(\beta)_i = \frac{L_i - f \cdot l_i}{S_i - f \cdot s_i \cdot} \qquad \text{Eq.1}$$

where L_i is the integrated (initial) OSL from the regeneration dose and l_i is the measured background signal, S_i is the integrated (initial) OSL from the test dose (see Section 3) and si is the background; f is a scaling factor included to take account of the difference in duration of the L_i, S_i and l_i, s_i measurements.

The error on each dose-response data point (see Figure 4.1) is calculated by propagating 'counting statistics' errors (assuming Poisson statistics) from the integration of raw OSL data. The error on each term in Equation 1 is given by the square-root of the value. For example, the range for L_i is given by $L_i \pm \sqrt{L_i}$. The errors on each value are propagated in the standard way (see below) to give the uncertainty of $I(\beta)_i$.

In cases where the dose response can be (locally) approximated by a straight line, a weighted least squares linear fit is used. The errors in this case are calculated analytically using standard formulae.

In cases where the dose response is significantly non-linear, a single saturating exponential function is used to describe the dose response (a Simplex algorithm is used for fitting in this case). Occasionally an extra linear term is added to the exponential term in order to better describe the form of the dose response, although this is not commonly necessary. The uncertainty for non-linear fitting is calculated using a Monte-Carlo method in which 'random samples' of the dose response data are taken (assuming normally distributed probabilities) and used to obtain a D_e value. The spread in these values is then used to calculate the error on the mean D_e for each aliquot, giving a range for each De of $D_{ei} \pm \sigma D_{ei}$

Once the individual D_e values have been obtained from each aliquot (and the associated uncertainties calculated) the values are grouped to give a final overall estimate of D_e. The final estimate (D_e) is calculated using a weighted average. The weight of each D_e is referred to as w_i and defined as

$$w_i = \frac{1}{\sigma D_{ei}{}^2} \Bigg/ \sum_i \frac{1}{\sigma D_{ei}{}^2} \qquad \text{Eq.2}$$

The weighted mean is defined

$$\overline{D}_e = \sum_i D_{ei} \cdot w_i \qquad \text{Eq.3}$$

The weighted standard error, $\hat{\sigma}_{\bar{x}w}$, is calculated from

$$\hat{\sigma}_{\bar{x}w} = \sqrt{\frac{\sum_i w_i \left(D_{ei} - \overline{D}_e\right)}{1 - \frac{1}{n}}} \Bigg/ \sqrt{n} \qquad \text{Eq.4}$$

where n is the number of aliquots. The range of the weighted mean D_e is then defined as

$$\overline{D}_e \pm \hat{\sigma}_{\bar{x}w} \qquad \text{Eq.5}$$

Slight modifications to the approach outlined above are made in special circumstances, though in most cases this description is sufficient.

8.2 Dose rate

The errors on the dose rate are due to errors in a range of values, for example, the concentration of U, Th and K, the water content of the sample. The individual components of the dose rate calculation are shown in Appendix A. The uncertainty on the overall dose rate is calculated by combing the uncertainties according to the standard propagation formula given below.

8.3 Age calculation

The calculated age is obtained from dividing the mean D_e (Eq.3) by the total dose rate (Appendix A). The uncertainty on the final age estimate is calculated using the error propagation formula given below. All calculations were performed using software developed within the laboratory.

8.4 Standard error propagation

If a calculated value (y) is calculated using a function (f) which contains terms x_1, x_2, x_3.... x_n, then

$$y = f(x_1, x_2, x_3 ... x_n) \qquad \text{Eq.6}$$

Each term (x_i) has an associated uncertainty with a range expressed as $x_i \pm \sigma_{xi}$. The overall error of y can be calculated through the addition of the partial derivatives of y with respect to each term. Formally, this is written as

$$\sigma_y = \sqrt{\sum_i \left(\frac{\partial y}{\partial x_i} \cdot \sigma_{xi} \right)^2} \qquad \text{Eq.7}$$

giving a range for y as $y \pm \sigma_Y$.

Section 9: Selected references

Adamiec G. and Aitken M. J. (1998) Dose-rate conversion factors: update. *Ancient TL*, 16, 37-50.

Aitken M. J. (1998) *Introduction to optical dating*. Oxford University Press, Oxford.

Bailey R. M. (2001) Towards a general kinetic model for optically and thermally stimulated luminescence of quartz. *Radiation Measurements*, 33, 17-45.

Bailey R. M. (2000) Circumventing possible inaccuracies of the single aliquot regeneration method for the optical dating of quartz, *Radiation Measurements*, 32, 833-840.

Banerjee D., Murray A. S., Bøtter-Jensen L. and Lang A. (2001) Equivalent dose estimation using a single aliquot of polymineral fine grains. *Radiation Measurements*, 33, 73-94.

Gautier A. (2001) Luminescence dating of archaeometallurgical slag: use of the SAR technique for determination of the burial dose. *Quaternary Science Reviews,* 20, 973-980.

Huntley D. J., Godfrey-Smith D. I and Thewalt M. L. W. (1985) Optical dating of sediments. *Nature* 313, 105-107.

Mejdahl V. (1979) Thermoluminescence dating: beta dose attenuation in quartz grains. *Archaeometry*, 21, 61-73.

Murray A. S. and Wintle A. G. (2000) Luminescence dating of quartz using an improved single-aliquot regenerative-dose protocol. *Radiation Measurement* 32, 57-73.

Prescott J. R. and Hutton J. T. (1994) Cosmic ray contributions to dose rates for luminescence and ESR dating: large depths and long term time variations. *Radiation Measurements* 23, 497-500.

Rhodes E. J. (1988) Methodological considerations in the optical dating of quartz. *Quaternary Science Reviews* 7, 395-400.

Rhodes, E.J. and Schwenninger, J.-L. 2007 Dose rates and radioisotope concentrations in the concrete calibration blocks at Oxford. Ancient TL; 25: 5-8.

Smith B. W., Aitken M. J., Rhodes, E. J., Robinson P. D. and Geldard, D. M. (1986) Optical dating: methodological aspects. *Radiation Protection Dosimetry* 17, 229-233.

Smith B. W., Rhodes E. J., Stokes S., Spooner N. A. and Aitken M. J., 1990, Optical dating of sediments: initial results from Oxford. *Archaeometry*, 32, 19-31.

Zimmermann, D.W. 1971 Thermoluminescent dating using fine grains from pottery. Archaeometry, 13, 29-52.

Appendix 3.1 Sample details

Sample reference code	**NPC10-01**	**NPC10-02**
Laboratory code	**X5044**	**X5045**
Palaeodose (Gy)	1.535	*(179)*
Uncertainty	0.600	66.686
Measured uncertainty	0.599	*(67)*
Source calibration error (2%)	0.031	3.569
Grain size		
Min. grain size (μm)	180	180
Max grain size (μm)	255	255
External gamma-dose (Gy/ka)	0.585	0.498
error	0.059	0.050
Measured concentrations	ICP-MS	ICP-MS
standard fractional error	0.050	0.050
% K	1.320	1.100
error (%K)	0.066	0.055
Th (ppm)	4.300	2.600
error (ppm)	0.215	0.130
U (ppm)	1.100	0.700
error (ppm)	0.055	0.035
Cosmic dose calculations		
Depth (m)	0.330	0.520

error (m)	0.100	0.100
Average overburden density (g.cm^3)	1.900	1.900
error (g.cm^3)	0.100	0.100
Latitude (deg.), north positive	53	53
Longditude (deg.), east positive	-2	-2
Altitude (m above sea-level))	75	75
Cosmic dose rate (μGy/ka)	0.204	0.199
error	0.063	0.041
Moisture content		
Measured water content (%)	10.90	7.80
Estimated mean moisture (water / wet sediment)	0.110	0.080
error	0.030	0.030
Total dose rate, Gy/ka	**1.81**	**1.54**
error	**0.12**	**0.10**
AGE (years before 2010)	**845**	***(116000)***
error	**335**	***(44000)***

SLR

global environmental solutions

AYLESBURY
7 Wornal Park, Menmarsh Road,
Worminghall, Aylesbury,
Buckinghamshire HP18 9PH
T: +44 (0)1844 337380

BELFAST
24 Ballynahinch Street, Hillsborough,
Co. Down, BT26 6AW Northern Ireland
T: +44 (0)28 9268 9036

BRADFORD-ON-AVON
Treenwood House, Rowden Lane,
Bradford-on-Avon, Wiltshire BA15 2AU
T: +44 (0)1225 309400

BRISTOL
Langford Lodge, 109 Pembroke Road,
Clifton, Bristol BS8 3EU
T: +44 (0)117 9064280

CAMBRIDGE
8 Stow Court, Stow-cum-Quy,
Cambridge CB25 9AS
T: + 44 (0)1223 813805

CARDIFF
Fulmar House, Beignon Close, Ocean
Way, Cardiff CF24 5HF
T: +44 (0)29 20491010

CHELMSFORD
Unit 77, Waterhouse Business Centre,
2 Cromar Way, Chelmsford, Essex
CM1 2QE
T: +44 (0)1245 392170

DUBLIN
7 Dundrum Business Park, Windy
Arbour, Dundrum, Dublin 14 Ireland
T: + 353 (0)1 2964667

EDINBURGH
No. 4 The Roundal, Roddinglaw
Business Park, Gogar, Edinburgh
EH12 9DB
T: +44 (0)131 3356830

EXETER
69 Polsloe Road, Exeter EX1 2NF
T: + 44 (0)1392 490152

FARNBOROUGH
The Pavilion, 2 Sherborne Road, South
Farnborough, Hampshire GU14 6JT
T: +44 (0)1252 515682

GLASGOW
4 Woodside Place, Charing Cross,
Glasgow G3 7QF
T: +44 (0)141 3535037

HUDDERSFIELD
Westleigh House, Wakefield Road,
Denby Dale, Huddersfield HD8 8QJ
T: +44 (0)1484 860521

LEEDS
Suite 1, Jason House, Kerry Hill,
Horsforth, Leeds LS18 4JR
T: +44 (0)113 2580650

MAIDSTONE
19 Hollingworth Court, Turkey Mill,
Maidstone, Kent ME14 5PP
T: +44 (0)1622 609242

NEWCASTLE UPON TYNE
Sailors Bethel, Horatio Street,
Newcastle-upon-Tyne NE1 2PE
T: +44 (0)191 2611966

NOTTINGHAM
Aspect House, Aspect Business Park,
Bennerley Road, Nottingham NG6 8WR
T: +44 (0)115 9647280

ST. ALBAN'S
White House Farm Barns, Gaddesden
Row, Hertfordshire HP2 6HG
T: +44 (0)1582 840471

SHEFFIELD
STEP Business Centre, Wortley Road,
Deepcar, Sheffield S36 2UH
T: +44 (0)114 2903628

SHREWSBURY
Mytton Mill, Forton Heath, Montford
Bridge, Shrewsbury SY4 1HA
T: +44 (0)1743 850170

STAFFORD
8 Parker Court, Staffordshire Technology
Park, Beaconside, Stafford ST18 0WP
T: +44 (0)1785 253331

WARRINGTON
Suite 9 Beech House, Padgate Business
Park, Green Lane, Warrington WA1 4JN
T: +44 (0)1925 827218

WORCESTER
Suite 5, Brindley Court, Gresley Road,
Shire Business Park, Worcester
WR4 9FD
T: +44 (0)1905 751310

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