THE WRECK OF THE *LONDON*

Archaeological Investigations of a 17th-century Warship

edited by Michael Walsh



Cotswold Archaeology

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a 17th-century Warship

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Edited by
Michael Walsh

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Front cover: Contemporary drawing of the stern of the London *showing the Royal arms (© Royal Collection Enterprises Limited 2026 Royal Collection Trust)*

Top: Gun carriage after conservation (© Historic England Archive, photograph Christopher Redgrave); Middle: Chapter-ring with folding gnomon from the horizontal pocket sundial (© Historic England Archive, photograph James O. Davies); Bottom: Shoe 3064/3065 (© Historic England Archive, photograph James O. Davies)

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Summary

Since March 2014 a programme of archaeological excavation, geophysical survey and finds assessments has been undertaken by Cotswold Archaeology (CA) and its specialist sub-contractors on the site of the *London* wreck.

The *London* was an English second-rate ship-of-the-line built at Chatham in 1656 during the Interregnum. The *London* served in both the Cromwellian and Restoration navies, saw action during the Anglo-Spanish War in 1657 and participated in the English show of strength during the Battle of the Sound. At the time of the Restoration in 1660 the ship formed part of the fleet that brought the future King Charles II back from exile in the Netherlands.

The *London* sank in the Thames Estuary in 1665 while preparing for the Second Anglo-Dutch War. The ship was blown apart by an explosion, probably of its gunpowder magazine, and, as mentioned in Samuel Pepys' diary entry of 8 March 1665 (Latham 1996b, 138), only 24 personnel survived. The site was rediscovered in 1962 and was designated in 2008 under the Protection of Wrecks Act 1973.[1] The wreck has been on the Heritage at Risk (HAR) register since 2009, owing to the risk of exposure and environmental decay of archaeological material.

More than 700 items have been recovered both through excavation and under the terms of a surface-recovery licence by the licensee team led by Steve Ellis. The artefacts, ecofacts and environmental samples brought up from the vessel during the excavations have been subject to initial stabilisation and processing (as required), assessment, analysis and conservation.

This volume presents a brief summary of the excavations and the results of the assessments of the recovered finds, subsequent analyses and the conservation of the materials. It considers the archaeological, historical and documentary evidence collectively in its local, regional and national context. The remarkable results of the conservation of the broad range and variety of recovered artefacts and material types have presented an ideal opportunity to contribute to the public understanding of the principles, practices and achievements of conservation science through this volume and online resources. The project has also provided many opportunities for public engagement including the use of quayside volunteers, provision of web content, articles in popular archaeological magazines, talks and the early display of artefacts in museums. It has also enabled a collaborative professional training opportunity in an environmental specialism.

The rare and well-preserved objects provide an exceptional insight into the navy during one of the most significant periods in England's history, a time when English naval power was emerging on the European stage. The close dating of the assemblages adds greatly to its contribution to our understanding of the development of various 17th-century technologies and trade patterns. The collective assemblage also enhances our understanding of the known history of the vessel, particularly details of onboard life and provisioning, and our understanding of the last days of the ship.

1. https://www.legislation.gov.uk/ukpga/1973/33 (accessed 3 September 2025).

Chapter 1
Introduction

Michael Walsh

Project background

The English second-rate[1] ship-of-the-line *London* (Fig. 1.1) was in service for less than nine years but for some of that time, during one of the rare periods of peace, it had been laid up 'in ordinary'. The ship was commissioned on 3 June 1654 and launched on 19 June 1656. It was one of only three ships of this type completed and the wreck is the only surviving remains of a second-rate 'large ship' from the ship list of 1642–60. The *London* was involved in the restoration of the monarchy as it formed part of the fleet that brought the future King Charles II back from exile to England. Shortly after leaving Chatham dockyard, following refitting and revictualling, having been laid up for several years, several contemporary diarists, including Samuel Pepys ((Latham 1996b, 138), record that on 7 March 1665 the ship was destroyed by an explosion, probably caused by an accident in the gunpowder magazine while preparing salutes for the arrival of the captain, Vice-Admiral Sir John Lawson. The accident resulted in more than 300 casualties, with only 24 or 25 survivors.

The wreck, lying in around 18m of water in the Thames Estuary, approximately 2.4km south of Southend-on-Sea, Essex and 5.3km north of Sheerness, Kent, was rediscovered in 1962 (Fig. 1.2). It was surveyed several times in the intervening years before it was designated a protected wreck in 2008 under the Protection of Wrecks Act 1973, owing to the exposure and environmental decay of archaeological

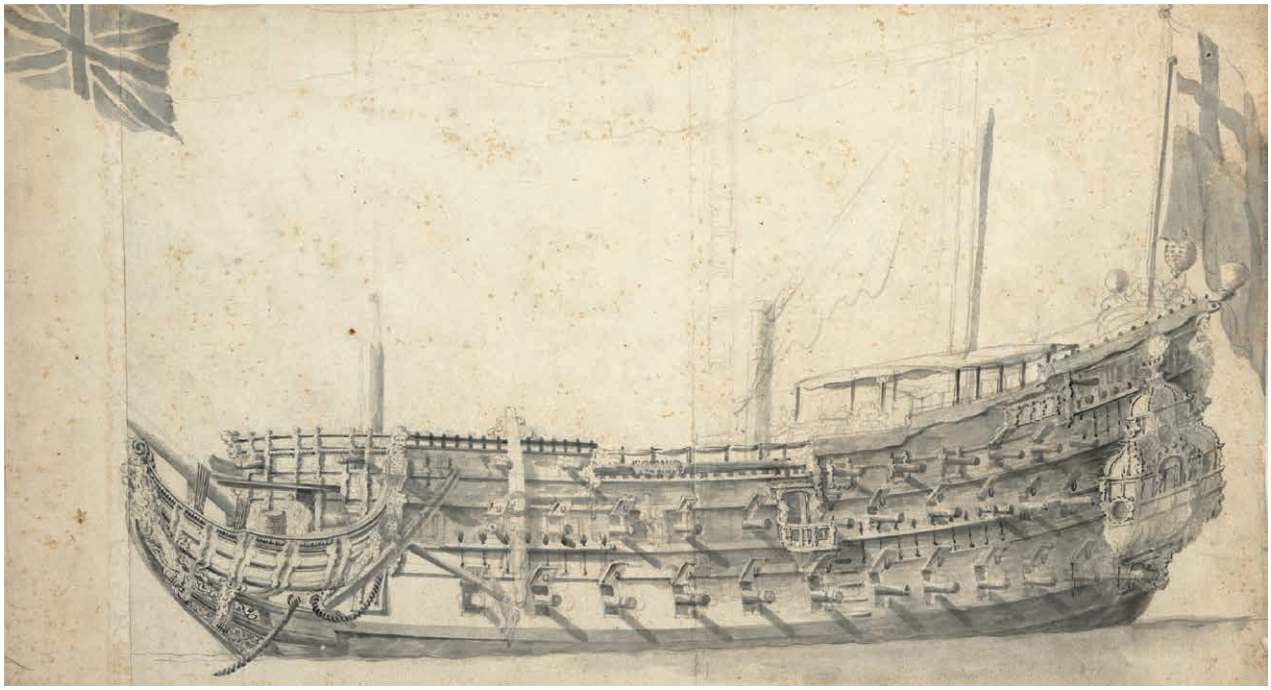


Figure 1.1 The London *(Willem van de Velde the Elder* c. *1660) © National Maritime Museum, Greenwich, London; PX6182)*

1. The system of rating warships was only formally adopted just prior to the outbreak of the Third Anglo-Dutch War although it was used unofficially at the start of the Second Anglo-Dutch War (Konstam 2011, 14).

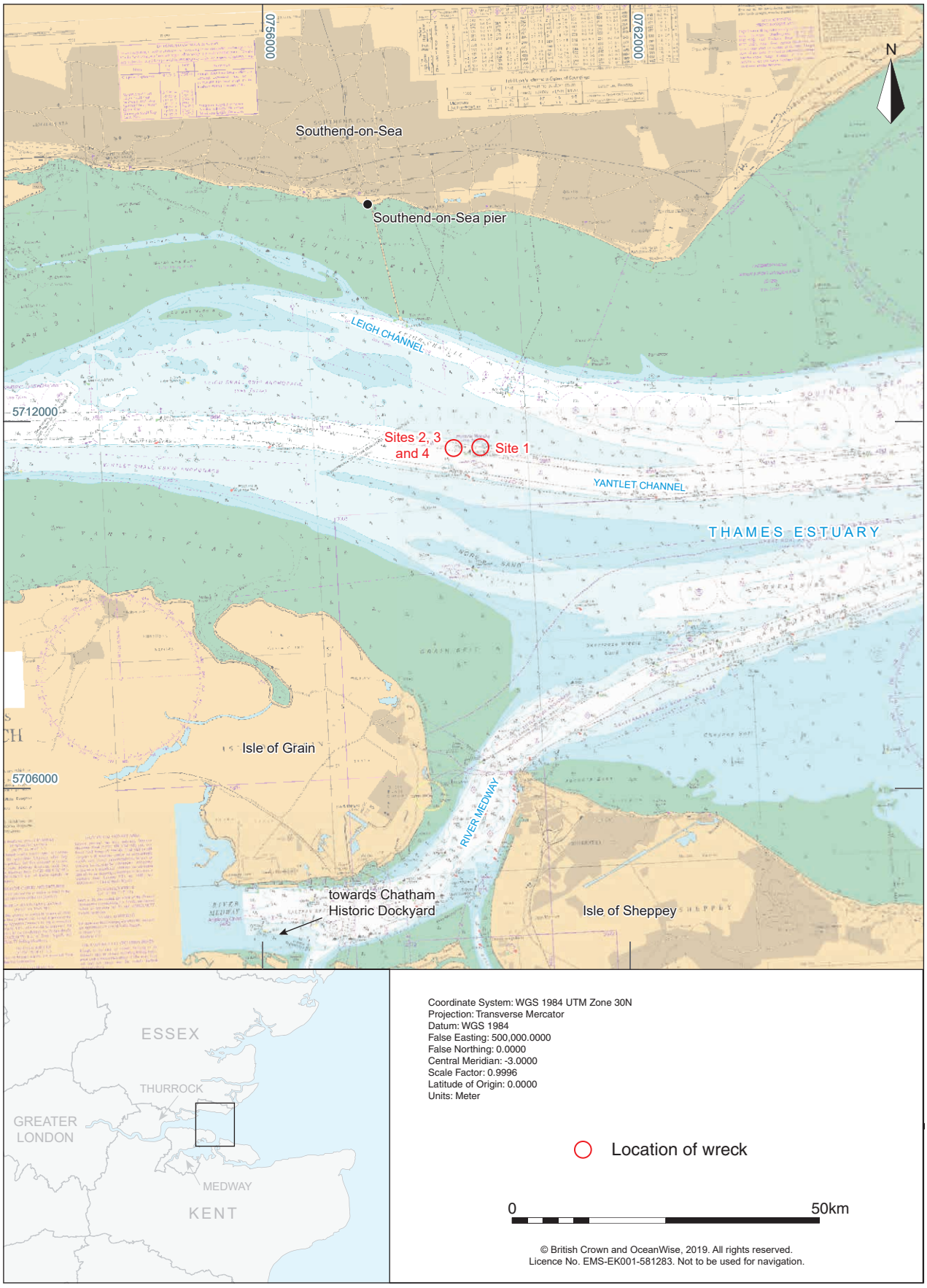


Figure 1.2 Site location (© Historic England)

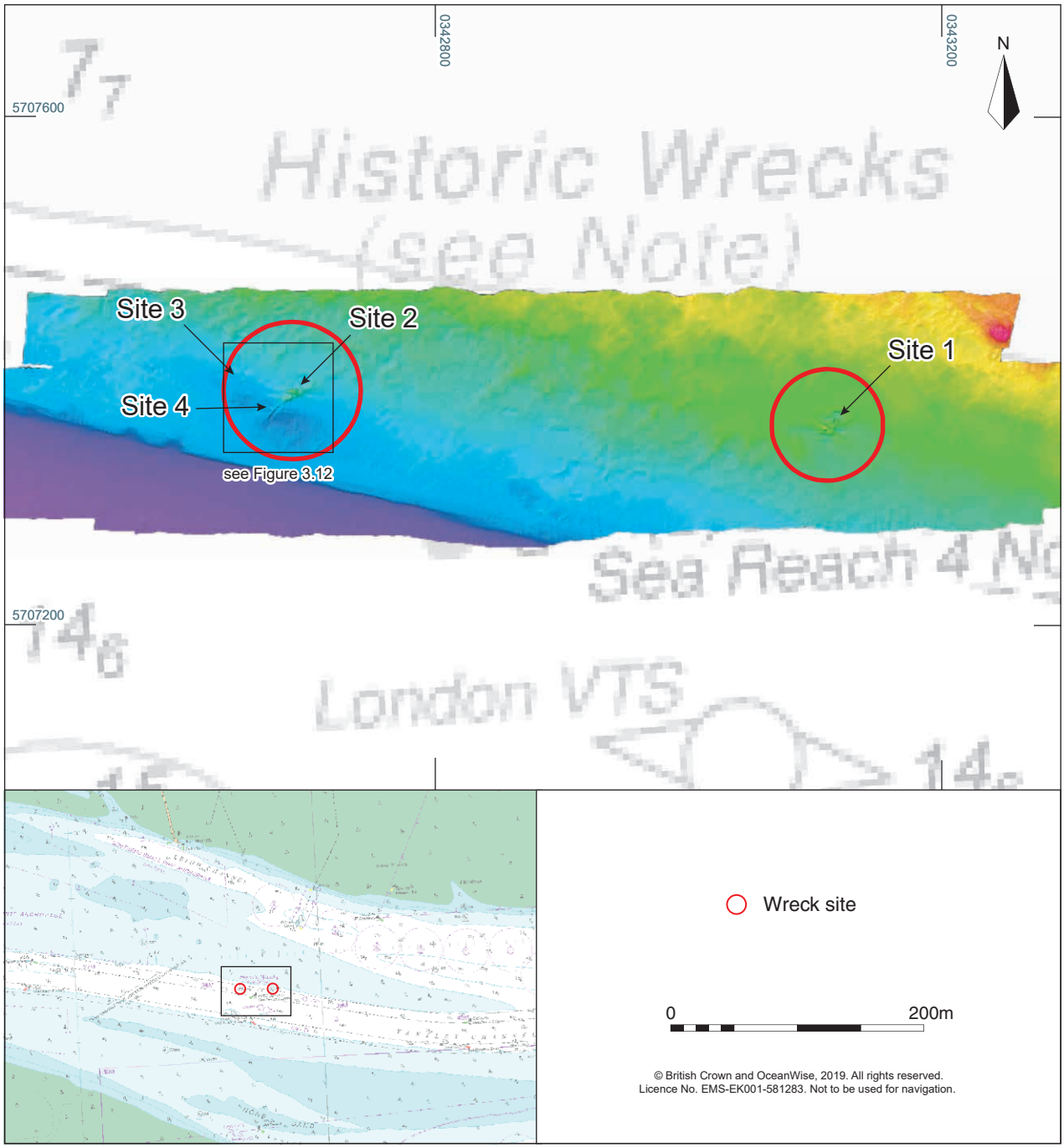


Figure 1.3 Bathymetric data showing sites S1, S2, S3 and S4 (© Historic England)

material. The wreck contains various elements including structural timbers, artefacts, cannon and human remains. During fieldwork in 2014, 2015 and 2016, which involved a collaboration between Historic England, Cotswold Archaeology, licensee divers[2], Southend Museum and local volunteers, more than 700 objects were recovered from the seabed, either under surface recovery or excavation licences.

This volume follows the completion of post-excavation conservation, assessment and analyses on the *London* site, its recovered finds and biological specimens. It briefly summarises the excavations that were undertaken and then reports the conservation results and assessments and analyses undertaken by specialists. The excavations and the methods by which the conservation and assessments were undertaken are summarised below; detailed accounts can be found in previous reports (Cotswold Archaeology 2016; 2017a). There have been a number of developments since the project's inception, including the publication of *People and the Sea: Maritime Archaeological Research Agenda for England* (Ransley *et al.* 2013) and updates to the *London*

2. Since 2012, the licensee team, lead by Steve Ellis, have recovered artefacts deemed at risk under the terms of a surface-recovery licence. Their request to Historic England to excavate a test pit to examine the wreck site led to Cotswold Archaeology's involvement.

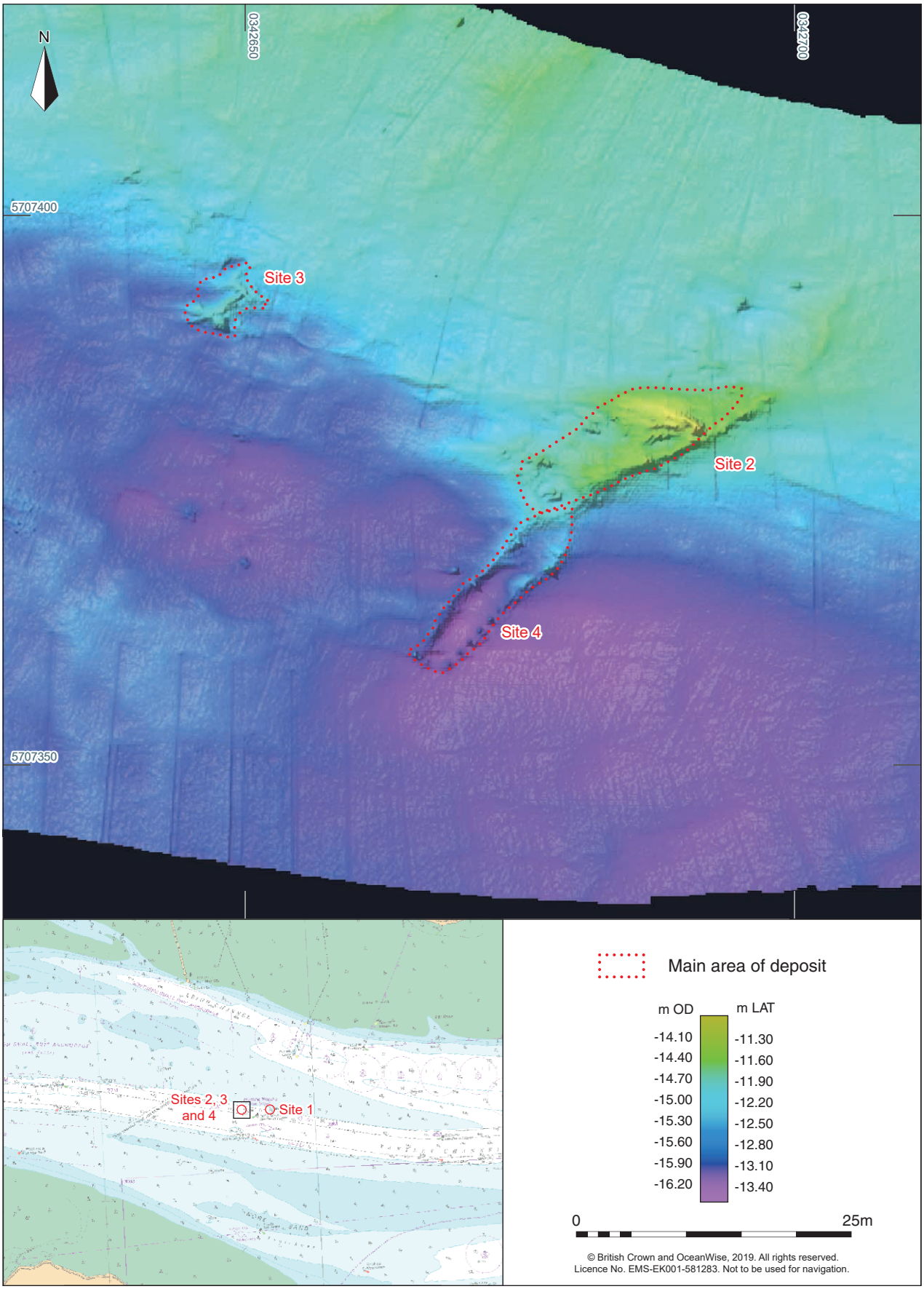


Figure 1.4 Close up of bathymetric data showing S2 (© Historic England)

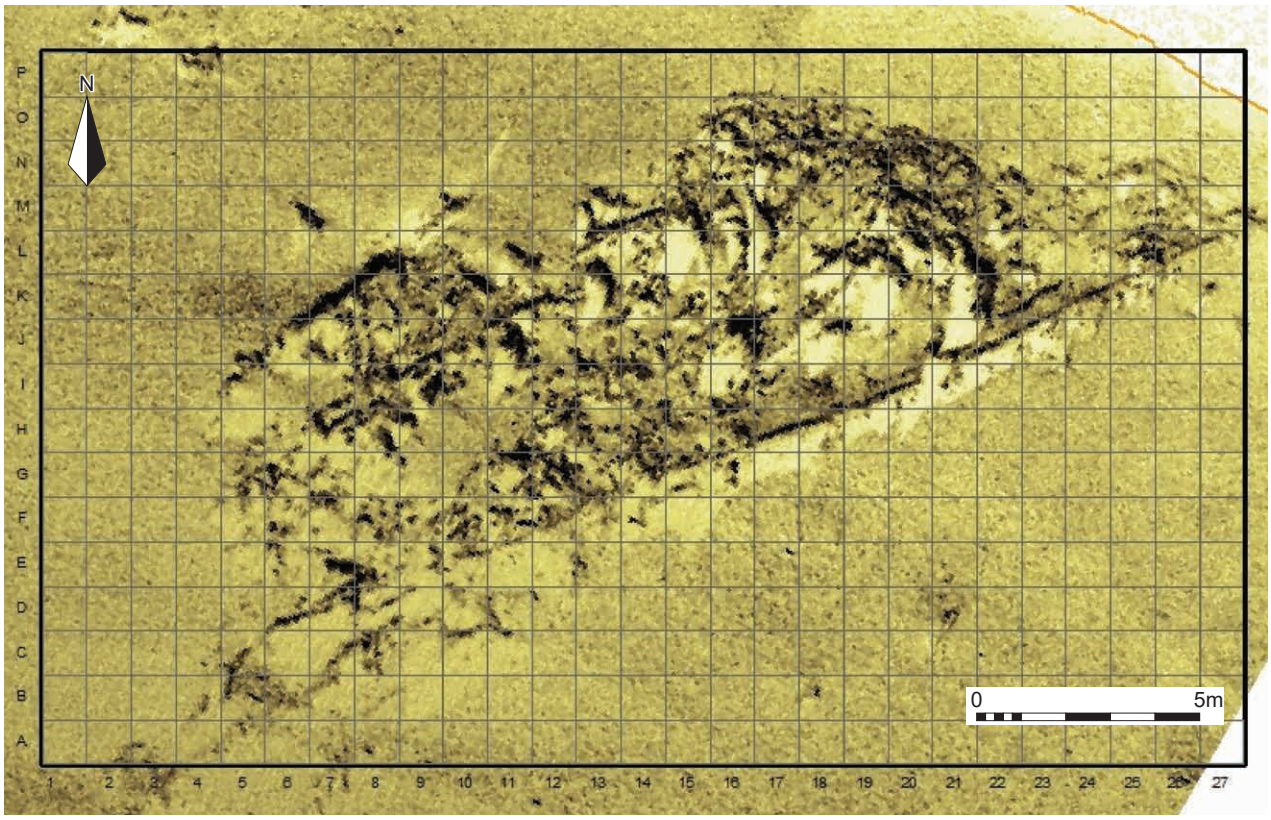


Figure 1.5 Site grid superimposed over a multibeam and sidescan sonar image of S2 (© Historic England)

Conservation Statement and Management Plan (Cotswold Archaeology 2017a). Key aims set out within these documents complement the original aims of the project.

Publication of the results of the investigations on the *London* illustrates the methods and great benefits of a collaboration between disparate interested groups, including the national curator (Historic England), professional archaeologists (Cotswold Archaeology), the licensee team (Steve Ellis, Carol Ellis and Steve Meddle), finds and conservation specialists, the local museum and local volunteers. The licensee team underwent HSE self-contained underwater breathing apparatus (SCUBA) training, partly funded by Historic England, in order to fully participate with the dive team during the excavations. This project not only provides a useful comparison with the excavation of the similarly dated Cromwellian Duart Castle warship (Martin 2017) but also provides a useful contrast with the *Mary Rose* which sank in 1545, 120 years earlier.

Over the course of three years' (2014–16) evaluation, survey and excavation work was conducted on the wreck site. The 'wreck site' comprises four elements:

- Site 1 (S1): the easternmost section of the *London* (Fig. 1.3);
- Site 2 (S2): the westernmost section of the *London* – the site on which the most recent excavations were conducted (Fig. 1.3 and 1.4);
- Site 3 (S3): wreckage to the west of Site 2 containing the remains of a later vessel (Fig. 1.3 and 1.4), and
- Site 4 (S4): later wreckage abutting Site 2 to the south (Fig. 1.3 and 1.4).

The excavations focused on four trenches on S2, which provided detailed insights into the wreck, its survival and its significance. Three evaluation trenches were opened during 2014 and excavation continued in 2015 and 2016, when a fourth trench was excavated.[3] In total more than 700 artefacts were recovered, both through the excavation of the trenches and through collection by the licensee team under the terms of a surface-recovery licence. These artefacts include personal items, coinage, navigational instruments, medical instruments, domestic items, tools and equipment, weaponry, gunners' implements and a well-preserved gun carriage, recovered amid considerable media attention in August 2015.

To aid with the identification of the locations from which surface finds were recovered, a virtual 1m x 1m grid was superimposed over a bathymetric image of S2 (Fig. 1.5). Finds were then located within a 1m² square using a two-digit alphanumeric reference. This system was used only to locate surface finds; finds from excavations are referenced by the trench from which they were recovered.

Although only a fraction of the site has been excavated, on-site observations combined with specific artefact distribution

3. A marine licence issued under Part 4 of the Marine and Coastal Access Act 2009 was acquired and work has been conducted in line with the requirements under the Protection of Wrecks Act 1973 and the Merchant Shipping Act 1995.

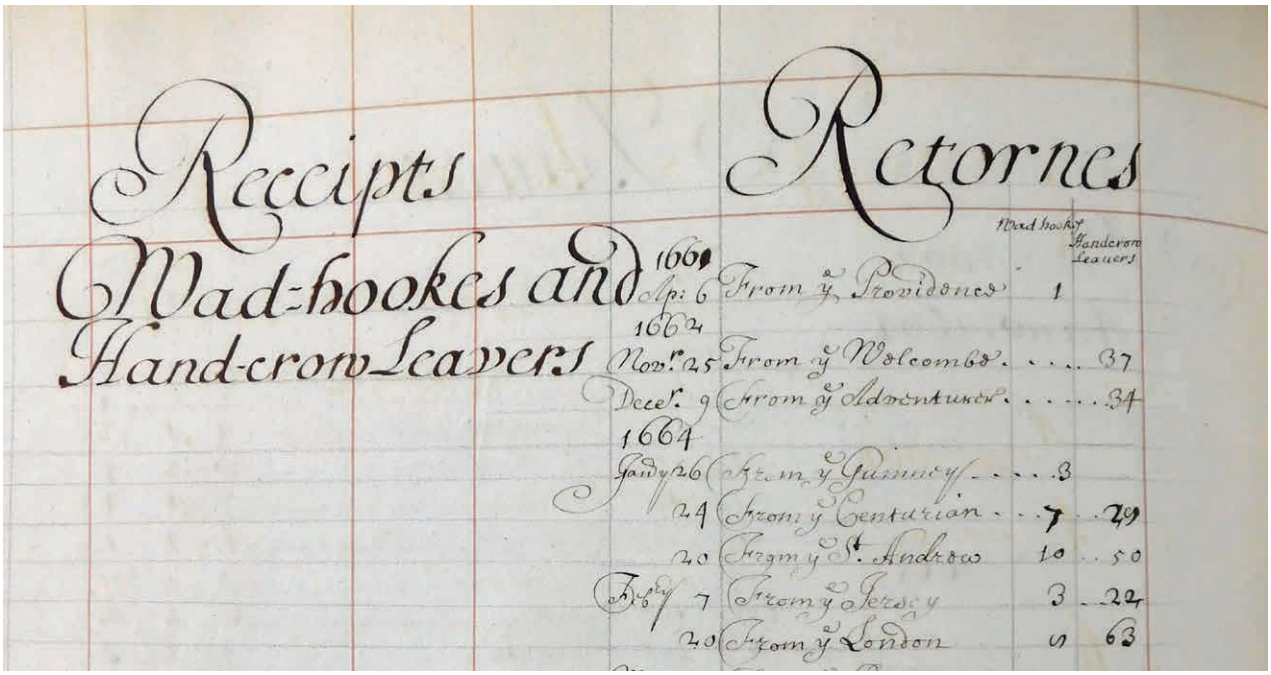


Figure 1.6 An entry in the Chatham Ledger recording the return of 63 'hand crow levers' from the London *on 20 February 1665 (last entry) (TNA WO55/1667 © TNA, photograph Michael Walsh)*

analysis has enabled description and interpretation of parts of the vessel, its construction, use and loss. One of the key aspects is the close dating of the assemblage, as would be expected from the excavation of a known ship whose date of loss is well recorded. This affords the ability for many items to contribute to our understanding of chronological changes in artefact typologies and technologies.

The wreck of the *London* provides a rare archaeological resource for understanding this period in the history of the Navy and illustrates why Samuel Pepys fought hard for a professional navy in the last quarter of the 17th century. The reported absence of officers, possible evidence of a lack of discipline on board, and the explosion itself are strong arguments for the subsequent introduction of tests for potential officers and the need for standardisation.

Warships of the 17th century are well represented in UK waters, including such vessels as the aforementioned Duart Castle wreck (1641–53), the *Dartmouth* (1655–90), the *Anne* (1678), the *Restoration* (1678), the *Stirling Castle* (1679), the *Northumberland* (1679), the *Coronation* (1685) and the *Eagle* (1696). Much is still unknown, however, about many of these ships and life on board, owing either to a lack of archaeological attention or to the highly dynamic environments in which they lie. The work on the *London* has therefore provided an excellent opportunity to improve our knowledge and understanding of life on board ships of this period.

Although only a small section of the ship has been excavated it revealed that intact areas of the ship survive, protecting a huge assemblage of artefacts. This assemblage is significant archaeologically as it is extremely rare to find these artefacts together and in their original context, and in such good condition. As the ship had just been revictualled at Chatham it was undoubtedly heavily laden with stores and provisions, which explains the wealth of onboard material culture and the tremendous potential of the wreck site.

In particular the opportunity to study such a concentrated and complete collection of firearms equipment, for example, the bandoliers, with both wooden and leather components is rare. A key facet of their significance is the contextual and associative relationships between the bandoliers and other military remains recovered from the same area (in and around the chest in which the bandoliers were found). The chest itself was not recovered.

The high degree of preservation and cohesion of the remains and their distribution in a small area of the vessel offer insights into the final actions of those on board the *London* in the moments prior to its loss, providing a snapshot of life on board the ship. Comparisons with the Chatham Ledger (TNA WO55/1667), as an historical inventory of equipment on board the *London*, also provides insights into provisioning.

Some brief notes on terminology

The Chatham Ledger (TNA WO55/1667), an extant contemporary document, contains detailed records of most of the ordnance and stores that were reloaded following refitting work just two weeks before the disaster that befell the ship. Unless otherwise stated, reference throughout this volume to items issued to the *London* refers to the items listed in the Chatham Ledger that were issued on

23 February 1665.[4] Terms used in the Chatham Ledger for items issued to the ship, such as hand crow levers (also known as hand spikes, Fig. 1.6) or priming irons (which were made of copper alloy), will be used throughout this volume.

For items not recorded in the Chatham Ledger, such as powder boxes (also known as powder cartridges, chambers, bottles or 'apostles' (the latter an apocryphal term)), the nomenclature used in the publication of a Cromwellian warship wrecked off Duart Castle (Martin 2017) will be adopted. At the time of the sinking all copper-alloy (bronze) guns were referred to as 'brass' (Fox 2012, 59). To avoid confusion, except in verbatim quotations, 'copper alloy' will be used henceforth as a catch-all term to refer to all items made of bronze, brass, gunmetal or their derivatives. Similarly, 'iron' will be used to refer to all forms of wrought iron (plain and alloys; see Historic England 2015; Pleiner 2006). Where specific terminology is used the metallurgy of the object under discussion has been determined through analysis.

Many of the finds and structural features are accompanied by both metric and imperial measurements for greater ease of comparison with existing sources, both historic and modern. All dates are *anno domini* (AD).

Although more than 700 items were recovered, the precise number of objects represented does not correlate with the original number of registered finds/small finds numbers. This is because each item was numbered as it emerged from the water prior to any assessment or interpretation. Consequently, in some instances, such as the concretion of coins (Fig. 1.7), a single finds number (3382) was assigned to an item that subsequent analysis has revealed contained hundreds of coins. Conversely, some fragmented finds that comprised one object, such as the urethral syringe, were found in several pieces that were each assigned a small finds number (3394 to 3396). Thus the total number of finds, overall or in individual categories, is not easy to ascertain.



Figure 1.7 Concreted lump of coins (3382; © Historic England Archive, photograph James O. Davies)

A note on the artefacts

Some of the artefacts are examined in more than one chapter but they are cross-referenced. Further details may be found in the archive at Southend Museums and the online Historic England Research Reports (https://historicengland.org.uk/research/results/reports/).

4. The year of issue is recorded throughout the Chatham Ledger as 1664. This is because, until the adoption of the Gregorian calendar by England in 1752, the new year began on Lady's Day, 25 March; the modern financial year-end is a legacy of this anomaly. So, although the date of issue is recorded in the Ledger as 23 February 1664, in modern parlance the date was 23 February 1665. To avoid confusion, in this volume modern dates have been used throughout. https://www.nottingham.ac.uk/manuscriptsandspecialcollections/researchguidance/datingdocuments/juliangregorian.aspx (accessed 3 September 2025).

Chapter 2
Setting and Site Condition

Michael J. Grant and Justin Dix

Setting

Sites 1 (S1) and 2 (S2) lie in the outer Thames Estuary, approximately 2.4km south-east of Southend Pier (see Fig. 1.2). The wreck is located on the northern edge of the main shipping channel, the Yantlet Channel, within the inbound Yantlet secondary channel. This area is known as Sea Reach, with the sites located just north of the Sea Reach 4 North channel buoy. The seabed in the Yantlet Channel is approximately 14.6m below lowest astronomical tide (LAT), rising to 12–10m below LAT in the secondary channel, with the muds to the north, separating the Leigh and Yantlet Channels, rising to around 5.5m below LAT.

The Thames Estuary is macro-tidal with a mean spring tide range of 5.2m at Sheerness, gradually increasing upstream as a result of the funnelling effect of the estuary and the extent of intertidal land claim. Historically the Thames Estuary has experienced an elevation in high water levels; Rossiter (1969) and Bowen (1972) demonstrated that between 1934 and 1966/69 there were increases in mean high water (MHW) and mean low water (MLW) at Southend-on-Sea, with tidal range increasing 1.0 to 1.1mm per annum over this period.

Generally, tidal currents in the Thames Estuary show an increasing degree of asymmetry in an upstream direction, although this is complicated locally by the large tidal prism at the confluence of the Medway and Thames Estuaries. Overall the sediment transport environment tends towards depositional features in the outer Thames Estuary. Modelling of the wave regime (Wallingford 2002) demonstrated that wind action was the main wave generation process in this part of the Thames Estuary. Offshore waves dissipated over the outer Estuary banks and wide intertidal flats before reaching Sea Reach, leading to relatively small overall wave heights (Wallingford 2004).

The characteristics of the main subtidal channel bed sediments in the Sea Reach area generally comprise sand, with the adjacent intertidal flats characterised by sediment with high sand content owing to the winnowing action of waves generated locally and those that propagate in the North Sea. In 2011 the seabed at the wreck site was recorded as comprising a thin silt veneer overlying fine sand, with a firm layer of gravelly sand in areas of scour.

This sedimentary sequence is confirmed by borehole data from the area (Soil Mechanics 1966). These show a consistent pattern of Holocene estuarine silty clays and sands, occasionally with thin peat horizons, typically measuring 2.5–3m thick along the secondary outward Yantlet Channel. These increase to more than 3.5m thick east of Sea Reach and on the adjacent flats north and south of the channel. These in turn overlie Pleistocene sands and gravels, often more than 3m thick, that rest on the underlying London Clay geology.

The Thames Estuary has provided a national gateway port since the Roman period. Access was maintained despite encroachment through land claim and wharf construction works, although some dredging was necessary by the early 19th century, principally to lower shoals in the main channels but also to provide a source of ballast. From 1857, when the Thames Conservators (historically, a body responsible for the management of the River Thames) was founded, dredging activity in the Thames increased to maintain and improve the main navigation, ensuring the safe passage of new classes of commercial shipping, whose drafts were both wider and deeper. Between 1878 and 1908 approximately 4.5 million cubic metres of solid material was dredged to improve navigation. This included capital dredging in *c.* 1908 to develop the Yantlet Channel as the main shipping channel in the Lower Sea Reach, with the dredged material redeposited in the adjacent Leigh Channel (Roberts *et al.* 2014).

A second capital dredging campaign was completed by 1928; since then dredging in the Thames has been associated primarily with maintaining water depths. During the development of DP World London Gateway, however, substantial capital dredging was undertaken for the berth pockets, the manoeuvring area and the approach channels, amounting to around 31.35 million cubic metres. The main navigation channel was deliberately moved south in order to avoid the *London* wreck site. While maintenance

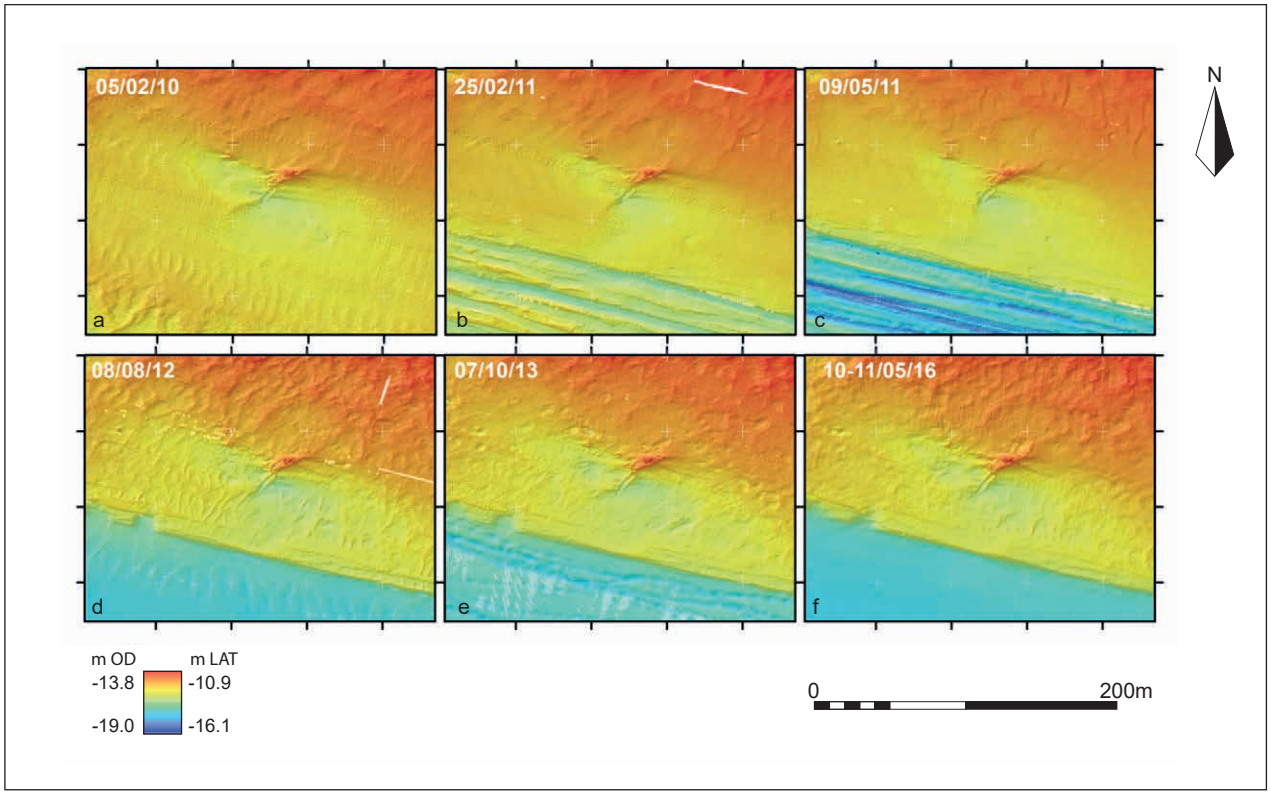


Figure 2.1 Bathymetric data collected from S2 (centre of image) over six years (2010, 2011, 2012, 2013 © PLA and 2016 © Cotswold Archaeology)

dredging since the completion of the capital dredge campaign has been minimal, it is estimated that dredging of up to 250,000 cubic metres may be required from the navigation channel, mostly in the Sea Reach area (Roberts *et al.* 2014).

Site evolution processes and monitoring

Mitigation work, undertaken between 2006 and 2013 by the Port of London Authority (PLA) for the capital dredging associated with the London Gateway scheme, has included monitoring surveys of the *London* designated areas (Wessex Archaeology 2011; Firth *et al.* 2012). The data from these monitoring surveys have been used to guide diver surveys and to inform management reports undertaken for Historic England under the Contract for Archaeological Services in Relation to the Protection of Wrecks Act 1973. The initial surveys, conducted in 2006 and in 2010, were undertaken prior to the commencement of dredging and have been used as a baseline for subsequent analysis and reporting of post-dredging surveys (2011–13). Cotswold Archaeology (2017b) was commissioned by Historic England and Southend-on-Sea Borough Council to undertake the most recent geophysical surveys of the site (Fig. 2.1).

The bathymetric data collected by the PLA (surveys undertaken in 2010, 2011, 2012 and 2013) and by Cotswold Archaeology (2017b) over a number of years at S2 (the prominent feature in the centre of each panel in Fig. 2.1) provides a useful comparator as the field of view is identical in each panel so the evolution of the deep water channel is clearly demonstrated.

The first panel (a) shows data collected in February 2010 before any dredging had taken place. The next two panels from February (b) and May (c) 2011 show the dredging in progress (the pale blue tracks to the south of the site), while the lower three panels display the completed channel (the pale blue area to the south of the site). It appears from these data that there was some minor dredging between August 2012 (d) and October 2013 (e) but again the system had recovered by the time of the next survey in May 2016 (f).[1]

Flow perpendicular bedforms in both the channel (2012; d) and on the channel margin (all panels) are oriented N–S/NNE–SSW, which suggests that sediment transport is parallel to the channel margin, i.e. an ESE–WNW orientation. Scour associated with both sides of the wreck conforms to this orientation, although scour tends to develop more consistently to the ESE, which suggests

1. The depths on these charts differ from the average depth stated in the opening paragraph as these illustrate the maximum dredging depth, whereas Admiralty charts provide the average channel depth under normal conditions (once some infill and channel stabilisation after dredging has ended).

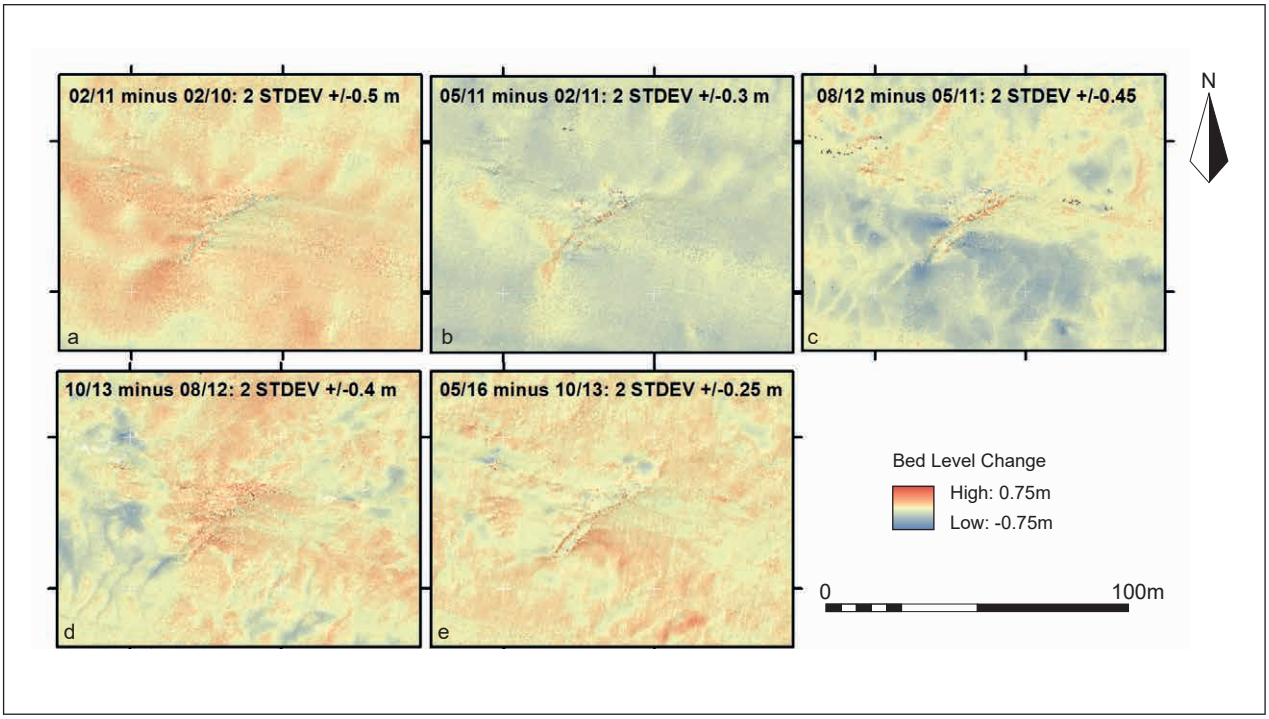


Figure 2.2 Illustration of bed level change on S2 over five years (2011, 2012, 2013 © PLA and 2016 © Cotswold Archaeology)

that sediment transport may be slightly dominant in this direction.

Preliminary assessments of these datasets suggest that until 2013 the site dynamics on both S1 and S2 were generally stable to accumulative over the six-year period, with intermittent scouring and subsequent refilling in a west to east direction and isolated scouring associated with upstanding wreck features (Cotswold Archaeology 2017b). Inter-annual comparisons, however, show higher site-dynamism, with scour extension and contraction and bedform migration around the sites.

Analysis of these datasets, which span several years, has identified a number of key features. As would be expected the dominant seabed mobility is aligned with the dominant currents in the outer Thames Estuary, running east–west parallel to the dredged channel. It appears from the comparison of bed level change (see Fig. 2.2) that the top 200–300mm of seabed sediment is mobile. It is worth noting, however, that the total bed level change variation is only a maximum of +/- 0.75m and in fact the mean bed level change is zero in each plot with movement over two standard deviations of < +/- 0.5m.

The bathymetric data demonstrates clearly that the dredged channel (the angled pale blue (deeper)) area to the south of the site in Figure 2.1 appears to have had little or no impact on sediment mobility. Note, for example, the distinct and well-defined edge of the dredged channel which shows little or no sign of degradation owing to seabed mobility.

There is, however, little comparative seasonal data over one year; the two surveys in 2011, for example, were conducted in February and May with no comparative data from summer, autumn or early winter. Neither is there comparative data from different tidal states, such as from spring or neap tides.

The licensee team has observed and recorded the shorter-term sediment movement across the site during their monitoring dives (e.g. Ellis 2012, 2015) which they suggest may be causing general site instability. In May 2012 the licensee team installed control points on the wreck to monitor sedimentation and erosion. The control points consisted of upright silt-level monitors, comprising 10cm black and white segments, placed to the north of S2 on the outside of the wreck. At the same time numbered yellow survey tags were placed across the inside of the wreck.

Observations by the licensee team suggest that there was little movement of silt around the upright control points placed outside the wreck area, while the silt levels within the wreck seemed to fluctuate between spring and neap tides, with some areas suffering from localised erosion. Many of the yellow survey tags were lost owing to a combination of corroded fixings and deterioration of the fixing points on the wreck (S. Ellis pers. comm.).

A human cranium and other vulnerable items, adjacent to a small timber frame inside the northern edge of the wreck (survey tag 2035) were observed to be covered and uncovered by the silt, supporting the hypothesis that deposition fluctuates between tides. All items were deemed to be at risk so their locations were recorded and the items recovered by the licensee team. A complete large wooden cask, recorded by digital video eroding from the seabed in 2012, was much eroded when filmed again in 2016; all

that remained of the cask were a few staves with another cask emerging from the silts beneath. Another area of scour in the vicinity, which was detected in the 2016 bathymetry data, had uncovered other artefacts including shoes, leather book covers and a complete bottle (S. Ellis pers. comm.).

This appears to confirm the results of earlier assessments which found that 'up to 2013 the depositional environment on S2 was generally stable to accumulative, with intermittent scouring in a west to east direction and isolated scouring associated with upstanding wreck features. These patterns appear to have been in evidence before dredging commenced. Although the seabed within the S2 designated area appears to be generally stable, it is the scour associated with exposed parts of the wreck which is of greatest concern as these are the most vulnerable parts of the wreck' (Cotswold Archaeology 2017b).

Recent studies and licensee reports indicate that patterns of sediment accumulation and loss on S2 may fluctuate, with localised areas of erosion and sedimentation (Cotswold Archaeology 2017b). Sediment transportation and near-bed flow dynamics have been observed to affect the remains of the wreck, leading to the dissipation and/or loss of artefacts and exposure of the ship's structure to deterioration from erosion and marine organisms, factors which are already at work on the site (Cotswold Archaeology 2017b).

Chapter 3
Historical and Naval Background

Michael Walsh

The wider historical context

by Darren Glazier and Michael Walsh

It is little exaggeration to describe the middle of the 17th century as one of the most significant periods in the history of modern Britain. It was a period of great social unrest, political upheaval and natural disaster, yet it also witnessed the foundation of the Royal Society and the flourishing of the dramatic and literary arts. Most strikingly, perhaps, it was a period dominated by wars, both at home and abroad; wars that resulted in the execution of a monarch and prolonged conflict between the mercantile powers of northern Europe.

The loss of the *London* was the first of a series of calamities that befell England, and especially London, in the middle of the 17th century that resulted in significant loss of life and property. These catastrophes included the Great Plague (1665) and the Great Fire (1666), and culminated in the infamous Dutch raid on the Medway (1667). This, coupled with the appearance in the night sky of a great comet,[1] presaged a sense of 'ill-boding' for the city and for England:

> *In the first place, a blazing star or comet appeared for several months before the plague, as there did the year after another, a little before the fire…those two comets passed directly over the city, and that so very near the houses that it was plain they imported something peculiar to the city alone…I was apt to look upon them as the forerunners and warnings of God's judgements; and especially when, after the plague had followed the first, I yet saw another of the like kind, I could not but say God had not yet sufficiently scourged the city.*
> (Defoe 1992, 29)

The English Civil Wars and the Restoration[2]

From August 1642 the First Civil War raged within the three kingdoms of England, Scotland and Ireland until the surrender of Charles I to the Scots in May 1646 marked its end. From 1646 to 1648 the division between Army and Parliament widened until the combined forces of the Presbyterian party, the Scots and the remaining Royalists rose, resulting in the outbreak of the Second Civil War. This nascent Scottish Royalist army, however, was routed by Cromwell's Parliamentary forces at the Battle of Preston in August 1648, leading ultimately to the execution of the monarch on 30 January 1649.

Yet the execution of Charles I served merely to galvanise Royalist support. His son, the future Charles II, was crowned king of Scotland in January 1651 and raised a force that was soundly defeated by the New Model Army at Worcester to end the Third Civil War (1649–51).[3] Charles was forced to flee into exile, first to France, later to Spain and then, ironically given later events, to the Netherlands.

For the next seven years the newly formed Commonwealth of three kingdoms was dominated by Oliver Cromwell, first as a member of the Rump Parliament, then as Lord Protector. His death in 1658 and the succession of his son Richard left a power vacuum at the heart of the Commonwealth, which swiftly fell into financial and administrative chaos. In May 1659 the Army intervened, before it too descended into factionalism (Keeble 2002, 34), which resulted ultimately in the restoration of the Stuart monarchy.

It is interesting and relevant to consider the loyalty of the armed forces throughout the period of the Civil Wars, the Interregnum and the Restoration. It certainly appears that neither the Army nor the Navy had difficulty in serving different masters during the Commonwealth and the Restoration. This may, at least in part, have resulted from the restructuring of both the Army and the Navy under

1. Also recorded in Pepys' diary, 15 December 1664 (Latham 1996b, 113).
2. Though traditionally known as the English Civil Wars, this is something of a misnomer. Indeed, it might be more accurate to refer to this period as the 'British Wars' (www.nam.ac.uk/explore/british-civil-wars; accessed 3 September 2025) although even this does not reflect the broader impact of the conflict: none of the three kingdoms were left untouched by the wars between the Stuart monarchy and Parliament.
3. www.nam.ac.uk/explore/british-civil-wars (accessed 3 September 2025).

Cromwell and the subsequent promotion of officers on merit (the so-called tarpaulin officers, which included Vice-Admiral Lawson, the captain of the *London* (see below). It may also reflect a desire to avoid another vicious civil war. It is important to recognise the psychological toll that successive civil wars had on the individuals who fought them. Far easier to unite the nation against a foreign enemy in the Dutch (the three Anglo-Dutch Wars) or the Spanish (Anglo-Spanish War).

This ability to transfer loyalties is exemplified by George Monck, a key figure in both the Royalist and Parliamentary forces of the 1640s and 1650s.[4] Monck's refusal to join the Army after the declaration against Parliament in 1659, and his subsequent elevation to Commander-in-Chief of Parliamentary forces, bloodlessly united different factions, with the Navy and the majority of Army garrisons swiftly declaring allegiance to Parliament.

Similarly, Vice-Admiral Lawson had been a staunch supporter of the republican movement and the Commonwealth cause, for which he had been imprisoned and exiled. Following Cromwell's death, when radical elements of the Army took control of government, Lawson used the ships under his command to blockade the River Thames on 13 December 1659 in a desperate attempt to restore a Commonwealth government. The first page of Samuel Pepys' famous diary, begun early on 1 January 1660 (Latham 1996a, 1), records how army officers were forced to yield while 'Lawson lies still in the river'. Three months later, Lawson (as the captain of the *London*) participated in the fleet that brought the future Charles II back from exile (Blanchard 2017).

An eagerness to forget the Civil Wars and the promise by Charles II, in the Declaration of Breda, to pardon crimes committed against the Royalist cause, encouraged Parliament retrospectively to declare Charles II lawful monarch in England from 1649. This was in essence a legislative attempt to reimagine the Interregnum and to ensure a seamless transfer of loyalties back to the Crown.

By 1649 the Dutch fleet had become the dominant naval force in Europe, largely through the need to oversee and protect their developing global trade routes. By 1652 in Europe only England and the Dutch Republic had sizeable battle fleets. While the Dutch had established control of the Spice Islands, English merchants had established themselves on the coast of India (Milton 1999). But Dutch naval dominance posed a threat to the expansion of maritime trade and as mercantile rivalry increased so too did tensions, resulting in the First Anglo-Dutch War (1652–4), fought to establish naval and thus economic dominance over trade routes. Dominance of the seas, however, was not achieved by either side in this conflict, resulting in the Second (1665–7) and Third (1672–4) Anglo-Dutch Wars. Unusually, and for the first time in the modern era, these wars were fought almost exclusively at sea (Konstam 2011, 5).

The First Anglo-Dutch War (1652–4) and its aftermath

The end of the English Civil Wars in 1651 did not preface a period of peace in the 1650s. Rather, it simply shifted the focus of the Commonwealth from internal conflict to conflict on the wider international stage. By the middle of the 17th century the mood in England had grown increasingly hostile towards the Dutch, as typified by George Monck in 1652, 'the Dutch have too much trade, and the English are resolved to take it from them' (Kennedy 1976, 48). This hostility was caused at least in part by the aggressive free trade policies and economic expansionism of the Dutch mercantile classes.

This was epitomised by the Dutch East India Company (*Vereenigde Oost Indische Compagnie* or VOC) and their conquest of the spice-rich former colonies of the Portuguese. Trouble had been brewing between the English and the Dutch over control of the Spice Islands since the early 1600s (Milton 1999). By the 1650s the Dutch had more merchant ships than all other trading nations combined (Israel 1995). Existing economic tensions were exacerbated by the end of the Thirty Years War (1618–48); the resultant rush to Empire saw clashes between Dutch and English traders across the globe (Groenveld 1987; Israel 1995). This culminated in the passing of the Navigation Act in England in 1651, which effectively limited Dutch trade with English colonies in north America (Coward 2002).[5]

It is too simplistic, however, to suggest that the cause of the First Anglo-Dutch War was purely economic. Officially, the United Provinces of the Netherlands, eager to minimise the impact on trade, had maintained a policy of neutrality during the English Civil Wars. In reality, however, the Dutch *stadtholder*,[6] Frederik Henry, provided significant financial support to the armies of Charles I, while continuing to negotiate with both Royalists and Parliamentarians (Rowen 1990).

The situation was further complicated by the succession to the stewardship of Henry's son, William II of Orange. William was the husband to Charles I's eldest daughter, Mary. The vociferous support offered to the Royalists led to unease amongst republicans in the Netherlands and an increasingly hostile atmosphere in the English Parliament (Groenveld 1987). The causes of the First Anglo-Dutch War are therefore more accurately described as economic and political. Although the Dutch states appeared unwilling (or perhaps unable) to quash pro-Stuart Orangist factions, it is unlikely that the English would have gone to war were

4. A complex character, Monck fought with distinction for both the Royalists and Parliamentarians in the English Civil Wars, and as a General-at-Sea in the First Anglo-Dutch War. He later served as Cromwell's Commander-in-Chief of the Scottish Army and as Governor in Scotland.
5 It is also important to note the role of English privateering, sanctioned by the State, in disrupting trade and increasing economic hostilities between the Commonwealth and the United Provinces. In January 1652 alone, 30 Dutch ships were seized by English privateers (Israel 1995).
6. Or steward – the nominal head of the United Provinces.

they not also keen to impose restrictions on Dutch trade and sovereignty (Israel 1995).

The Navy that fought the First Anglo-Dutch War had changed considerably since the time of Charles I. Internal divisions in the First and Second Civil Wars had severely weakened it, which enabled Cromwell to undertake an ambitious restructuring plan in the late 1640s. This restructuring, ostensibly designed to continue the fight against Royalist factions in the colonies, had resulted in a Navy with a greater number of larger, more powerful ships than the Dutch, with officers promoted on merit rather than hereditary right (Israel 1995). Indeed, despite their mercantile supremacy, at the beginning of the 1650s the Dutch had fewer than 50 seaworthy warships, all of which were inferior to their English counterparts (Brujin 2016).

It is nevertheless true that the outbreak of hostilities might have been avoided had it not been for an unfortunate encounter in late spring 1652 (Groenveld 1987). An ordinance from Cromwell dictated that any ship in the North Sea or English Channel should dip their flag in salute to the long-held English claim of 'sovereignty of the seas'. Escorting a Dutch merchant convoy in May 1652, Lieutenant-Admiral Tromp failed to comply when in sight of the English fleet positioned just off Dover. Rankled by this perceived slight, General-at-Sea Blake opened fire on the convoy, which resulted in the Battle of Goodwin Sands. Although Tromp lost two ships, the majority of his convoy was escorted to safety. Less than six weeks later, on 10 July 1652, the English Parliament declared war on the United Provinces of the Netherlands.

The First Anglo-Dutch War (1652–4) was exclusively a naval conflict. Despite the English dominance in large warships, the arming by the Dutch of swifter, more agile merchant ships resulted in successful skirmishes and raids on the English fleet. Indeed, it was not until the publication of Robert Blake's *Sailing and fighting instructions* in 1653, which contained the first formal description of the line-of-battle formation (Palmer 1997) that the English began to assert a dominance in naval battles, culminating in the Battle of Scheveningen in August 1653. Lessons learned by the English following the First Anglo-Dutch War had influenced the design of warships, as manoeuvrability was sacrificed for greater firepower (Konstam 2011, 12). The *London* was a product of this new thinking.

It is, however, important to recognise the significance of privateering throughout the conflict. It has been suggested that the Dutch lost more vessels in the First Anglo-Dutch War (around 1000–1700) to privateers than in the Second and Third Wars combined (Davis 2012, 12–13), while increased attacks on English merchant ships in the winter months of 1653 left both economies significantly weakened (Israel 1995). It is also true that by 1654 Cromwell's attention had been diverted to Catholic Spain and the rich pickings of her colonies in the Caribbean and the Americas.[7] Both sides were therefore keen to bring to an end a conflict that was increasingly damaging to their economic interests, at home and in their colonies.

The Treaty of Westminster, signed on 1 April 1654, marked the official end of hostilities between the two nations. Cromwell's sole condition was that no Prince of Orange should be able to hold high office in the Netherlands; a stipulation deemed so controversial that it was only included as a secret annexe. It was therefore agreed that the English Parliament would delay ratification of the treaty until the Dutch passed the Act of Seclusion in May 1654 (Rommelse 2006, 26). The Secret Annexe would prove crucial in the lead up to the Second Anglo-Dutch War, some 11 years later.

The build-up to the Second Anglo-Dutch War

It is argued traditionally that commercial maritime rivalries led to the outbreak of the Second Anglo-Dutch War (1665–7; Rommelse 2010). It is certainly true that the Treaty of Westminster did little to resolve economic tensions between the two nations, not least in the battle for control of the lucrative spice trade and clashes between the dominant VOC and the British East India Company (see Milton 1999). It is again too simplistic, however, to characterise the conflict as solely commercial, as political and ideological factors were also key in drawing the two nations back to war (Rommelse 2010).

Following the Restoration Charles II was keen initially to maintain good relations with the United Provinces. The House of Orange had, after all, loaned significant sums of money to the Royalist cause, and it was from the Netherlands that he returned triumphantly from exile, in a fleet that included the *London*. Following the death of his sister Mary, however, Charles sought to manoeuvre his nephew William III into the role of *stadtholder*, explicitly contrary to the terms of the Secret Annexe (Groenveld 1991).

The Secret Annexe, and the subsequent Act of Seclusion, was ostensibly engineered by Cromwell and his allies to prevent the House of Orange regaining political prominence in the Netherlands. It has been suggested, nevertheless, that the provision was inserted at the behest of republican factions in the United Provinces, keen to suppress Royalist ambitions at home. It is certainly true that English Royalists and Calvinist Republicans in the Netherlands viewed each other as an existential threat on a fundamental ideological level (Pincus 2002).

It is clear, therefore, that commercial, ideological and political factors all played key roles in increasing tensions between the two nations in the period leading up to the Second Anglo-Dutch War. Charles II also viewed the

7. The Anglo-Spanish War (1654–1660) was primarily a war fought over commercial and economic interests, despite the Commonwealth's ideological opposition to Catholicism. It included both large-scale naval expeditions and privateering. In 1657 the Commonwealth formed an alliance with France against the Spanish, bringing England into the land war in Flanders. It is interesting to note that the Spanish troops were augmented by a force of some 3000 English Royalists, led by the future King James II, brother of Charles II (Hutton 2000).

Table 3.1 The second-rate ships ordered by Cromwell that were completed (after Lavery 1983, 160)

Name	Launched	Rate	Renamed	Sank	Details	Found
London	1656	2nd	–	1665	Blew up en route to London	1962
Dunbar	1656	2nd	*Henry*	1682	Accidentally burned in Chatham Dockyard	–
Richard	1658	2nd	*Royal James*	1667	Scuttled then burned by the Dutch below Chatham and broken up	–

prospect of a lucrative, popular war fought overseas as an important means to bolster his authority at home, at a time when some were beginning to question the extravagant spending of the Royal Court (Rodger 2004). As enthusiasm in England for war increased, privateers began to mount increasingly audacious attacks on Dutch merchant ships, while the Restoration Navy sought to harass and occupy the Dutch colonies of North America.[8] By the time war was declared, on 4 March 1665, some 200 Dutch ships had already been brought into English ports (Israel 1995).

England and London in the 1660s

It is difficult to overestimate the impact of the Restoration on England and on London in particular. The nation underwent sudden, sweeping and profound changes at every level of society. The great puritan agenda of Cromwell and the Protectorate was swept aside overnight; restrictive moral codes of conduct and celebration of austerity were replaced by conspicuous consumption and the increased import of foreign luxuries, including silks, tea, coffee and chocolate.[9]

It was also an era in which learning and the arts flourished. Pepys, the great chronicler of his age, began his diary on 1 January 1660, Milton published *Paradise Lost* and, after the Great Fire, the architecture of Christopher Wren transformed the London skyline. Theatre, too, flourished under the patronage of both Charles II and James, Duke of York, while the foundation of the Royal Society in November 1660 sought to promote advances in science, endeavouring to position England at the forefront of Enlightenment thinking. Coffee houses became places for people to trade ideas as well as goods; the remarkable expansion of coffee houses that occurred during the abstemious Protectorate,[10] were reconfigured to match the times.

The period immediately following the Restoration is also viewed generally as one of social and religious tolerance. It is certainly true that the officially sanctioned persecutions of non-conformist groups only began in the 1680s. It is nevertheless important to recognise that tensions simmered beneath the surface; England in the 1660s was a country still divided politically, ideologically and theologically, with fervent anti-Catholicism driven by successive wars at home and abroad.

The outbreak of plague in March 1665, which coincided with the start of the Second Anglo-Dutch War, increased social and economic tensions, particularly in London. Although plague was far from uncommon in 17th-century cities,[11] the scale of the Great Plague was unprecedented. It is estimated that by December 1665, 100,000 Londoners, or a quarter of the city's population, had perished.[12] Within a year the city itself was reduced to ashes when, on 2 September 1666, the Great Fire swept through London, destroying two-thirds of the capital.

The economic impact of successive wars, plague and fire in the 1660s was unparalleled. Though the population of England was approximately four times that of the Dutch Republic it was largely agrarian in nature and therefore a limited source of tax revenue. In contrast the Dutch urban population was almost double that of England. Large tracts of the Netherlands were wholly unsuitable to agricultural exploitation, so the population was forced into urban centres and ports that encouraged commercial growth based on trade and commerce, which was an area ripe for taxation. It is little wonder then that throughout the Second Anglo-Dutch War the Dutch were able to spend twice as much on their Navy as their English rivals (Rodger 2004, 79).

By early 1667 the financial position in England was parlous. The famous Dutch Raid on the Medway in June 1667,[13] some two years after the sinking of the *London*, remains 'the most humiliating defeat in the history of the Royal Navy' (Boxer 1974, 39) and further fractured the psyche of the nation. It led Pepys to exclaim memorably, 'never were people so dejected as they are in the city … this day' (Latham 1996c, 80). A population already vulnerable after plague, fire and the extravagant spending of the court of Charles II was left febrile and mutinous by the Dutch Raid, accelerating peace negotiations and leading ultimately to the signing of the Treaty of Breda in July 1667.

8. The Anglo-Dutch squabbles over Manhattan Island and the surrounding territories are a fascinating case in point. In 1664 the area known as New Amsterdam was captured and occupied by a force led by James, Duke of York (later James II and VII), who had returned from exile on the *London*. The 1667 Treaty of Breda formally ceded the colony to the English in exchange for a recognition of Dutch sovereignty over the island of Run, a small Indonesian island measuring some 3km x 1km. Though Run was a crucial source of nutmeg in the 17th century, it would be fair to say that its impact on modern history has been somewhat less than that of the now renamed New York.
9. www.historyextra.com/period/stuart/1660-the-year-that-changed-everything (accessed 3 September 2025).
10. In 1652 the first coffee house in London opened in Cornhill; less than ten years later there were more than one hundred.
11. London suffered thousands of plague deaths in 1603 and 1625, for example.
12. www.historyextra.com/period/stuart/coffee-plague-and-the-great-fire-the-pleasures-and-perils-of-restoration-london/ (accessed 3 September 2025).
13. Fifteen English ships, including three 'big ships', were destroyed at the Naval dockyard in Chatham, while the fleet's flagship, HMS *Royal Charles*, was captured without a shot being fired (Rodger 2004).

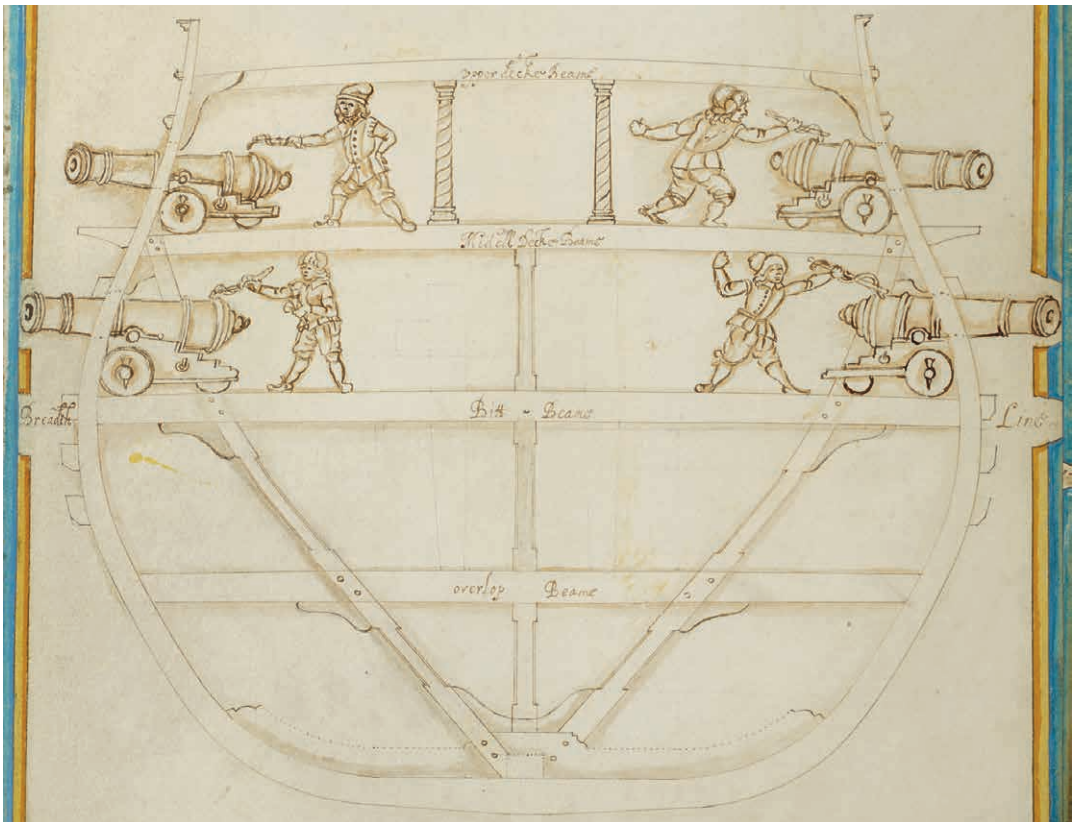


Figure 3.1 Contemporary cross-sectional drawing of the London *(© Royal Collection Enterprises Limited 2024 Royal Collection Trust)*

The construction, use and loss of the *London*

The *London* was one of four second-rate ships ordered on 3 July 1654 by Lord Protector of the Commonwealth Oliver Cromwell. There were, however, insufficient funds to complete the order, as the Navy was in debt to the tune of £600,000, owing to the extensive shipbuilding programme undertaken for the First Anglo-Dutch War, which had ended on 15 April, less than three months earlier. The *London* was one of two ships completed in 1656, the other being the *Dunbar* (later renamed the *Henry*); the first new second-rates launched in some 22 years. The third ship, the *Richard*, was completed in 1658 while the fourth was never built (Fox 2012, 60; Pascoe 2017; Table 3.1).

Lessons learned from the battles fought during the First Anglo-Dutch War were incorporated into the design. In that conflict, fought entirely at sea, the fighting took place close to shore in the North Sea where line-of-battle tactics demonstrated the importance of heavy broadside firepower. The short distances sailed to engage with the enemy enabled the sacrifice of food, beer and other stores in favour of more heavy guns. The additional weight of so many heavy guns often resulted in gunports too close to the water but, rather than removing guns, the ships were made wider to accommodate the additional weight (R. Endsor pers. comm).

The *London* was typical and had to be 'girdled' with six-inch thick planks on each side to carry the intended guns. Although the ship was only a third of the size of Nelson's *Victory*, the *London's* guns were of a similar size. Later, as Britain became a global power, ships like the *Victory* had to sail much longer distances, so they had to be large enough to carry a vast quantity of stores (R. Endsor pers. comm.). The recorded dimensions of the *London* include a keel length of 123' 6" (37.6m), and a beam as launched (to the outside plank but not including the wales) of 40' 0"(12.1m), later widened to 41' 0" (12.5m). The depth in hold was 16' 6"(5m) with a burden of 1104 tonnes (Winfield 2009, 27; Fox 2012, 60). These dimensions are very similar to those of the sixth-rate single deck *Trincomalee* of 1817, which is preserved at Hartlepool (R. Endsor pers. comm.).

The *London* was built at Chatham under the supervision of master shipwright, Captain John Taylor, who upgraded the ship to carry 64 guns rather than 60 as originally planned (TNA SP18/137 f.32). It was built with three complete flush decks (although arranged internally as two decks), a short quarterdeck extending forward of the mizzenmast, and a small poop deck (Fig. 3.1).[14] It had only two complete tiers of gunports, 13 each side on the

14. Despite appearances, rather than a rear-skid carriage, as seems apparent in this image, the recovered carriage had four trucks or wheels (see Pascoe *et al.,* Chapter 7).

Table 3.2 Cannon on board the London *on 13 October 1657*

	Lower tier	Second tier	Upper tier
Cannon of 7	12	–	–
Demi-cannon	12	–	–
Culverin	–	18	–
Culverin-drake	–	6	–
Demi-culverin	–	–	8
Culverin-cutt	–	–	4
Demi-culverin-cutt	–	–	2
Saker-cutt	–	–	4
Total	**24**	**24**	**18**

Table 3.3 The London *armaments as listed on the 'issues' pages of the journal on 23 February 1665, 12 days before the sinking (TNA WO55/1667; Fox 2012, 66)*

	Main gundeck	**Upper deck**	**Quarter deck**
Demi-cannon	16	–	–
24-pounder	8	–	–
Culverin	2	24	–
Demi-culverin	–	20	4
Minion	–	–	2
Total	**26**	**44**	**6**

lower deck and 12 each side on the second, while the third (upper) deck had three guns each side forward and five guns aft. Stern and bow chase ports shared guns with adjacent broadside ports (Fox 2012, 61–2).

The great cabin was on the second deck; when Pepys went to collect the future king from the Netherlands he commented that the stateroom on the *London* was much bigger than that on the *Naseby* (renamed after the Restoration as the *Royal Charles*) but was not so rich (Pepys, 24 April 1660).[15] The coach (officers' dining cabin) and the roundhouse (the master's cabin) and cabins for the lieutenant and the warrant master were on the upper deck beneath the quarterdeck (TNA SP18/137). Rather than a complete deck beneath the gundeck the ship had platforms fore and aft 'in hold'; the cook room with its brickwork and a pair of copper 'furnaces' was on the forward platform (Fox 2012, 60–1).

The *London* was launched on 19 June 1656, during the Interregnum, and was one of the most important warships in the Navy; at the time only three English warships were larger (Fox 2012, 60). It served as a flagship in both the Cromwellian and Restoration navies. The *London* saw action during the Anglo-Spanish War in 1657, at the Flemish coastal fortress of Mardyck and was present at the blockade of the French port of Dunkerque during the Battle of the Dunes (or Battle of Dunkirk) in 1658. This was the last clash between Commonwealth and Royalist forces, when the English joined with France in the continuing war against Spain in Flanders. Mardyck was captured and garrisoned by Commonwealth troops. The *London* also participated in the English show of strength during the Battle of the Sound in 1658. At the time of the Anglo-Spanish war the *London* carried 66 guns, as recorded in a volume in the Royal Collection (Table 3.2; Fig. 3.2).[16]

In 1660 the ship, commanded by Stayner, played a key role in the Restoration as the second largest ship in the fleet that brought future King Charles II back from exile in the Netherlands. The royal convoy left from Scheveningen on 23 May and landed in Dover on 26 May. While the king sailed on the flagship *Royal Charles* (formerly the *Naseby*), the *London* carried his younger brother James, Duke of York, future King James II, as its principal passenger. It is interesting to note that the two most modern and most prestigious ships of the Navy had been sent; both Charles and James (the impending Lord High Admiral) took a keen interest in the Navy. During its lifetime the *London* carried other royals including the wife of Charles I, Queen Henrietta Maria, and the mother of both Charles II and James II, Princess Henrietta (Fox 2012, 65).

Between 1661 and 1663 the vessel underwent various repairs and modifications including the girdling of the hull, as stated above, which enabled the *London* to carry a greater number of guns; 76 as opposed to 66 previously (TNA WO55/1667; Table 3.3; Fox 2012, 60–7).[17] The *London* was one of only four ships, and the only second-rate, with a full complement of copper-alloy guns; the other ships were all first-rates (Fox 2012, 59).

On 26 November 1664, approximately three months before the ship exploded, the Duke of York, the Lord High Admiral, authorised the Commissioners of the Ordnance to issue the *London* with a quantity of gunners' stores (TNA WO 55/331). It included:

- 20 pairs of trucks (wheels) of 22" (559mm);[18]
- 80 fathoms of white breeching rope;
- 150 fathoms of white tackle falls;
- 60 blocks of 6" (152mm);
- 72 blocks of 8" or 9" (203 or 229mm; see Figs 6.9 and 8.12);
- six dozen (72) rabinet (half-pound) shot for the ordnance;
- 1200 yards of canvas for bags for the rabinet shot;[19]
- two new carriages for the fortified demi-culverin (9lbr); and
- eight pounds of twine.

At the time the *London* had been in commission for five months so this order must have been to replenish ordnance stores. The considerable quantity of canvas for the rabinet shot shows that the *London* undoubtedly had much more of the same small shot already on hand to sew into canvas bags as grape shot (J. Schuster pers. comm.).

15. https://www.pepysdiary.com/diary/1660/04/24/ (accessed 16 September 2025).
16. RCIN 1047387; https://www.rct.uk/collection/1047387/the-ship-london-on-her-first-voiadge (accessed 3 September 2025).
17. The history of the *London's* guns was published by Fox (2012, 57–75). In addition there are other details of some of the gunners' stores taken on board just before the loss. These records may be of considerable help in identifying artefacts as they are recovered from the wreck. The configuration shown in Table 3.2 is based on the gunport arrangement as illustrated by van der Velde (Fox 2012, 67).
18. The same size as the front trucks on the recovered carriage.
19. The *London* had no guns of this type but the shot was to be bagged for use in larger guns (Fox 2012, 74 n54; TNA WO55/331).

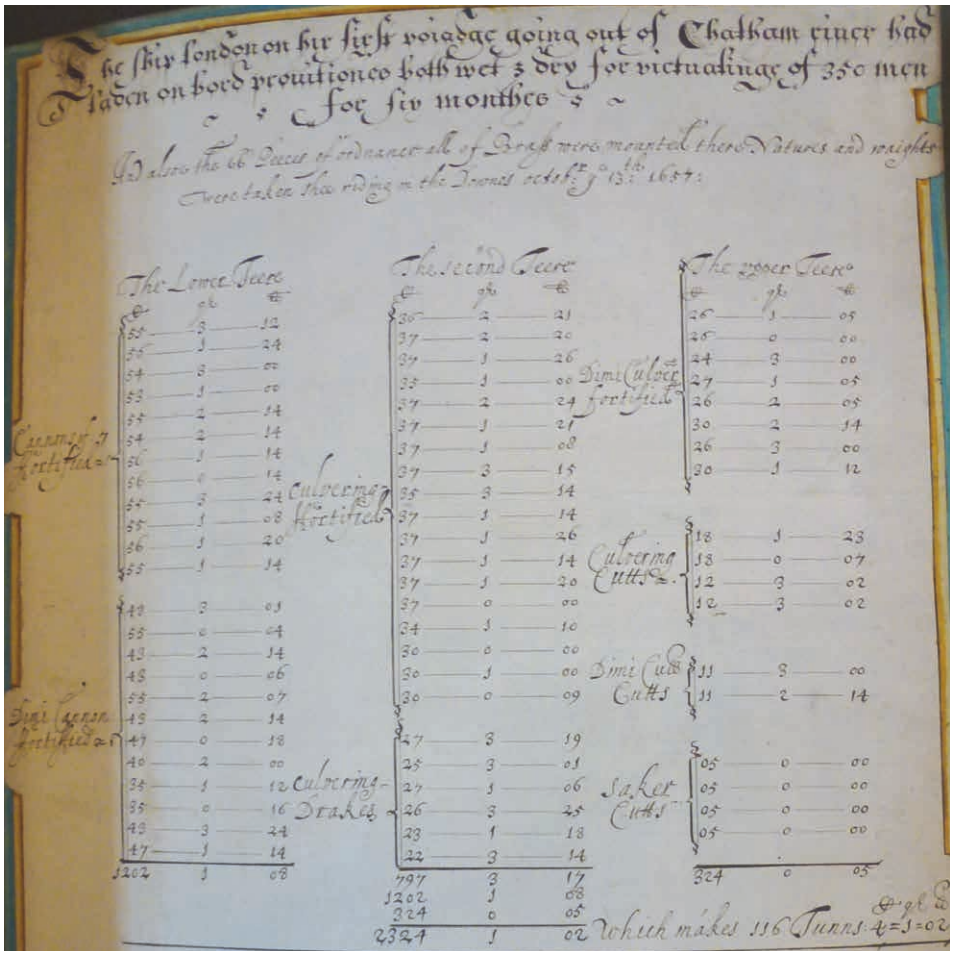


Figure 3.2 Cannon on board the London *listed in a document dated 13 October 1657 (© Royal Collection Enterprises Limited 2024 Royal Collection Trust)*

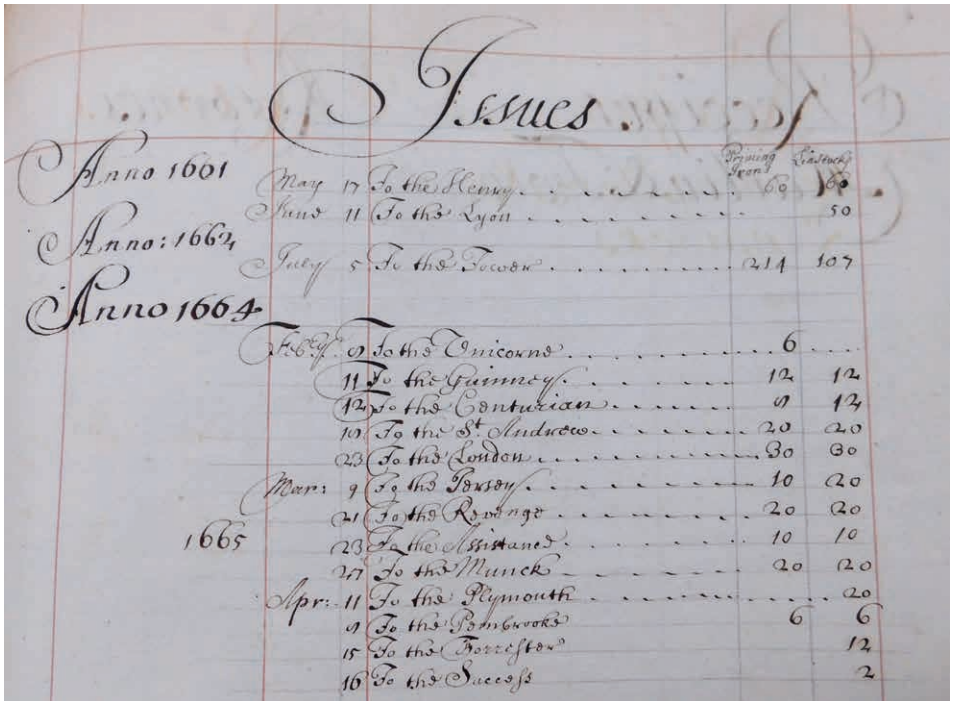


Figure 3.3 Chatham Ledger entries on 23 February 1664[5] (TNA WO55/1667 © TNA, photograph Michael Walsh)



Figure 3.4 Admiral Sir John Lawson by Sir Peter Lely (© National Maritime Museum, Greenwich, London; BHC2833)

Further quantities of gunners' stores were issued to the *London* on 23 February 1665 (Fig. 3.3), two weeks before the sinking (TNA WO55/1667), including:

- linstocks
- priming irons
- hand crow levers
- covers of lead
- quoins
- beds
- axletree trucks
- pulleys
- tampions
- rope sponges
- powder horns
- crows of iron
- rammers
- formers
- budge barrels
- tanned hides
- sheepskins
- baskets
- paper cartridges
- canvas cartridges
- oil
- wad hooks
- hand screws
- port ropes
- ordinary lanthorns
- dark lanthorns
- moscovia lanthorns.

Some of these items were recovered during the excavations.

Charles II declared war on the United Provinces of the Netherlands on 4 March 1665, initiating the Second Anglo-Dutch War for control of trade and influence around the world. This was barely ten years after the end of the First Anglo-Dutch War, which had concluded on 15 April 1654 with the signing of the Treaty of Westminster.

The *London* was appointed the flagship of the Red Squadron, under the command of Vice-Admiral Sir John Lawson (Fig. 3.4), a well-respected officer. Prior to this commission the *London* had been the flagship of the Earl of Sandwich (Admiral Edward Montagu, whom Lawson had previously accompanied on expeditions in the Mediterranean; Blanchard 2017, 158), in the Channel, at Spithead and in the Downs (Fox 2012, 58, 67).

On 7 February 1665,[20] ahead of the change in command, the *London* sailed from the Downs to Chatham for refitting (Fig. 3.5; Fox 2012, 59). The onboard ordnance and stores were removed and were reinstated on 23 February 1665 once refitting had been completed (TNA WO55/1667; Fox 2012, 67). Archaeological investigations have shown that, despite the imminent arrival of the captain, some of these stores were not in stowage.[21]

The crew was also replaced at this time, as captains manned their ships with their own personally loyal officers, seamen and family. Vice-Admiral Lawson was a so-called 'tarpaulin officer', one who had risen through the ranks, who was immensely popular with his men, was intimately concerned with their welfare and therefore had little difficulty in attracting men to the service (Blanchard 2017, 13; Davies 1991). The previous crew had gone to join the *Royal Prince* on 20 February (R. Endsor pers. comm.). The new crew began to arrive once refitting had been completed on 23 February, and would have been unfamiliar with the ship, although the new gunner Richard Hodges had been selected in January. At the time of the sinking, warrant officers were the most senior ranks onboard (Fox 2012, 59).

On 7 March 1665 the *London* left Chatham and sailed down the Medway, heading for the Hope anchorage three miles east of Tilbury in the River Thames (approximately where the London Gateway port now stands),[22] to await the arrival of the Vice-Admiral and the other commissioned officers. Only approximately 325 of the full complement of 450 men were on board at this time, plus a number of women (wives, girlfriends, etc.) who were allowed aboard to say their final goodbyes (Fox 2012, 57; R. Endsor pers. comm.).

After passing west of the buoy of the Nore,[23] however, the ship was torn apart by an internal explosion attributed to the mass detonation of the gunpowder in the main magazine. The explosion was so violent that this must be the most likely scenario. The ship had been fully armed on 23 February 1665 in preparation for battle, with 272 barrels (around 13 tonnes) of corne [sic] powder (The Chatham Ledger WO55.1667; Fox 2012, 57; Fig. 3.6).

20. The winter of 1664–5 had been particularly harsh, with the River Thames blocked with ice on two occasions.
21. Whether these stores had just been reissued in preparation for war, or had never been stowed, is open to debate. The former scenario aligns with the evidence from the partially loaded guns. If the latter, this inactivity between 23 February and 7 March points to ill discipline and a lack of leadership onboard. Lawson later reported to the Navy Board on a lack of organisation of the stores on board (Blanchard 2017, 180–1; see Walsh, Chapter 18), which does suggest a lack of discipline.
22. The Hope (or Hope Reach) is the stretch of the Thames between Tilbury and the mouth of the Medway. Named after the Hope stream it was a noted anchorage for fleet assemblages and rendezvous. It was the site of a Dutch incursion and battle in 1667 in which several British ships were destroyed.
23. The Nore is a sandbank at the mouth of the Thames Estuary near the town of Sheerness, Kent, on the Isle of Sheppey. It marks the point where the River Thames meets the North Sea.
24. The blast was apparently heard in Holland (Blanchard 2017, 179). This might be a mistaken reference to the Dutch flagship Eendracht that blew up in June 1665 during the Battle of Lowestoft, breaking windows in Dunkirk and audible in the Hague, 45 miles away, although this is also mentioned by Blanchard (2017, 183; Fox 2012, 58).

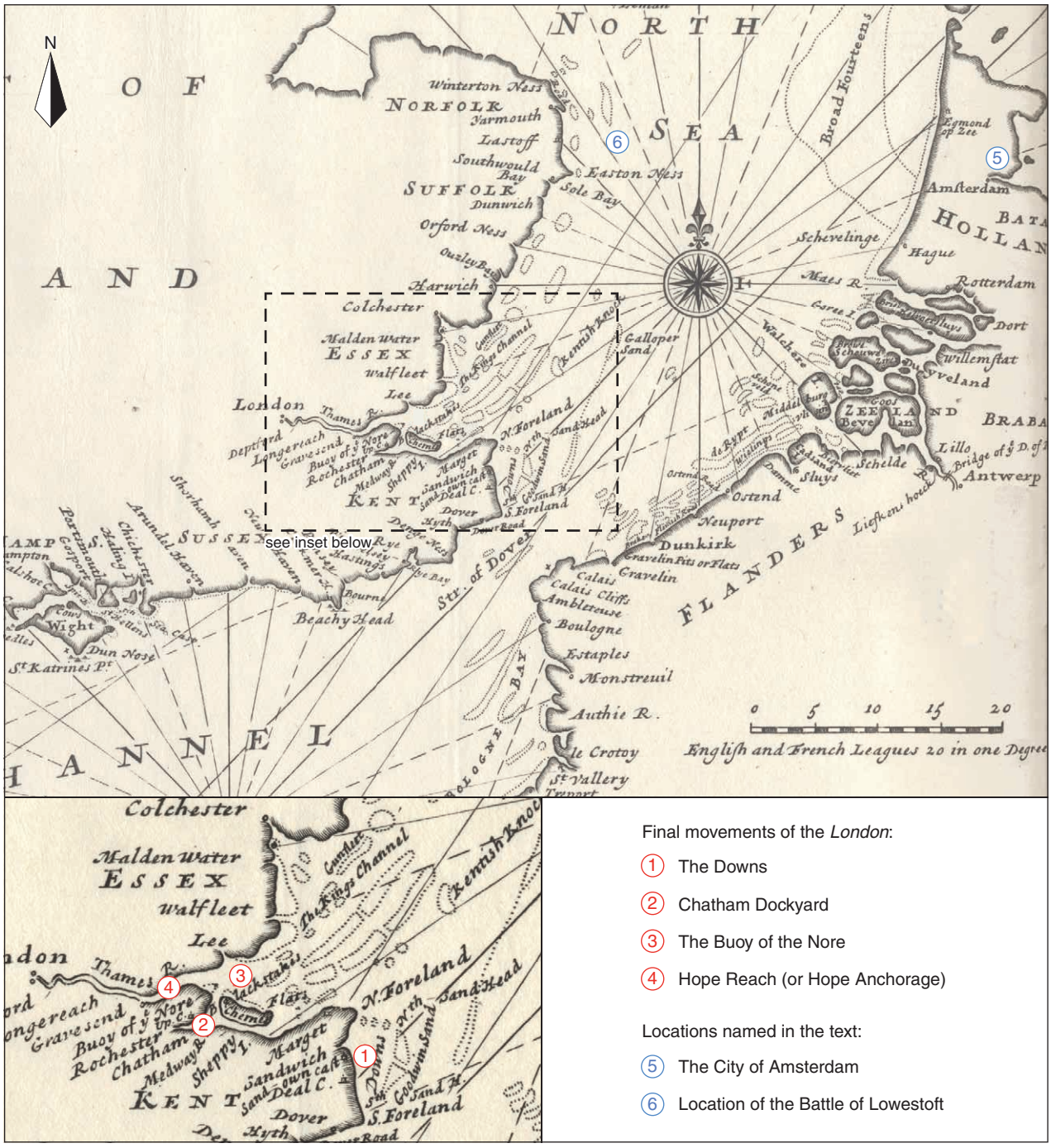


Figure 3.5 The final movements of the London *shown on 'A chart of the Channel between England & France and also Part of the Coast Sands & Banks Between England and Holland' by H. Moll Geographer* c. *1725 (© Petworth House Archives (PHA 3471), reproduced by kind permission of Lord Egremont)*

The violence of the explosion can be judged by the death of a man on a passing ship, the *Monleague*, who was killed by a flying splinter.[24] Samuel Pepys, the noted diarist and, at the time, Clerk of the Acts of the Navy Board, recorded the loss in his entry dated 8 March 1665 (Latham 1996b, 138):

> *This morning is brought me to the office the sad newes [sic] of 'The* London*', in which Sir J. Lawson's men were all bringing her from Chatham to the Hope, and thence he was to go to sea in her; but a little a 'this side the buoy of the Nower [Fig. 3.7], she suddenly blew up. About 24 [men] and a woman that were in the round-house and coach saved; the rest, being above 300, drowned: the ship breaking all in pieces, with 80 pieces of brass ordnance. She lies sunk, with her round-house above water. Sir J. Lawson hath a great loss in this of so many good chosen men, and many relations among them. I went to the 'Change, where the news taken very much to heart'.*

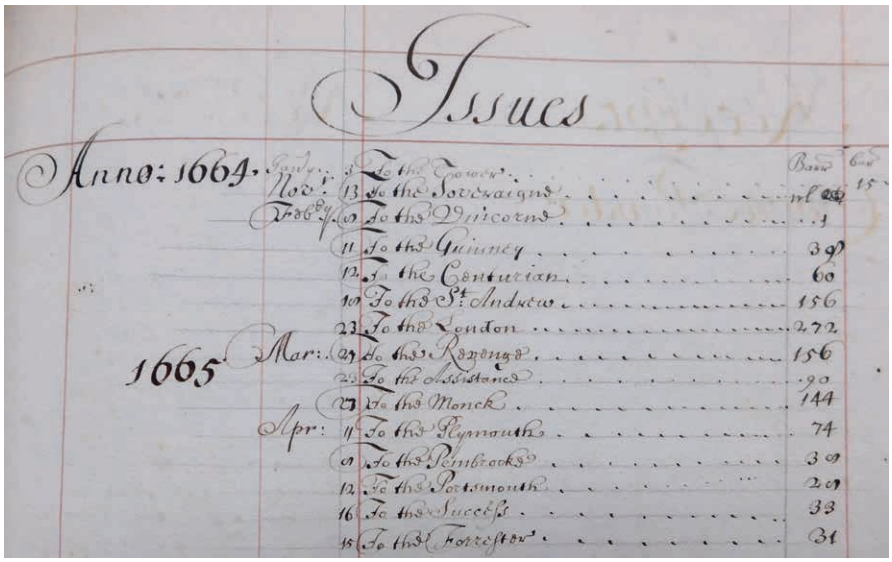


Figure 3.6 Barrels of corne powder issued to the London *(Chatham Ledger 23 February 1664[5]; TNA WO55/1667 © TNA, photograph Michael Walsh)*



Figure 3.7 The location of the Nore buoy (an anchorage in the Thames Estuary) (© Great Britain Historical GIS Project and the University of Portsmouth)

In his role as one of four Commissioners taking care of sick and wounded seamen and for the care and treatment of prisoners of war, John Evelyn noted in his diary on 9 March and on 16 May 1665:

> *I went to receive the poor creatures that were saved out of the* London *frigate, blown up by accident, with above 200 men … the poor orphans and widows … whose husbands and relations perished in the* London *frigate, of which there were fifty widows, and forty-five of them with child.*[25]

On 10 March 1665 the Dutch ambassador, Michiel van Goch, reported 'only 19 out of the crew of 351 saved',[26] although the Earl of Sandwich later reported 12 survivors (Fox 2012, 58), so either more details had emerged or some of the survivors had died. Twenty-one crewmen of Lawson's 'kindred and name' had perished in the accident.[27] Lawson,

25. https://archive.org/details/diaryofjohnevely02eveliala (accessed 12 February 2020).
26. Holland Correspondence, March 10, 1665, in Calendar of State Papers, Domestic, Charles II, 1664–5, Vol.114.
27. Rugge, cited in Blanchard (2017, 180).

Table 3.4 Cannon recovered from the wreck site

Year	Cannon type	Total	Recovered by
1665	Four demi-culverin cutts Two minions	6	Board of Ordnance
1665	Four demi-cannon Seven culverins Seven demi-culverins	18	Captain Giles Bond
1679	Seven guns (type unknown)	7	William Harrington
1689	Two guns (type unknown)	2	
1961	French demi-culverin 1636	1	PLA
1980	Two unidentified guns (unknown whereabouts)	2	PLA
2007	Commonwealth demi-cannon cast by George Brown in 1656 Tudor culverin cast by Peter Gill in 1590 rebored to 24-pounder Three Dutch 24-pounders – one cast by Coenraet Antonis (1600) and two cast by Gerard Koster (1616 & 1617)	5	Salvage diver
	Total	**41**	

who, as stated, had not yet arrived at the ship at the time of the disaster, was mortally wounded only three months later, on 3 June 1665, in the Battle of Lowestoft (Blanchard 2017, 183–5).

To put the calamity in its historical context the Great Plague, which took hold in London the following month, killed more than 100 people per week by late June 1665, while at its height in one week in September, more than 7000 people died in London alone. In addition the Great Fire of London the following year (1666) destroyed the homes of an estimated 70,000 of London's 80,000 population.[28]

Given the value of the 76 copper-alloy guns, which were expensive to produce and in short supply,[29] the Board of Ordnance wasted little time and deployed considerable resources to recover the lost guns. Four demi-culverin cutts and one minion had been salvaged and transferred to the *Royal Katherine* by 16 March 1665 (TNA PRO30/37/8) while another minion was taken aboard the *St George* (TNA WO 51/5). These guns had been on the quarterdeck which was still above water at low tide. Captain Giles Bond recovered 18 more guns, including four demi-cannon, seven culverins, and seven demi-culverins, by November 1665 using divers with diving bells (Fox 2012, 67; Pascoe 2017, 32).

No further salvage was conducted until William Harrington, a private salvor appointed by the Ordnance Board, used a new but unidentified method to recover seven copper-alloy guns in 1679 and two more in 1689 (he may have been away at sea in the interim) (TNA PC2/68 and PC2/73; Pascoe 2017, 32). Thus, by 1689, 33 of the 76 guns may have been recovered (*contra* Cressy 2021, 144).[30] Harrington, however, appears to have recovered both copper-alloy and iron cannon (TNA PC2/69, 161). As the *London* carried no iron weapons these may have been redundant ordnance which was sometimes used as ballast or they may have been deposited on the site by other action, such as the battle of the Buoy of the Nore on 26 July 1665 (Fox 2012, 68). It has been suggested that the current condition of the site might, in part, be the result of historic salvage operations (R. Brown pers. comm.).

There seems little doubt that the main magazine exploded but how it happened is open to speculation. Various theories have been expounded including:

- misappropriation of gunpowder – gunpowder at this time was an expensive commodity and there were examples of sailors pilfering gunpowder from the stores and hiding it in other areas of the ship for private sale (R. Endsor pers. comm.);
- an accident, negligence or mistake by a crew member, unfamiliar with the layout of their new ship and the powder room's candle lighting arrangements, possibly during the filling and stowing of the paper or canvas cartridges. Many men would have been below decks stowing the ship's stores (Fox 2012, 58; R. Endsor pers. comm.);
- a fire in the 'gun room' (Blanchard 2017, 179);
- the use of old artillery cartridges; the initial limited 'explosion' may have taken place in the forward magazine or platform, where gunners would have filled potentially dusty 'high risk' old cartridges with gunpowder, which then ignited the main store of more than ten tonnes of gunpowder kept in the vessel's hold (Keys 2015);[31] or
- the purchase of cheap, sub-standard gunpowder, although this seems far less plausible as powder quality was carefully controlled.[32]

28. Pepys' diary entry for this day recounts his agony with gallstones before mentioning this catastrophe (Latham 1996b, 138).
29. About eight times the cost of iron (Fox 2012, 59, 62).
30. Cressy believes only 42 cannon remain unrecovered.
31. Charles Trollope (Keys 2015) believes it is the only surviving exemplar of the spontaneous explosion phenomenon which had affected the major navies of Europe until that time. When reused, some of the cotton in the cartridges deteriorated into a fine dust, some of which then combined with tiny quantities of sulphuric and nitric acids in gunpowder to form a highly explosive substance which much later became known as 'guncotton'. Trollope believes that guncotton dust often came into contact with fresh gunpowder and friction between the dust and the gunpowder sometimes led to massive explosions. Trollope estimates that dozens of vessels worldwide self-destructed in the 16th and 17th centuries, causing deaths running into the thousands. The English suffered the loss of the *Fairfax* in the Medway, Kent, and the *Sussex* in Plymouth Sound, Devon, both in 1653. Indeed Trollope believes that, in England, it was the *London* disaster which finally forced the government to ban the reuse of old cartridges. The incidence of vessel self-destruction then reduced dramatically (Keys 2015).
32. Calendar of State Papers Domestic, Charles II, 1664–5, Vol.114, No. 90.

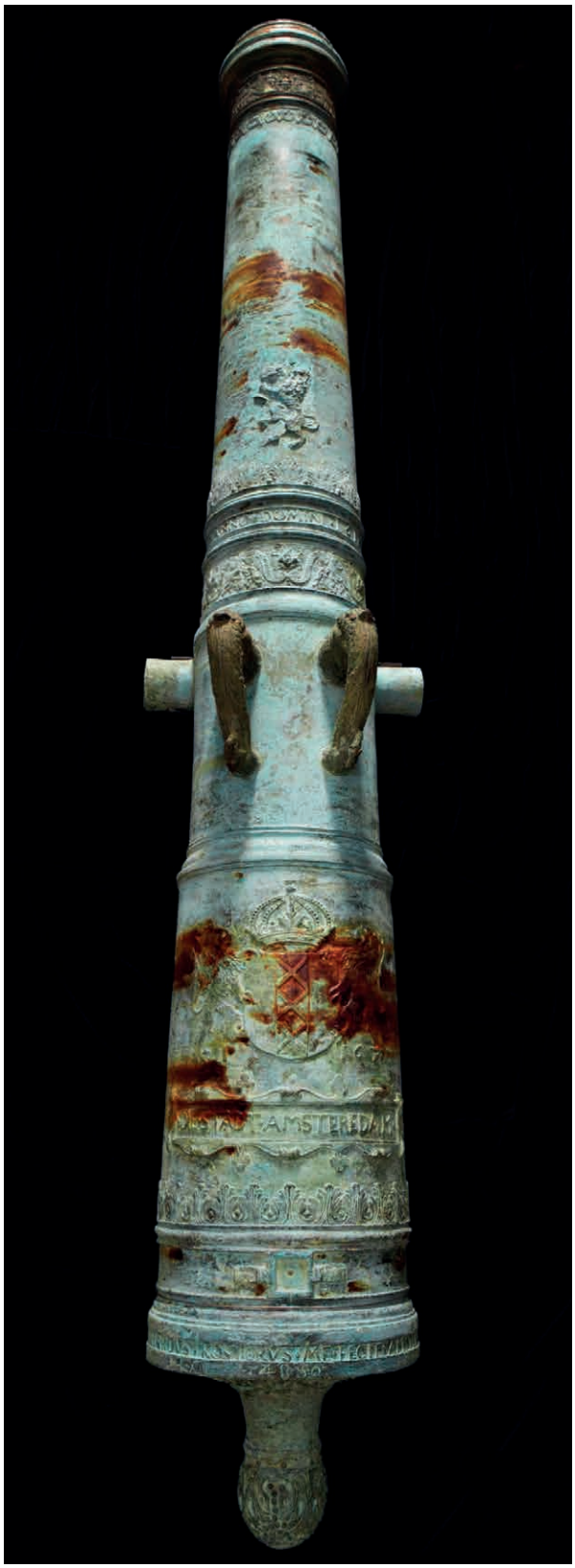


Figure 3.8 One of the Dutch cannon recovered from the London*, now in Southend Museum (© Southend Museums, photograph Tessa Hallmann Photography)*

In addition excavations on the site have recovered a considerable number of clay tobacco pipes that show clear evidence of having been smoked (see Chapter 10, Higgins), so this must remain another possibility.

Recent history of the site

The first site to be detected in recent times (S2) was reported as a 'foul'[33] in 1962 by the Port of London Authority's (PLA) Hydrographic Office,[34] although a wreck had been marked with a buoy in this location as recently as 1820. The PLA diver reported finding many timber ribs protruding from the seabed over a distance of 30m, as well as a cannon (see Table 3.4). This cannon, a 2.92m long French-made copper-alloy demi-culverin dating from 1636, was recovered by the PLA wreck-raising service (Jefferis and McDonald 1966, 181–2); it was the first cannon knowingly recovered from the wreck since 1689.

This cannon, now on display at the Royal Armouries Museum, Fort Nelson (XIX.237), is a rare example of the first regulation series of naval cannon with the size and decoration decreed by Cardinal Richelieu. It has been suggested that site S2 may have been subject to clearance operations in the 1960s including the removal of two guns (Wessex Archaeology 2011). Two more unidentified guns (current location unknown) were recovered by the PLA in 1980. A Royal Navy survey in 1985 detected 'numerous' guns but no further action was taken.

A PLA survey on 23 November 1979 reported a second site (S1) as an 'unusual-looking feature'. It also noted that site S2 had disintegrated since the previous PLA survey and that 'good fouls' were only obtained on the flood tide. This appears also to be the earliest reference to the site being the *'King'* although there are no recorded losses of that name in the vicinity (Wessex Archaeology 2006; 2011).

Further surveys in 1985, 1990 and 1999 relocated and refined the position of the two sites. In 2001 a sidescan sonar (SSS) survey commissioned by the PLA over site S2 revealed a large thin rectangular-shaped anomaly approximately 10m x 20m while further surveys in the following year using SSS and magnetometer identified a larger area with distinct features.

In 2005 multibeam and diver surveys conducted by the PLA and Nigel Nayling (University of Wales, Lampeter) identified three distinct sections of wreckage on site S1. The northernmost area comprised a concentration of disturbed timbers, including both framing and planking elements. The middle section was the largest and most cohesive, comprising thick wooden planking attached to large squared oak frames. The southernmost section lay somewhat deeper on the edge of the channel where planking attached to framing timbers was observed. Smaller round pieces of wood observed between some of the frames may represent

33. A 'foul' is an upstanding item or feature on the seabed upon which fishing nets etc. get snagged or fouled.
34. Recorded in *The Wreck Hunters* (Jefferis and McDonald 1966).

dunnage (packing material for cargo). A sample of timber, including treenails, was brought to the surface for dating. Dendrochronological analysis identified it as British oak felled sometime after 1639, which is consistent with the site's subsequent identification as the wreck of the *London* (Nayling 2005).

Wreckage comprising two sections 50m apart was also identified (S2) (Nayling 2005, 4). The largest and easternmost section of S2, measuring 25m x 12m, consisted of fragments of disturbed wood over a wide area, with a concentration of timber surrounding a single cannon. The cannon overlaid a concentration of apparent roundwood; initial measurements suggested it was either a saker or demi-culverin. A chamfered beam, possibly a carling, and a wooden wheel thought to be from either a gun carriage or a pulley were seen. Over the western section two discrete areas of wreckage were seen, with no debris in between.

Both sites were surveyed by HMS *Gleaner* in 2005. Site S1 was reported as measuring 47.1m x 28.4m lying in a north-east/south-west orientation and in a broken state. Site S2 was reported as measuring 37.5m x 27.4m. The site was discussed at the Advisory Committee on Historic Wreck Sites (ACHWS) meeting in 2006 as a possible candidate for designation but was not progressed as there was insufficient information to merit consideration and no threats to the site had been identified.

In 2006 the PLA conducted a multibeam echo-sounder survey of both sites (Wessex Archaeology 2006; 2008a). The survey confirmed that site S1 consisted of three main sections of wreckage with a large scour on the eastern side of the wreck. The overall dimensions were 30m x 20m and upstanding 1.1m. The scour, orientated east/west, measured 65m x 15m x 1.5m deep with steep sides. There appeared to be outlying features and scours surrounding the wreck, suggesting associated debris. Given the dramatic way in which the *London* sank and the subsequent salvage attempts this is to be expected.

The survey of site S2 revealed that it then appeared to consist of three main areas of wreckage with an associated large scour depression. In addition two sections of debris were located on the edge of the channel. The eastern section of wreckage was the largest, measuring 25m x 15m and upstanding 1m; along the eastern edge of this there was a scour 55m x 20m x 1m deep. The western section of wreckage measured 18m x 18m and upstanding 1m, although within this section there was a flat, featureless area measuring 10m x 7m. The third section of wreck was located further into the channel in an area of scour 30m x 20m and 0.6m deep.

In 2007 five large copper-alloy cannon were reported by a private salvage team to the Receiver of Wreck (RoW), only two of which, of English origin (Droits 257/07 and 338/07), were alleged to have come from the *London*. One was a Commonwealth demi-cannon and the other an unusual English 24-pounder. The other three were 24-pounders of Dutch origin (Figs 3.8, 3.9, 3.10 and 3.11; Droit 338/07), dated from 1600, 1616 and 1617



Figure 3.9 Dutch cannon cast by Gerald Koster in 1616–17 with little or no marine growth on muzzle on board salvage vessel following recovery by commercial salvor (reproduced with permission of the Maritime & Coastguard Agency)



Figure 3.10 Second Dutch cannon cast by Gerald Koster in 1616–17 almost entirely covered by marine growth on board salvage vessel following recovery by commercial salvor (reproduced with permission of the Maritime & Coastguard Agency)



Figure 3.11 Third Dutch cannon cast by Coenraet Antonis in 1600 recovered by salvage diver (© Wessex Archaeology)

respectively. Evidence presented during the court case concerning the illegal recovery of these guns, however, indicated that the three Dutch guns were in all probability recovered from the wreck of the *London* and were on board at the time of the sinking; this was admitted subsequently by the salvor (Pascoe 2017, 53).

The Dutch cannon were identified by Nico Brinck as land service guns from the city defences of Amsterdam that had been captured from Dutch ships by the English in the First Anglo-Dutch War. The presence of tampions[35] in the muzzles indicated that the ship had been lost by accident rather than during action (Fox 2012, 69). These eight guns recovered in modern times bring the total recovered to 41 guns,[36] so 35 of the original complement of 76 guns, plus any iron guns used for ballast, remain unaccounted for (Fox 2012, 72; Table 3.4).[37]

The two English guns recovered from the *London* represent two very rare examples of the period. One was cast by the noted *London* gun founder, Peter Gill, and is the only known surviving piece. It is in a good state of preservation and visually a very impressive gun. The second bears the arms of the Commonwealth and is the only known surviving copper-alloy gun of that period. The two English guns are now at the Royal Armouries Museum, Fort Nelson, while the three Dutch guns were sold at auction to a collector in the US in the summer of 2010. The Dutch guns were subsequently returned to Southend Museum (Pascoe 2017, 48).

A detailed study undertaken by the Nederlands Forensisch Instituut (2015) has traced the origins and movements of the Dutch cannon. These cannon were cast for use in the protection of the City of Amsterdam in the early 17th century. They were not intended to be used as naval guns, although they were employed for this purpose by the Dutch during the First Anglo-Dutch War, and are thought to have been captured by, and redistributed to, English ships including the *London* (Fox 2012, 70; Trollope 2008). The histories of these guns reflect aspects of the historical, military and political context of the period.

In 2007 and 2008 Wessex Archaeology was commissioned by the PLA to undertake archaeological diving investigations on the two sites as a result of further reported salvage (Wessex Archaeology 2008b). On site S2 they observed a good state of preservation of the material lying loose on the seabed but this was assessed as vulnerable to both damage and loss through natural processes. No cannon were seen but a number of artefacts, including leather 'string', a wooden wheel, a gun stock and a deadeye (or deadman eye), were removed to holding facilities at Denton Wharf (Paddenberg 2007). The whereabouts of these artefacts is not known currently. Little information was obtained for site S1 owing to poor visibility.

Wessex Archaeology (2008c) suggested that sites S1 and S2 may be two sections of the same wreck (the *London*) citing the following justification:

- The *London* is known to have broken up following an explosion; Pepys described it as 'breaking all in pieces' (Latham 1996b, 138). The sites are in close proximity to each other, so the possibility that site S2 represents the site of the sinking and site S1 is an outlier cannot be discounted. The geophysical evidence would suggest that site S2 is the main body of the wreck.
- Both sites have produced similar dating evidence. A ship timber from site S1 produced a felling date after 1639, while the gun recovered in 1962 from site S2 dates from 1636.
- The identification of site S2 as the *'King'* does not correspond with any recorded losses.[38]

Owing to reports of further salvage works being planned, the *London* (sites S1 and S2) was cited for emergency designation under the Protection of Wrecks Act 1973. The recommendation was presented to Parliament on 23 October 2008 and came into force the following day.[39] The designation is unusual in that it identifies two discrete designated areas (sites S1 and S2) for the same site, approximately 400m apart (see Fig. 1.2).

The designation was amended in 2012 to encompass an area of seabed in which wreck-related material had been found, but which lay beyond the area then designated.[40] In addition to sites S1 and S2, a further concentration of wreck material, site 3 (S3; see Fig. 1.3 and 1.4), was discovered through geophysical survey in 2009 approximately 140m to the west of site S2. Site S3 was investigated by divers in 2010 but was interpreted as modern debris (after Wessex Archaeology 2011). The possibility that site S3 overlies or contains material from the *London*, however, cannot be entirely discounted without further site investigations.

In 2009 Wessex Archaeology was commissioned by English Heritage (now renamed, and henceforth referred to as Historic England) to undertake a designated site

35. Stoppers for the muzzles of the guns to prevent loaded weapons from getting wet.
36. See Fox 2012, 72–3 for details.
37. https://museumcrush.org/the-archaeological-treasures-given-up-by-the-london-shipwreck/?fbclid=IwAR1EdUvd9w_oHHV152AZethulNQJSqxX2Vv5YqScODzpJ0b6r9DuETCFS8g (accessed 16 September 2025); www.theguardian.com/uk-news/2015/sep/04/diver-jailed-fraudulently-selling-three-cannon-found-uk-waters-vincent-woolsgrove (accessed 16 September 2025).
38. On 26 August 2008 the BBC broadcast a television programme 'Thames Shipwrecks: A Race Against Time' which featured the *London*. In it, Wessex Archaeology and Frank Pope were seen undertaking investigations into the vessel.
39. Statutory Instrument 2008 No. 2775.
40. Work on the wreck site over the last decade has made significant contributions to the understanding of the *London*. Research, surveys and underwater investigations have been undertaken commissioned by Historic England and the PLA. Prior to 2013 Wessex Archaeology was commissioned by both English Heritage and independently by the PLA to provide archaeological services in relation to the *London*. In 2014 Cotswold Archaeology was contracted by Historic England to undertake this work. In addition a court case relating to the potential recovery of ordnance from the wreck has been a catalyst for further research on the *London*. Throughout this period work by the licensee team, including monitoring, surveying and the recovery of at-risk artefacts, has continued on the site. The subsequent unpublished reports comprise the majority of the referenced work.

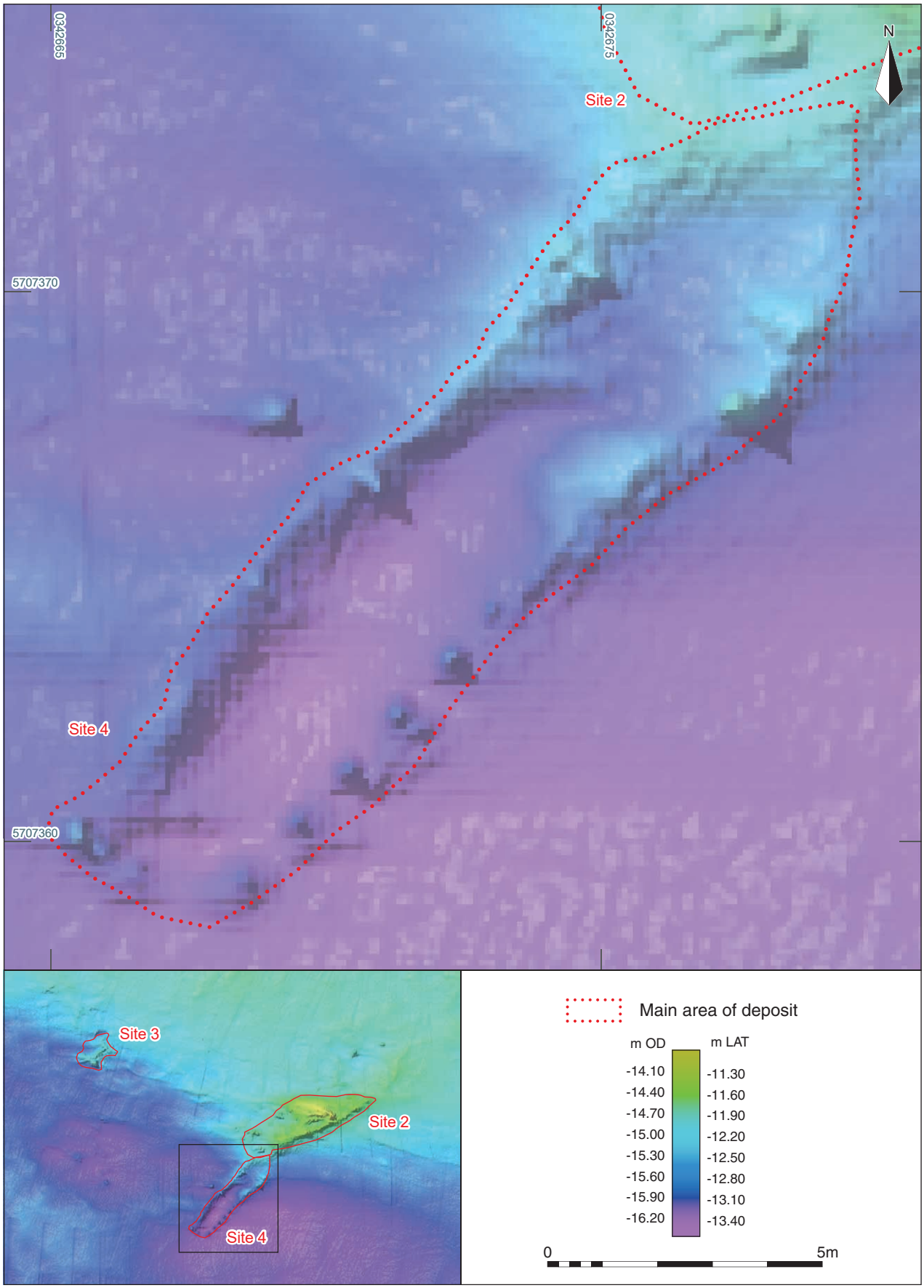


Figure 3.12 Bathymetric survey data clearly indicating S4 (© Historic England)

assessment of the *London* (Wessex Archaeology 2010). The survey revealed that site S2 measured at least 40m by 12m with the wreck material buried in the seabed to a depth of at least 1m. The sites appeared to represent two discrete areas of wreckage; wreckage and scour found during the diving investigation is consistent with previous investigations. The gun detected in 2005, however, was not found.

The shape of the structure identified suggested that the inboard face of the hull was visible. Deck beams and knees were observed to be fastened with large ferrous bolts and several large cuprous bolts were also observed attached to the timber. The presence of these large cuprous bolts originally cast some doubt on the identification of site S2 as part of the *London* because, while small cuprous fastenings are known to have been used in the 17th century, large fastenings are not believed to have been used until after the introduction of copper sheathing in the late 18th century. Immediately south of site S2 and abutting it, however, site 4 (S4) has been identified as a later copper-sheathed wreck (Fig. 3.12), which would account for these anachronistic discoveries. This later vessel may well have struck upstanding elements of the *London* as the site was still buoyed for navigation purposes in 1820.

The confirmation that the southern sector of the site (S4) contained the remains of an 18th/19th-century sailing vessel came from the analysis of the cuprous fastenings which dated to the mid-18th century (D. Dungworth pers. comm.). The northern sector of site S2, however, still contained remains consistent in date with those of the *London*. It is believed that the more recent wreck (S4) partially overlays the older site so some caution must be exercised in assigning finds to one site or the other.[41]

In 2010 local diver Steve Ellis became the licensee and was issued first with a visitor licence, in 2011 with a survey licence and in 2012 with a surface-recovery licence for at-risk artefacts and remains (Ellis 2012). The latter was issued as a result of the volunteer dive team's observations that exposed artefacts on the surface were being washed away and the emergence of further finds. Historic England funded a recording protocol (Wessex Archaeology 2012) enabling the licensee team to recover, between 2012 and 2016, 196 of the total number of recovered artefacts.

In 2011 a management report stated that, despite dredging to the south of the site associated with the London Gateway development, there was no evidence of significant change in the condition of sites S1 or S2 (see Fig. 1.3). The report did, however, point out that any impacts may be long term in their evolution and that both sites should be subject to ongoing monitoring. This report also recommended targeted archaeological investigations of the site to inform interpretations of the wreck itself, as monitoring alone would only improve understanding of how the site was evolving but would do little to further the understanding of how the ship was built or used (Wessex Archaeology 2011).

In 2014 Historic England commissioned Cotswold Archaeology to undertake evaluation, excavation and assessment under 'The *London* protected wreck site, Thames Estuary: Excavation of material at risk' project. The archaeological aims of the project were:

- to determine the depth of deposits on site;
- to recover artefacts at risk;
- to determine the density of objects within the wreck;
- to assess their state of preservation;
- to identify which part of the vessel is present at site S2; and
- to assess the extent to which the remains can shed light on the history (including construction, use and loss) of the vessel.

Currently, approximately 25m by 12m of the wreck is exposed with a line of closely spaced frames from the bottom of the ship demarking the extent of the site to the south-east. The wreck extends north-west of these frames, from the hold, seemingly up to at least the main gundeck.

The significance of the ship

There can be little doubt that the *London* is of great historical significance. As stated, only three 'large ships' were completed at the time but these remains are the only surviving example; the *Royal James* (formerly *Richard*) had been scuttled to prevent its capture by the Dutch in their infamous raid on the Medway in 1667 but it had then been set alight (Latham 1996c, 81), while the *Henry* (formerly *Dunbar*) was accidentally burned in Chatham Dockyard in 1682. At the time of its launch in 1656 only three English warships were larger than the *London* (Fox 2012, 60). In addition, having passed bloodlessly back into Royalist hands at the end of the Civil Wars, the *London* participated in the restoration of the English monarchy.

On the day of the fateful event the ship had been preparing for war, which Charles II had declared on the Dutch only three days earlier; the crew were awaiting the arrival of the Vice-Admiral when the explosion occurred. This was a personal tragedy for Vice-Admiral Sir John Lawson as around 20 members of his own family were on board as part of the crew. Lawson himself was mortally wounded at the Battle of Lowestoft, three months later; the first major confrontation of this war.

Could the loss of the *London* at the outset of the Second Anglo-Dutch War have affected the outcome of the war which, unlike the first, was won by the Dutch? Could England have won if the *London* had not sunk (see Chapter 17, Walsh)? Although a second-rate it was, after all, one of the largest and best armed of the Navy's ships, and one of

41. Three isolated adult human bones found in the northern sector, two skull fragments and a humerus, have been attributed by Jacqueline McKinley (Wessex Archaeology) to a minimum of two, but probably three, adults. It was thought that these bones might represent one male and one or two females, but this is difficult to determine owing to the fragmentary nature of the evidence (S. Mays pers. comm.). Their location suggests the remains are associated with the *London*.

only four ships to have had a full complement of copper-alloy guns; the other three were first-rates. The speed with which the Admiralty set about recovering the lost guns from the wreckage indicates just how prized and valuable these weapons were.

Incidentally, there is a contrary view (Bruijn 2011) that, although the English had won more naval battles and had sunk or captured more Dutch ships, they had in fact lost the first war. The facts seem to support this belief:

- at the end of the war the Dutch state was in a better financial position than their opponents, which enabled them to strengthen their position with a 'new Navy'; by spring 1666 the Dutch had rebuilt their Navy with much heavier ships with far greater firepower (Rodger 2004, 71). Moreover, immediately after the first war, the Commonwealth had embarked on a war with the Spanish (1654–60), which had not only depleted their financial resources further but had also disrupted what remained of English trade with Spain and southern Italy (Israel 1995). Rodger (2004, 79) has estimated that the Dutch were able to spend twice as much as England (the equivalent of £11 million) on the war. In October 1664 an enthusiastic Parliament had voted an unprecedented £2.5 million for war (Davies 2008, 20).
- the Dutch had continued to expand their trade networks throughout the war without fear of attack from English ships, which were concentrated predominantly in home waters.
- the English had lost access to both the Baltic and Mediterranean Seas as a result of the peace treaty signed in 1654.

So at the end of the war the Dutch were still the dominant European trading power.

Despite its size and armament, the *London* had participated in relatively few battles, probably because the best ships were deployed carefully, only in home waters in the summer (Davies 2008, 47), which implies a reluctance to place the ship in harm's way. So its loss, particularly its timing and manner, with an almost complete complement of crew, must have had a major impact not only on morale but also on man/firepower (the state's ability to conduct war) and on the state's finances, which, as stated, were already stretched as the English could not afford to sustain a long war.

Chapter 4
The Excavations

Michael Walsh

The *London* wreck site consists of two discrete designated areas, site 1 (S1) and site 2 (S2), approximately 400m apart. In addition to S1 and S2 an additional area of wreck material, site 3 (S3), discovered through geophysical survey in 2009, has since been shown to be an area of modern debris (after Wessex Archaeology 2011). Immediately south of S2, a later wreck, site 4 (S4), has been identified abutting S2 (see Fig. 1.3). Table 4.1 presents a more comprehensive and chronological description of surviving features.

Diving operations

The methods adopted for working on this challenging site necessarily evolved over the lifetime of the project in response to lessons learned during previous sessions. The challenges encountered included the site's location on the edge of a major shipping channel, a limited diving window, poor visibility, strong currents and restricted access to the dock. To use one example, visibility on site ranged from 0 to 0.5m on the high water (HW) slack to 0 to 0.2m on the low water (LW) slack.

These challenges had a significant impact on the methods employed and the pace at which work could be conducted. For example, a decision was taken early on that, rather than a site grid, a system of baselines would be established over the site. The changing practices attempted to improve efficiency and were adopted in response to changing permissions and the availability of larger vessels, which enabled the use of more appropriate equipment. All diving was undertaken in accordance with the *Health and Safety Executive (HSE) Scientific and archaeological diving projects. Diving at Work Regulations 1997. Approved Code of Practice and Guidance*,[1] using SCUBA utilising OTS Guardian full-face masks (FFM) with through-water communications monitored on the surface. HSE SCUBA was used for this project to ensure the full integration of the licensee team with the Cotswold Archaeology dive team during excavations.

In 2014 all diving was undertaken from the dive support vessel (DSV) *Joyride*, a 6m rigid inflatable boat (RIB) owned and operated by the site licensee, Steve Ellis. The size of the DSV limited options so all excavation was undertaken using a variety of hand tools. For the first session in 2015 the 16m fishing vessel *Indianna* was chartered as the DSV, which enabled the dive team to stay on station for longer periods. This larger DSV also enabled the use of two portable airlifts powered by 18 litre cylinders.

Prior to the second session, however, the PLA granted permission to place moorings over the site, so a 16m working barge, *Jumbo*, could remain stationed on site with personnel and kit transfers undertaken by *Joyride*. A shot line was then extended from *Jumbo* to the site, thereby increasing the working bottom time. Diving was undertaken directly from *Jumbo*, which enabled the use of two 100mm airlifts powered by a compressor on the barge. A similar arrangement was used in 2016 but with safety boat cover and crew transfers provided by a 7.5m RIB operated by the crew of *Jumbo*. The changes to working practices made an increasingly significant difference to the time spent on site (Table 4.2).

All finds recovered during the excavation were immersed in seawater before being transferred to SMS and then on to Historic England's conservation laboratory, except the gun carriage, which was transported straight to York Archaeological Trust (YAT). Environmental samples were recovered from various stratigraphic layers in trench 3 (Fig. 4.1) and from outside the south-eastern edge of the wreck. Sediment samples were also collected from various points on the recovered gun carriage. Sampling was also undertaken, if appropriate, once the finds had been cleaned and stabilised under laboratory conditions before appropriate conservation treatments were progressed.

The positions of surface finds were recorded using a 1m² grid system laid over the site plan. This method was adopted to facilitate recording of the distribution of finds in relation to the vessel's structure, which is thought to lie on its side.

1. https://www.hse.gov.uk/pubns/books/l107.htm (accessed 3 September 2025).

Table 4.1 The London *and related sites*

Site	Description
S1 '*London*'	Geophysical surveys indicate that S1 is much larger than its visible extent (Cotswold Archaeology, 2017a). Cohesive fragments of hull have been observed with elements of what is believed to be outer hull and ceiling planking. Evidence suggests that a large section of hull may be underpinning parts of the site. There are a large number of disarticulated timbers, freshly exposed timbers and timbers with freshly exposed surfaces, which suggests that the site remains unstable and that relatively small variations in seabed level may be causing this instability. A number of what appear to be heavily concreted iron guns have been observed sitting on top of timber frames with planking (Ellis 2011, 2015). These appear to be piled up; there is a suggestion that they may represent worn guns that were being used as ballast. Salvage operations in the 17th century also noted the presence of iron guns on the site (Fox 2012, 68). S1 has produced a variety of small finds including military and domestic equipment as well as structural remains of the ship (Ellis 2015). Lower densities of artefacts are recorded on S1 compared with S2 (Ellis 2015).
S2 Previously thought to be the '*King*'. Now known to be part of the *London*	S2 contains the remains of the *London*. The remains suggest the presence of part of the hull, from the bow section. Investigations of S2 carried out between 2014 and 2016 recorded remains thought to represent a section of the hull from the main gundeck down to the hold. Surviving internal details include decking, internal partitions and a section of a gunport, adjacent to which was found the remains of a well-preserved gun carriage; this was recovered from the site in 2015 (Cotswold Archaeology 2016). Owing to the density of finds and timbers within the site, in 2016 it was decided to excavate a trench (trench 4) following the outside of the hull, in order to determine the full extent of the deposit. This trench was excavated to a depth of approximately 1.8m but neither the keel nor the bottom of the deposit was reached. This suggests that the keel of the ship is not present but does offer some indication of the depth of the deposit surviving on S2 (Cotswold Archaeology 2017b). Remains from the upper decks indicate survival of the upper parts of the ship, although in a less coherent form than the lower sections (main gundeck to hold). Geophysical survey results indicate that there may be about 20m length of hull present on S2 (Cotswold Archaeology 2017b, 16). Galley tiles, bricks and possible firewood have also been recorded in the investigations on S2, as have extensive remains of gunnery equipment (linstocks, hand crow levers, bandoliers etc.). These artefacts indicate that S2 may contain remains of the galley and gunner's store, both of which are usually located in the bow in vessels of this period (Cotswold Archaeology 2017b). Thus, in summary, S2 is thought to include a section of one side of the bow, from the main gundeck to the hold (excluding the keel), with fragmentary remains from upper decks and clear evidence for domestic and military activities on board the vessel. Human remains have been discovered on S2, although the possibility they are from the later vessel (S4) cannot be discounted. Freshly exposed and eroded timbers together with well-preserved organic material suggest the site remains unstable as a result of relatively small changes in seabed level. Recent site investigations suggest that the deposits on S2 are in excess of 2m thick (Cotswold Archaeology 2017b).
S3 Modern debris	S3 was identified through geophysical survey, subsequent investigation revealed modern debris. However, the possibility that remains from the *London* lie underneath cannot be discounted.
S4 19th-century wreck	A later, *c.* 19th century, as yet unidentified wreck abutting S2.

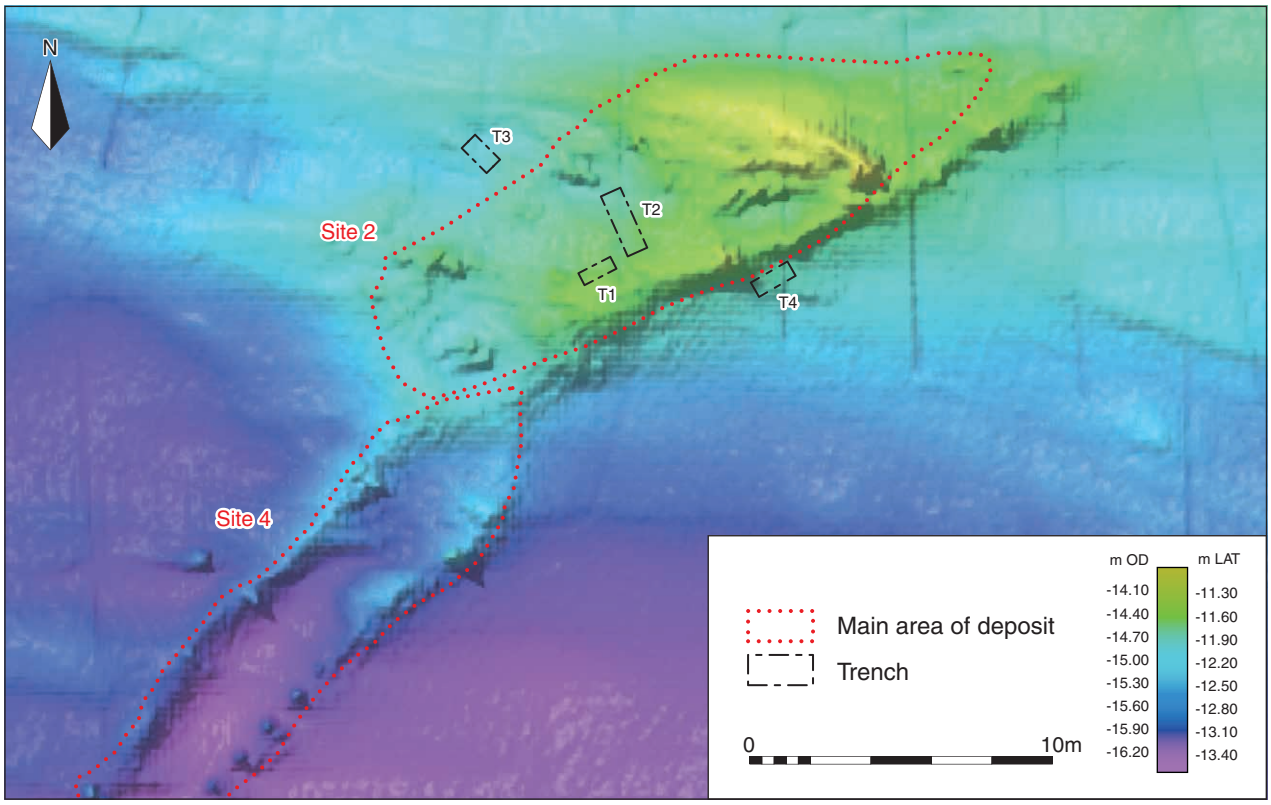


Figure 4.1 Location of excavated trenches (© Historic England)

Table 4.2 Details of diving operations

Year	Session	Days on site	No. of dives	Total bottom time (approx. hrs)	Av. bottom time per day (mins)
2014	One to four	13	13	22.5	105
2015	One	5	29	21.5	260
2015	Two	3	28	20	398
2016	One	6	48	37	370

Improved mapping of finds distribution enables a greater understanding of the density of different find types in different locations, thus contributing to the interpretation of the vessel's layout, and assisting in the identification of the remaining elements of the ship (Cotswold Archaeology 2014; 2017a; 2017c).

Excavation results

Excavations by Cotswold Archaeology (2014) in collaboration with the licensee team focused solely on S2 and were first undertaken in 2014. Three trenches were excavated across the centre of the wreck mound from the south-east to the north-west. A fourth trench was excavated on the outside of the hull in 2016 in an effort to locate the keel to ascertain which part of the ship survives and to ascertain the depth of the deposit; the trenches within the structure failed to reach the bottom of the stratified deposits owing to the density of finds and structure:

- Trench 1 – located on the south-eastern edge of the site;
- Trench 2 – located centrally on the wreck mound;
- Trench 3 – located close to the north-western edge of the site; and
- Trench 4 – located outboard of the south-eastern edge of the site (Figs 1.3 and 4.1).

Two of the trenches (1 and 2) were opened on the inboard side of a 20m line of frame timbers, protruding from very fine, soft, mobile silts,[2] extending along the south-eastern boundary of the site. The frame timber sizes are consistent with those of the lower hull of the ship, probably the lower futtocks and floor timbers, representing a section of the hold of the ship; the north-western area of the site represents upper sections of the ship.

Two 2m square trenches (1 and 2) were excavated; trench 1 was sited adjacent to the frame timbers while trench 2 was sited 1m further inboard. The sedimentary sequence in both trenches was similar, with 0.2m thick soft muddy mobile silts overlying a firm grey clay. Both trenches contained a combination of disarticulated as well as structurally sound timbers. Their condition was similar, with timber surfaces exposed in the mobile sediments badly eroded by the physical and biological environment, whereas the surfaces buried in the underlying firm grey clay were much better preserved. Both trenches were abandoned at 0.5m deep as the sheer volume of disarticulated timbers prevented further gainful investigation.

Trench 1

The disarticulated timbers in trench 1 appear to have collapsed as the vessel broke up, and were then subject to post-depositional disturbance. The structurally sound timbers appeared to be secured to the inside of the hull; a row of three substantial timbers 1.5m inboard from, and running parallel to, the edge of exposed frames, may represent the ends of timber knees or riders. Staves from a cask, a section of a possible spar, numerous musket shot and clay pipes were also recovered.

Trench 2

The ends of a series of timbers along the edge of trench 2 appeared to be cohesive and comprised possible beams and half beams. A disarticulated deck beam, with a series of recesses for half beams, was found adjacent to these timbers. A section of partition planking or panelling in this area could be related to the internal structure, such as cabins or compartments, of the ship. The discovery of large concentrations of musket and pistol shot might indicate the proximity of the gunners' store room. Other small finds in this area included a candle, a spoon, other pewter ware and a pile of possible firewood, which may be associated with the cook room, which would have been located on a platform in the hold.

Trench 3

Trench 3 was excavated on the north-western edge of S2, close to what was believed to be a section of exposed deck. This trench was delimited by:

- the inner side of the hull and the remains of a gunport (north);
- the remains of what appears to be the main gundeck, which is inclined at an angle of approximately 45° to 60° to the seabed (south); and
- a deck beam, possibly from the deck above, lying perpendicular to the hull planks, sloping downwards from the deck to the side of the hull (east).

2. This layer of soft mud and silts is extremely mobile and fluctuates depending on the strength of the currents. The strongest spring tides erode these soft mobile deposits exposing artefacts and leaving the site most vulnerable.

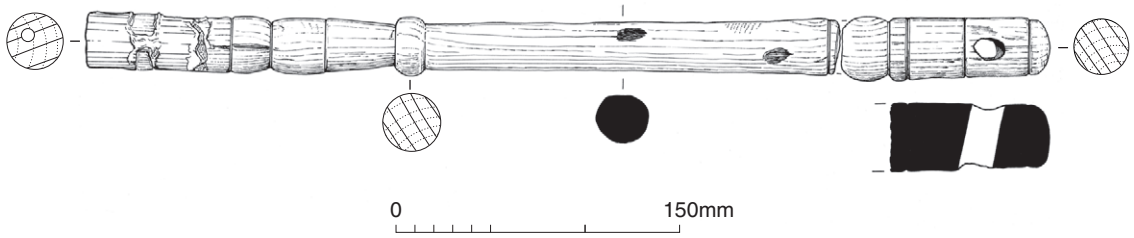


Figure 4.2 Linstock (3186; © Historic England, drawing Ruth Parkin)

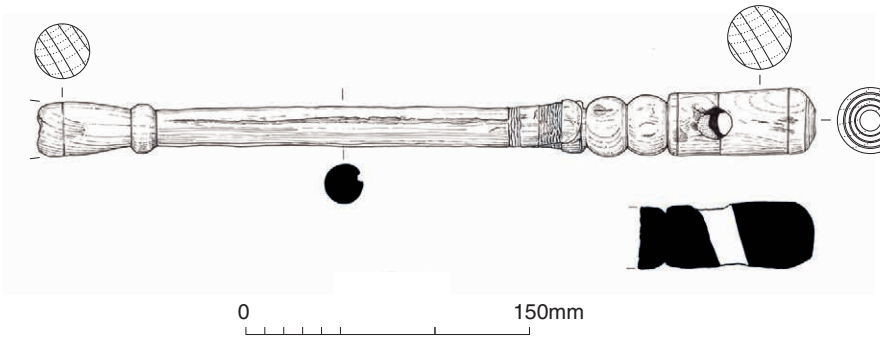


Figure 4.3 Linstock (3188; © Historic England, drawing Ruth Parkin)

It revealed a complete gun carriage (3239) with most of its associated gun tackle, furniture and numerous gunners' implements. The rear bed of the carriage was exposed with the rear trucks (wheels of the carriage) abutting what appeared to be the main gundeck[3] (Cotswold Archaeology 2017c).

Initially the gun carriage was only partially excavated, revealing the top half of both cheeks, the bed and the rear axle and trucks. A single block was recovered from one cheek and a double block from the other. These blocks were part of the gun tackle used to run the gun in and out and to secure it to the side of the ship. Pieces of the breeching rope that fastened around the cascabel (a projection behind the breech) of a muzzle-loading cannon were also found around the carriage. The ends of ram rods (gunner's implements) were found on each side of the carriage. A wicker basket (not recovered) full of rope fibres may have been related to lighting and holding the match used to fire the gun. The carriage and associated accessories were in a remarkable condition; the only thing missing was the gun itself.

The excavation of trench 3 continued in 2015 (Cotswold Archaeology 2017c); at this time a timber extension piece fitted to the rear of the bed of the carriage had become loose, then detached, and was recovered. As the gun carriage was at risk of further deterioration, the recovery of the carriage and its associated artefacts became the focus of the 2015 excavations.

Although relatively small, the extension piece is an extremely important diagnostic part, as it aids the identification of the cannon associated with this gun carriage. Further excavation recovered more artefacts associated with the carriage, including a double block (3127) and fragments of a hand crow lever (3160), a breeching rope (3163) and gunners' implements. The recovery of two double blocks and two single blocks completes the carriage's associated gun tackle.

Other artefacts, recovered at the time, included a button (3359), a human vertebra (3158, from grid square I9), clay pipe (3329) and a leather shoe (3162). Five sediment samples were also recovered. A jumbled group of fragmented, fragile linstocks were found on the east side of the gun carriage. Three were recovered intact (3199–3201) and three were each in two pieces (3186a and b (Fig. 4.2), 3188a and b (Fig. 4.3) and 3198a and b). A further 80 pieces appear to comprise fragments of additional linstocks.

The bottom end of a hand crow lever (3235), a complete unidentified wooden object with rounded ends (3234) and two fragments of a rod or hand crow lever (3204–3205) were recovered from the east side of the carriage, while two rammer heads (3206–3207) from a flexible rammer were recovered from the west side. These would have been implements for the gun that was mounted on this carriage. The recovery of these artefacts enabled the final excavation and removal of the gun carriage.

The bed and front trucks were found to abut a horizontal timber, while timber frames, protruding vertically from the seabed to the east, were clad by inner and outer planking. These appeared to be the structural remains of the side of the hull, with the horizontal timber possibly representing the bottom sill of a gunport. Another large timber on the inside of the hull appeared to be a wooden knee. It therefore seemed apparent that the gun carriage was situated directly

3. The deck is oriented approximately north-east–south-west. These features and their layout indicate that S2 consists of a section from one side of the ship, seemingly from the gundeck to the hold.

behind the gunport with the forward part of the carriage abutting the sill.

The carriage, the rear trucks and axle were recovered but the front trucks and axle were secured to the sill by concretions. The concretions may represent iron shot that had rolled to the side of the vessel during the sinking. The removal of the carriage revealed a dense concentration of gunners' implements, including more loose hand crow levers, that were recovered.[4] Further excavation allowed the recovery of the front axle and one of the trucks but the other truck was reburied. Six sediment samples were collected from various points on the carriage after it had been recovered.

A second gun carriage was found 2m to the west of the first carriage by the licensee team in 2014, while undertaking an investigative dive. This carriage was not excavated but was identified from the exposed cheeks and rear of the bed. It lay in a similar orientation to the first gun carriage and was also missing its gun. This demonstrates the potential for substantial areas of the main gundeck, on this side of the ship, to survive. Exploratory investigations to the north-west of the gun carriages have found more structure, which implies the presence of sections of the upper deck.

Excavations continued in trench 3 in 2016 (Cotswold Archaeology 2017d); removal of the infill from the gunport side of the trench revealed the reburied carriage truck (3531) and two remaining fragments of the front axle (3499 and 3503), so the complete gun carriage had been recovered. Removal of these last gun carriage components enabled a more detailed inspection and accurate measurement of the surrounding structural features.

The gunport measures 900mm (35.4") wide and the height survives up to 800mm (31.5") from its base. Each of the inner planks on the east side of the gunport measured 360mm (14.2") wide. The remains of two wooden knees were situated approximately 0.50m to the north and 0.9m to the south of the gunport. The more exposed knee to the north measured 210mm (8.3") by 140mm (5.5") at its widest point. Two concretions on the inner (as opposed to the fore and aft) surface of the knee suggests that it was secured to the hull by iron bolts. The arm of the knee appeared to taper at its lower end suggesting it was probably the lower part of a hanging, rather than rising, knee.

The remains of a concreted ring bolt, probably used to fasten either the breeching or gun tackle, was found fastened to the side of the hull just below the level of the gunport sill. It is unclear whether another loose ring bolt (3461) came originally from the side of the hull or from the gun carriage.[5] The remains of a leather shoe (3495/3542/3544–7) were found in the same area (Fig. 4.4).

Five rows of deck planking, including a simple butt-joint, were partially exposed following the recovery of the gun carriage. The planks were not of uniform size; one row measured 160mm (6.3") wide while the remainder measured 300mm (11.8") wide. The gaps between the planking were filled with caulking.



Figure 4.4 Shoe fragments (3495/3542/3544–7); © Historic England Archive, photographs James O. Davies)

Many hand crow levers were found lying in at least two layers on either side of the gun carriage, the lower layer of which was concreted to the deck. Concretions around the heads of the hand crow levers derived from the corrosion of the thin malleable wrought iron 'shoes' that were fastened to the heads to protect them. Four complete hand crow levers (3556–3559) were recovered, and at least another six were left *in situ* as they were either concreted to the deck or required further excavation. The grip ends of the recovered hand crow levers closely abutted the hull, level with the sill of the gunport.

A single 2m long beam on the eastern side of the trench overlies the sides of a broken chest or chests and the remains of many hand crow levers. This suggests the beam was originally located above the gundeck and probably collapsed from the deck above.

A number of bandolier sets (see Fig. 9.1), comprising leather belts, wooden powder boxes (see Fig. 8.1) and remains of leather pouches, now believed to be musket ball

4. It is probable that these artefacts rolled between the deck and the bed of the carriage as the ship turned on its side as it sank.
5. One double and one single block was found on each side of the cheeks at the front and at the rear respectively of the carriage. The blocks would have been attached by an eye bolt; the double blocks to the hull either side of the gunport and the single blocks either side of the carriage. The latter were found adjacent to the concreted remains of eyebolts on the side of the carriage but most of the tackle had perished or was too fragile to recover. The locations of the blocks, approximately in their correct positions, demonstrate that the carriage had remained intact with its associated tackle in its original location in front of the gunport.

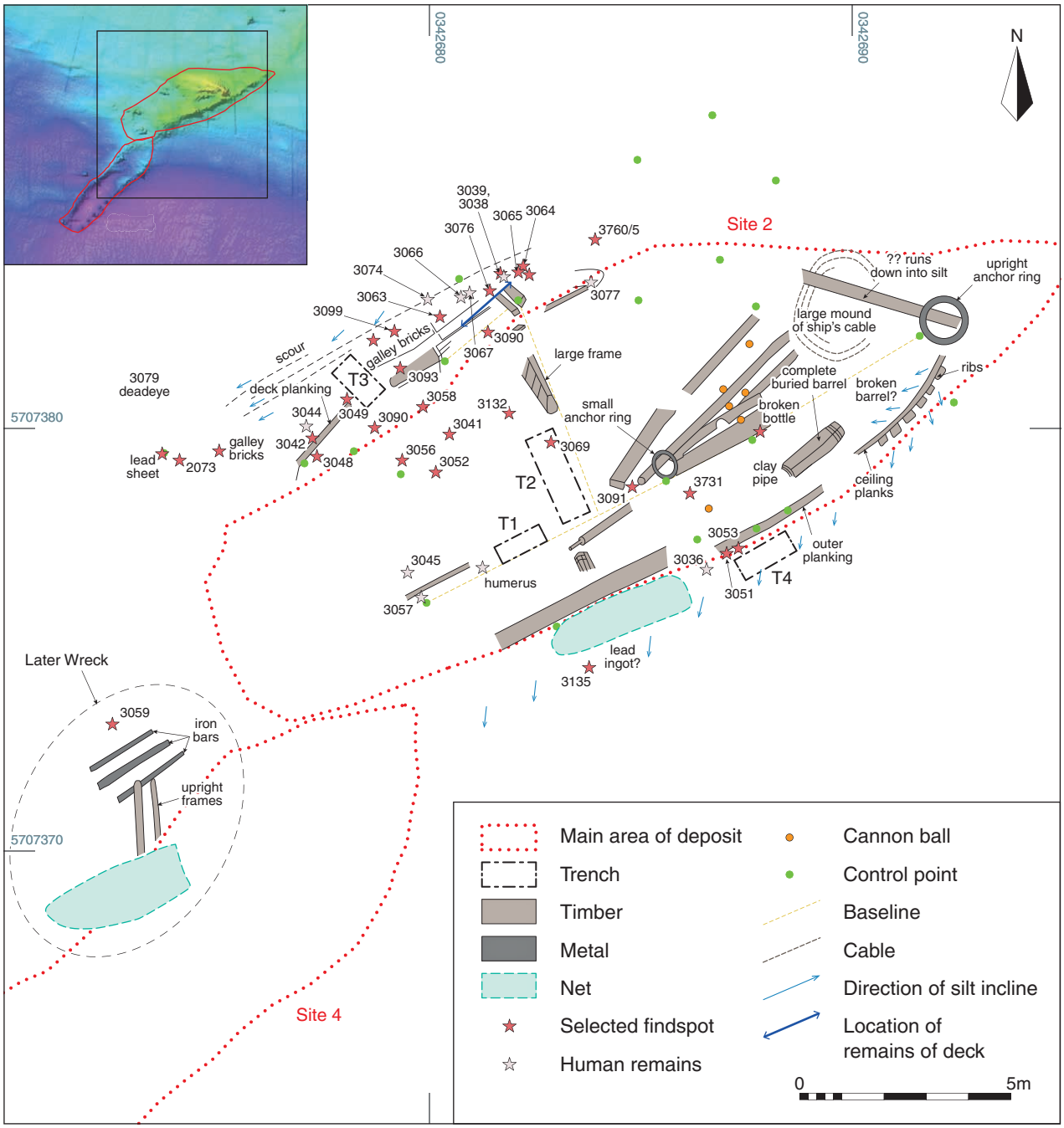


Figure 4.5 The London *site plan (© Steve Ellis)*

(or shot) pouches, were found in at least two alternating layers inside a chest located to the west of the gun carriage; a fragment of a pistol (3634; see Fig. 8.21) was also recovered from the lower levels of the chest. Time constraints prevented the full excavation of the contents of the chest but probing revealed that it extended at least another 200mm; this was left *in situ*. A single copper-alloy priming iron (3715; see Fig. 7.16), a pair of navigational dividers (3477; see Fig. 11.9) and two pewter spoons (3430 and 3600; see Fig. 11.3) found above the bandolier sets are unlikely to have been part of the contents of the chest.

Trench 3 was extremely artefact-rich, including numerous galley tiles and a fragile wooden box containing a number of glass bottle fragments with *in situ* corks. The tiles, used in and around the cooking hearth, along with the evidence from trench 2, suggests proximity to the cook room.

Trench 4

Trench 4 was located on the south-eastern edge of the site, outboard of trench 1. The exposed structure on this part of the site comprises closely spaced frames and inner and outer planking associated with the lower parts of the ship. The excavation followed the outer hull planking downwards with the aim of locating the keel, which was not encountered before the bottom of the trench became inaccessible

owing to the curvature of the hull. This suggests that the lowest section of the ship that includes the keel no longer survives.

The 1.5m square trench reached a depth of 1.4m below the seabed, so given the height of structure above the seabed (0.6m) the surviving depth of ship structure at this point is at least 2m. The very few finds encountered in trench 4 included a human clavicle (3441) and a clay pipe fragment (3440). The exposed planking was in very good condition and measured approximately 100mm (4") thick.

Discussion

The excavations on S2 confirmed the presence of a section of one side of the *London*, which appears to survive from the level of the main gundeck down to a point close to where the keel would have been (Fig. 4.5). The recovery of a complete gun carriage (3239) from trench 3 in 2015 identified stratified deposits within the gundeck of at least the length of the carriage (1.69m), while trench 4 recorded surviving structure to a depth of 2m.

The hull survives to a height of 800mm (31.5") above the level of the gunport sill in trench 3, which is thought to be the uppermost surviving structure of the wreck. A document of unknown date written by master shipwright Peter Pett (1610–72), who became Commissioner of Chatham dockyard in 1648 (Henning 1983), describes the dimensions of the ports for second, third and fourth-rate ships (TNA SP46/136/388). Although the document is undated it probably relates to the 1664 shipbuilding programme of two second-rates, four third-rates and two fourth-rates (Fox 1992, 277).

Pett stated that, with the exception of the four chase ports,[6] the gunports on the lower deck of all second-rates were to be 32" (813mm) square. The gunport found on the *London*, built in 1656, is wider at 35.4" (900mm), which suggests that the size of gunports on second-rates had been reduced by the time of the 1664 shipbuilding programme. If it is assumed that the ports on the broadside were square, then it appears that only the upper 100mm of the gunport is missing.

The distance from the outside of the hull in trench 3 to the outside of the hull near trench 4 on the opposite side of the wreck measured 8.4m. When this measurement (8.4m) is transcribed from the top of the gunport on to the cross-section, recently discovered in the Royal Collection, it strikes the vessel just below the keel (see Fig. 3.1).[7] This suggests that a section of one side of the hull survives from approximately the top of the gunport on the main gundeck to just before the keel at the bottom of the hold. This is speculative as there is likely to be a margin of error in the measurement taken on site owing to upstanding features and the challenging conditions. In addition the hull may have become distorted as a result of the explosion and settling.

A measurement taken from the geophysical image from the line of exposed timbers on the southern edge to the gundeck was recorded as 5m (16' 6"). This corresponds closely with the recorded depth of the *London's* hold and further supports the hypothesis that the remains survive to a point close to the keel.

The finds included organic objects, wood, leather, cordage (fibre), textile, candles, ivory, oakum, animal bone and human remains. A large assemblage of wood included ship's equipment such as blocks, hand crow levers and linstocks. Inorganic objects comprised metal, brick, tile, pottery, clay tobacco pipes and glass. Composite items comprised wood/metal and wood/fibre. Ship equipment included ship's parts, gunners' implements, small arms and other weaponry. The small finds can be categorised variously by function as used in commercial (coinage), domestic, medical, nautical, navigation, tools/equipment, weaponry (including a large amount of lead shot) and as yet 'uncertain'.

6. The four chase ports were to be 36" (914mm) wide by 33" (838mm) high.
7. The *London* had a recorded beam of 40' (8.4m) as built (41ft girdled) and a depth of hold of 16' 6" (approx. 5m) (Winfield 2009, 27; Fox 2012, 60).

Chapter 5
Conservation

Angela Middleton with a contribution by Ian Panter

With the exception of the gun carriage (see Panter, below), all finds, recovered either through surface collection by the licensee team or during the excavations, were delivered to Historic England at Fort Cumberland. The gun carriage recovered in 2015 (composite wood and iron) was taken to York Archaeological Trust (YAT) for conservation (see Panter, below).

At Fort Cumberland, remedial and investigative conservation work was undertaken on 718 numbered artefacts.[1] Remedial and investigative conservation aimed:

- to realise the artefact's research potential;
- to contribute to the project's aims and objectives; and
- to convert the artefacts to a stable and accessible condition, ready for archive deposition.[2]

X-radiography

Eighty-seven artefacts were X-radiographed (resulting in 82 X-ray plates[3]) for the following reasons:

- to aid identification when artefacts were obscured by corrosion products or embedded in concretions;
- to record the current level of preservation (Fig. 5.1a);
- to record the shape and dimension of metal components inside organic artefacts (e.g. linstocks) (Fig. 5.2);
- to reveal/record maker's or owner's marks on metal artefacts (e.g. pewter spoons) (Fig. 5.3); and
- to image internal components when disassembly was not possible (e.g. flexible rammer heads) (Fig. 5.4).

Desalination

Materials from the marine environment require desalination prior to the implementation of conservation treatments and before drying (Cronyn 1990, 81). Failure to remove these salts would result in salt efflorescence on drying, which in turn can lead to the delamination of surface layers owing to an increased volume of salt crystals when dry. Moreover, salts are hygroscopic and will attract moisture, which results in increased corrosion, especially detrimental to metal artefacts.

For the majority of artefacts (organic materials, copper alloys, glass, ceramic) desalination was undertaken by submersion in distilled water with regular water changes.[4] When conductivity readings reached levels below 100 micro-Siemens per centimetre (μS/cm) desalination was considered complete.

Iron artefacts

As iron corrodes rapidly in tap or distilled water, ferrous artefacts were desalinated using 0.5 molar (M) sodium hydroxide. This solution is highly alkaline (pH 14) and inhibits the corrosion of iron while the chlorides can still be extracted in an aqueous solution (Rimmer *et al.* 2013). Once the extraction rate of chloride plateaued, the solution was renewed. This process was continued until chloride extraction consistently measured less than 5 parts per million (ppm) (Rimmer *et al.* 2013), provided a ratio of 1:5 object weight (g) to solution volume (mL) was observed (Watkinson 1982).[5]

1. Artefacts were, in most cases, delivered wet to Fort Cumberland. Initial recording and registration of the artefacts was followed by a conservation assessment (Middleton 2016; Middleton and Nordgren 2017).
2. Close collaboration with all project specialists was required for access to the artefacts and sharing information. Especially close working was necessary between conservation and the material scientists (Dr Sarah Paynter, Dr Florian Ströbele) and palaeoecologist (Dr Zoë Hazell) for selection of artefacts for destructive sampling or confirmation of material compositions. Permission for sampling was given by Southend Museum Service, who are the archive repository. A tabulated overview of treatment per artefact is available in the archive.
3. A list of the X-radiographs and parameters is available in the archive. X-radiography was undertaken using a Gulmay HS 225kV Hi-Stability X-radiograph system and following established HE procedures. Computed radiography (CR) was employed using a Kodak Industrex HPX-1 scanner and Carestream Industrex Digital Viewing Software. Kodak Industrex High Resolution and XL Blue Digital Imaging Plates, both with and without copper, were scanned at 25-micron resolution; laser power: high; and photomultiplier setting: 10. Quality was ensured by using an Image Quality Indicator (IQI): Duplex wire type EN462-5.
4. The extraction of soluble salts was tracked by taking conductivity readings. The only exceptions are the hand crow levers, which due to their size were stored in a large tank. It was deemed uneconomic to use distilled water in this case so desalination was undertaken with tap water.
5. The extraction rate of chlorides in ppm was tracked using Hach Quantab® strips and the pH was tested at the same time. The chloride concentrations were plotted on a graph against the time elapsed between measurements.



Figure 5.1a Pulley block (3052); although the block looks well preserved, the radiograph reveals marine wood-borer damage (© Historic England Archive, photograph James O. Davies; © Historic England, radiograph Angela Middleton)

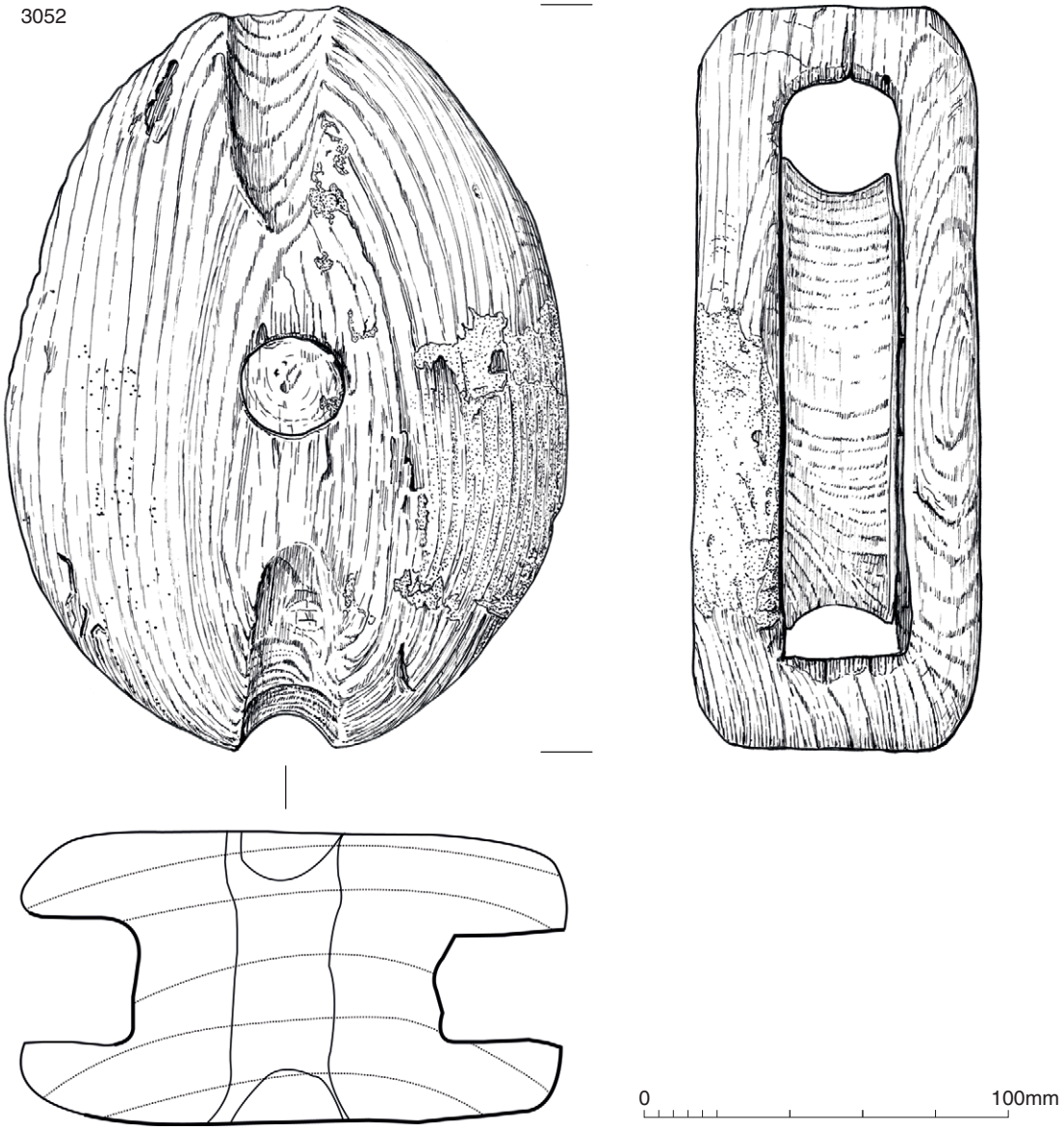


Fig 5.1b Pulley block (3052; © Historic England, drawing Ruth Parkin)

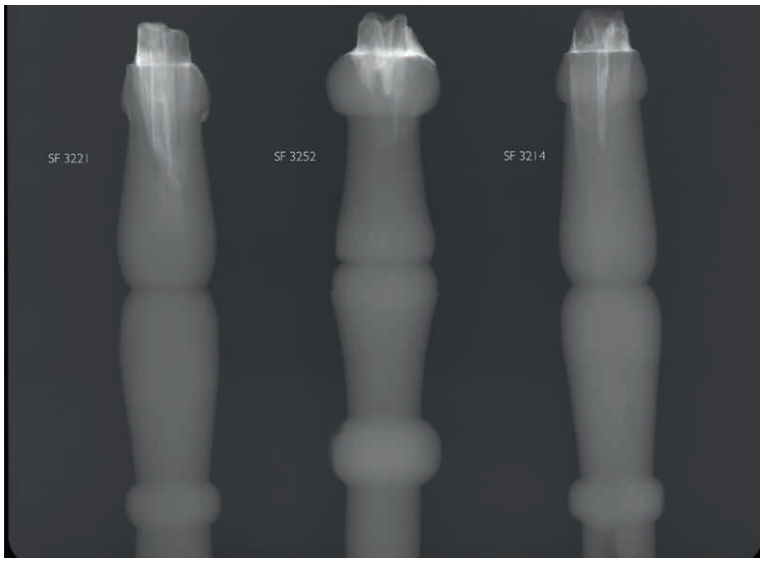


Figure 5.2 Radiograph of the ends of three linstocks revealing the remains of iron spikes and corrosion products (© Historic England, Eric Nordgren)



Figure 5.3 Photograph and radiograph of a pewter spoon (3600; © Historic England Archive, photograph James O. Davies) showing details of touchmark including the initials 'BA' (© Historic England, Eric Nordgren)



Figure 5.4 Radiograph of a sponge head (3324) revealing the internal rope and the location of nails at the wider end (© Historic England, Eric Nordgren)



Figure 5.5 Concretion removal from a hammer (3732; © Historic England, photograph Angela Middleton)



Figure 5.6 Concretion removal from a deadeye (3079; © Historic England, photograph Angela Middleton)

Composite objects (iron and wood)

If desalination in distilled water was undertaken on some composite artefacts, the iron would corrode heavily. This not only causes unsightly orange discolouration of any wooden component but would also jeopardise the preservation of the iron and wood elements. In the case of the pistol butt (3634; see Fig. 8.21), the hammer (3732; see Fig 5.5) and the deadeyes (3079 (see Fig. 5.6) and 3315) a corrosion inhibitor[6] was added to the distilled water. This enabled the extraction of soluble salts in an aqueous solution while keeping the iron corrosion at bay.[7]

Remedial conservation

Inorganic materials

Inorganic materials were generally cleaned using brushes, sponges and wooden skewers to remove loosely adhering sediment or easily removable marine accretions.[8] Some copper-alloy artefacts were cleaned while wet using the air-abrasive (aluminium oxide powder) to remove thin layers of corrosion. After desalination glass, ceramic, copper alloy, pewter, lead and silver artefacts were slowly air-dried at ambient conditions.[9] The pewter artefacts were cleaned after drying with the air-abrasive (aluminium oxide powder). This removed thin but hard corrosion layers and brought out details such as the touch mark on a spoon (3600; see Fig. 5.3).

Iron artefacts were recovered either as concretions or as heavily concreted components of composite objects (see below). Concretion layers were removed using a hammer and cold chisel, or the air-scribe, which revealed the shape and size of the iron artefact or component.[10] Concretion removal was followed by desalination (Fig. 5.5 and 5.6).

Even though the heads of hand crow levers were covered in thick layers of concretion, and in one case the concretion had fused three hand crow levers together, X-radiography revealed that no iron actually remained. The bulk of the concretions were removed by hammer and chisel, with the last remaining layers close to the wooden surface removed by ultrasonic scaler. This revealed the nail holes that originally attached the iron shoes to the heads of the hand crow levers. As iron was no longer present, desalination was undertaken using tap water.

Organic materials

Organic materials were cleaned using brushes, sponges and an air-scribe or ultrasonic scaler (operated with tap water).[11] After cleaning and desalination, wooden artefacts were conserved with the two-step polyethylene glycol (PEG) treatment, followed by vacuum freeze-drying.[12] Leather artefacts were cleaned on a mesh-covered frame using running tap water, sponges and soft brushes (Fig. 5.7). In some cases artefacts were cleaned additionally with the air-brush (operated with tap water). After cleaning, leather artefacts were conserved with PEG treatment, followed by vacuum freeze-drying (Fig. 5.8).[13]

In almost all cases textile finds were associated with other artefacts (see Chapter 16, Gleba). In these cases (e.g. a leather sole/insole with textile fragment (3118H) and a linstock with textile binding (3188A and B)) the two materials were treated together. Textile associated with leather was treated like leather, while textile associated with wood was treated like wood. Textiles unassociated with other materials (3704 and 3632) were conserved with PEG treatment, followed by vacuum freeze-drying (Fig. 5.9).[14]

A trial was undertaken to identify the most suitable conservation method for the rope finds (Middleton 2018). Freeze-drying without prior impregnation with PEG proved more successful in terms of colour, dimensions and flexibility than the prior application of PEG,[15] which had produced the best results for individual rope strands (Fig. 5.10).

6. 1% Hostacor IT.
7. Desalination progress was tracked using Hach Quantab® strips and the readings were plotted on a graph.
8. In cases where extra cleaning was undertaken this is mentioned below.
9. Artefacts were laid out on trays covered with a lid or plastic sheet. After two days the cover was removed for short periods during the day and then replaced overnight. This procedure was repeated until the artefact was completely dry. Artefacts were turned regularly and visually checked for surface loss.
10. This aided desalination as chlorides did not have to penetrate thick layers of concretion and a substantial amount of chlorides trapped in concretions was physically removed.
11. In cases where additional cleaning was undertaken this is mentioned below.
12. Wooden artefacts were immersed in a 30% (v/v) PEG400 solution for approximately three months and then a 30% (w/v) PEG4000 solution for a further three months. Artefacts were then rinsed briefly with tap water and dabbed dry with tissue paper before being pre-frozen in a domestic chest freezer at -30°C. After about one week the frozen artefacts were weighed and transferred into the vacuum freeze-drying chamber where drying commenced at -30°C. As ice sublimated, the weight loss was recorded regularly. The endpoint was determined when the weight loss plateaued or when the artefact looked and felt dry. Post-drying, excess PEG was removed using brushes, blowers and wooden skewers. This step required minimal input as most of the PEG was already removed when still wet.
13. After cleaning, leather was impregnated with 30% PEG400 for two weeks. Preparation for freeze-drying followed those for wood. Vacuum freeze-drying was monitored closely and leather was weighed every two hours. The endpoint was determined when the weight loss plateaued or when the artefact looked and felt dry. Especially thin artefacts often finished drying after two hours. Where thicker and thinner layers on one leather artefact were present (e.g. shoe with stacked heel) the thinner layers were protected with silicone release paper, cardboard and/or grain-filled plastic ziplock bags. This slowed sublimation in the thin areas down while still allowing sublimation in the thicker layers of leather (Fig. 5.7). In some cases the quarters and uppers of a shoe were supported on X-Lite® inserts to preserve the 3-D shape of the shoe (Fig. 5.8). Post-drying, excess PEG was removed using brushes, blowers and wooden skewers. This step required minimal input as most of the PEG was already removed when still wet.
14. These textiles were impregnated with 10% PEG1500 for four weeks. They were then removed from the solution and gently dabbed dry with tissue paper before being pre-frozen in a domestic chest freezer at -30°C. After about one week the frozen artefacts were weighed and transferred into the vacuum freeze-drying chamber where drying commenced at -30°C. As ice sublimated, the weight loss was recorded regularly. The endpoint was determined when the weight loss plateaued or when the artefact looked and felt dry (Fig. 5.9). Post-drying, excess PEG was removed using brushes, blowers and wooden skewers. This step required minimal input as most of the PEG was already removed when still wet.
15. 10% PEG1500.



Figure 5.7 Leather book cover (3391) during treatment, where the thinner edges are covered and protected during vacuum freeze drying (top) and post-treatment (bottom) (© Historic England, top photograph Angela Middleton, © Historic England Archive, bottom photograph James O. Davies)

Human remains, worked bone and ivory were air-dried at ambient conditions after desalination (Fig. 5.11).[16]

Composite materials

To compensate for the corrosive effects of PEG on metal components when impregnating wood (Guilminot *et al.* 2002) a corrosion inhibitor[17] was added to the impregnation solution for the hammer (3732) and the deadeye (3079). The artefacts were then treated as for wood. Cork stoppers were found firmly wedged inside the necks of three glass bottles (3155, 3157 and 3436) and could not be removed (Fig. 5.12). During desalination, however, one cork (3112 in bottle 3436) fell out, so it was used to undertake a drying trial.[18]

Other materials

The candles were washed under running water to remove loosely adhering soil, using a soft brush. The conch shell and coal fragments were washed in water. After desalination these remains and artefacts were slowly air-dried at ambient conditions.

16. This involved laying out the remains on trays and covering the tray with a lid or plastic sheet. After two days the cover was removed for short periods of time during the day and then covered fully overnight. This procedure was repeated until the artefact was completely dry. Artefacts were checked visually for surface loss and were turned regularly.
17. 1% Hostacor IT.
18. The wet cork was immersed in increasingly higher concentrations of industrial methylated spirit (IMS) and water. It remained fully submerged in 100% IMS for two days. It was then submerged in a fresh solution of 100% IMS for another two days to ensure the complete removal of water. The cork was then air-dried slowly at ambient conditions, inside a glass beaker with a glass cover. This cork underwent considerable shrinkage. The other two corks inside the glass bottle fragments (3155 and 3157) were air-dried slowly under a cover of a wet semi-permeable membrane (Fig. 8.19), which worked better as shrinkage was reduced.



Figure 5.8 Leather shoe (3064/3065) during treatment on a former (top) and post-treatment (bottom) (© Historic England, top photograph Angela Middleton, © Historic England Archive, bottom photograph James O. Davies)



Figure 5.9 Textile and rope (3704) pre- and post-treatment (© Historic England, top photograph Angela Middleton, © Historic England Archive, bottom photograph James O. Davies)



Figure 5.10 Rope (3163) pre- and post-vacuum freeze-drying without impregnation (© Historic England, photographs Angela Middleton)

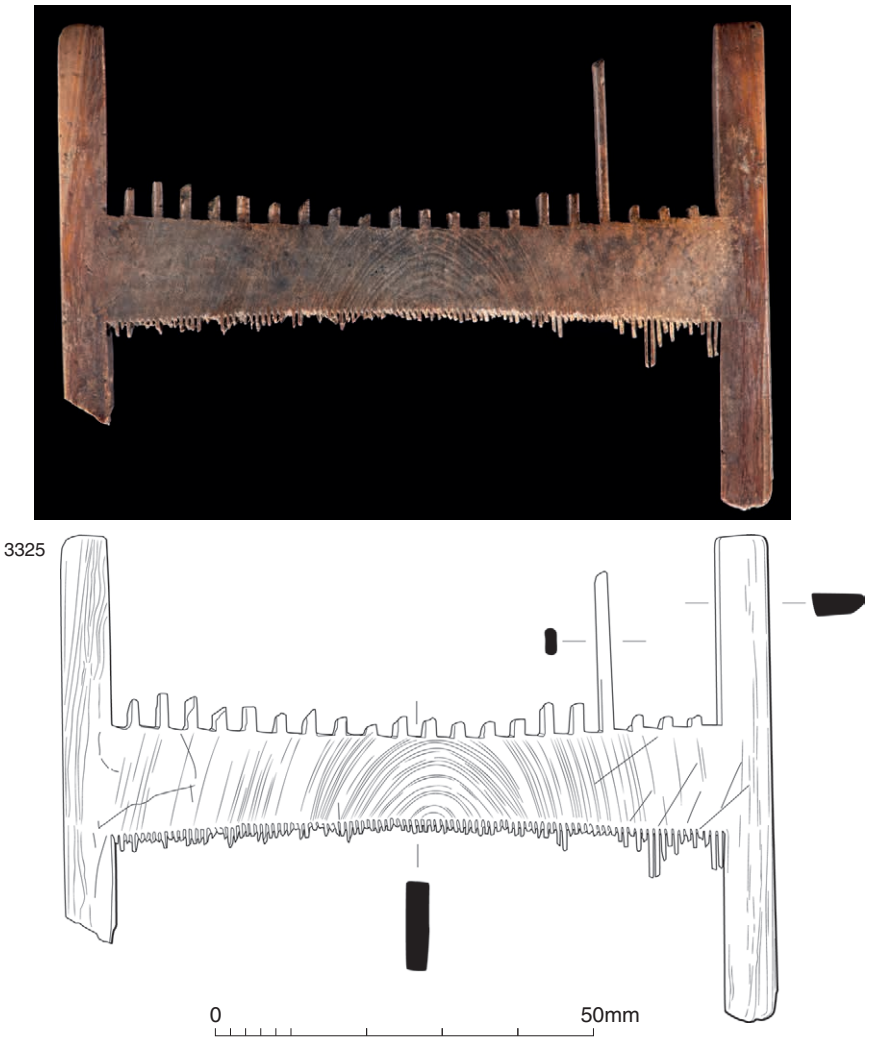


Figure 5.11 Photograph and drawing of ivory comb post-treatment (3325; top © Historic England Archive, photograph James O. Davies, bottom © Historic England, drawing Aleksandra Osinska)



Figure 5.12 Glass bottle neck with cork (3157) before (left) and after treatment (right) (© Historic England, photographs Angela Middleton)

Conservation of the wooden gun carriage

by Ian Panter

The gun carriage (Fig. 5.13) comprises a number of wooden elements (3149, 3239, 3317, 3318, 3357, 3499, 3503 and 3531) all made from *Ulmus* sp. (elm).[19] It measures 1.57m long, tapering from 0.84m to 0.67m in width, with each cheek measuring 0.52m in height. The wood is well preserved although there is evidence of both woodworm infestation, probably from the time when the carriage was in storage when the ship was in ordinary, and post-deposition marine gribble (a wood-boring crustacean) attack (Fig. 5.14).[20] In addition the wrought iron components (bolts and cross braces) are corroded and heavily encrusted with concretion. The iron corrosion stains the uppermost sections of the two cheeks. As the preservation of the gun carriage was good, it was conserved 'as found' rather than being dismantled into separate individual components, which may have resulted in unacceptable damage (Fig. 5.15).

Conservation procedure

The concretions (Fig. 5.16) were removed mechanically (using hammer and chisel) (Fig. 5.17)[21] and were then X-radiographed to assess the extent of survival of wrought iron fittings encapsulated within the concretions. This revealed variable states of preservation; some of the lumps are devoid of any surviving iron, while others display substantial survival of metalwork (Fig. 5.18). Two small sections of the front and rear bolts on the right-side cheek could not be removed without damaging the wood, so they were left *in situ*.

Once the concretions had been removed and the gun carriage had been cleaned it was immersed in freshwater to remove harmful chlorides.[22] The wood was then consolidated using two grades of PEG.[23] Once appropriate levels of concentration had been achieved,[24] the gun carriage was left to soak for almost two years to ensure adequate penetration of the PEG throughout the timber. It was then dried using accelerated vacuum freeze-drying,[25] which is a very gentle drying process as the water is removed as a vapour; this process removed a total of 232.5 litres of water (Fig. 5.19).[26]

Excess PEG that remained on the surface of the wood was then removed carefully using a combination of hot-air blower and absorbent paper towel moistened with tapwater (Figs 5.19–5.21). As long as no damage would be caused to the underlying wood, residual concretions adhering to the wood were carefully removed using a hammer and chisel.[27] The small boards that had been nailed to the inner face of each cheek (as part of the adaptation to fit a longer but narrower cannon) were reattached; the nails used to fix the boards had corroded (Fig. 5.22)[28] and where necessary gaps, including a large crack towards the base of the left-side cheek, were filled.[29] The wood surface was then treated to provide additional protection.[30]

The wrought iron bolts that remained in the wood were cleaned mechanically,[31] degreased[32] and painted (Fig. 5.23).[33] The wrought iron elements removed from the carriage underwent desalination[34] and were then washed further to remove the sodium hydroxide, then solvent-dried and repacked in a very dry environment.[35]

19. Identified by Steven Allen, YAT. Species identification was undertaken through examination of thin slices of the transverse, radial longitudinal and tangential longitudinal planes of the wood using a transmitted light microscope at x40, x100 and x200 magnification as appropriate. Samples for identification were taken from already damaged areas of the artefacts to minimise damage to original surfaces. All species identifications follow Schweingruber (1982). These were the only wood identifications undertaken by Allen, to enable a conservation regime to be formulated for the gun carriage; all other wood identifications were undertaken by Hazell and Aitken (2019 and Chapter 8).
20. A rapid pin test survey of the wood demonstrated that overall the wood was very well preserved with pockets of decay to a depth of only 1–2mm below the surface and where there was surviving sapwood, which is always more decayed than heartwood. Areas of wood affected by marine gribble were observed to be more brittle than surrounding areas, probably a function of the loss of the lignin component from the wood fibres.
21. As it was not possible to bring a suitable X-radiograph source sufficiently powerful to penetrate the concretions to the York facility, nor was it deemed acceptable to submit the carriage to potential risks from further movement and transportation, a Faxitron cabinet X-radiograph source was used at the YAT conservation laboratory.
22. To an acceptable concentration of less than 50ppm. Readings were taken on a weekly basis and the water was changed when chloride extraction had plateaued. Desalination took six weeks and required two changes of water.
23. These were 5% PEG400 and 35% PEG4000. The PEG400 is a liquid at room temperature and acts to prevent the volume increase that water goes through as it freezes (which could rupture fragile wood cell structures) while the PEG4000 is solid at room temperature and functions as a scaffold within the wood cells, preventing them from collapsing as the water is removed during the drying phase. Initially the gun carriage was immersed in a 5% v/v aqueous solution of PEG400, containing 0.2% v/v Linkcide KMC®, a broad-spectrum biocide to control microbial activity, and 0.1% v/v Hostacor IT®, an iron corrosion inhibitor. After soaking for one month the PEG4000 was added in 5% w/v increments at monthly intervals, with further additions of biocide and corrosion inhibitor as and when necessary.
24. 35% PEG4000.
25. A 5m long Connell D16/50 vacuum freeze-drying unit was used (run #17, 28/2/19–16/5/19). The freeze-drying process uses sublimation to remove residual water from within the wood cells. Once frozen to a temperature of *c.* -15°C, a vacuum is applied to the entire system and the water in the wood (now existing as ice rather than liquid water) is converted from the solid state to the vapour state. This water vapour is collected in a separate condenser unit which operates at a lower temperature (usually between -40 and -50°C) than the drying chamber, where it reforms as ice.
26. The endpoint was determined when the quantity of water coming off the wood was less than 1 litre per week and temperatures within the wood (as measured by thermocouples inserted into cracks in the wood) had reached ambient temperature. The drying chamber was brought back up to atmospheric pressure and the moisture content of the wood was checked with a Wagner® electromagnetic type moisture meter. Moisture contents throughout the wood were observed to be between 10% and 15%.
27. In this situation the remaining concretion was consolidated with a 10% w/v solution of Paraloid B72 in acetone.
28. Using an epoxy adhesive (epoxy adhesives are unaffected by the PEG, which can soften the usual conservation-grade adhesives including Paraloid B72 and HMG cellulose nitrates).
29. Using dilute Paraloid B72 solution, glass microspheres and acrylic pigments to colour match the surrounding wood.
30. Using a solution of 20% w/v PEG6000 in water, brushed on.
31. With fine wire wool (grade 0000) to remove flash rusting.
32. With acetone.
33. With 10% w/v tannic acid solution in a 1:1 mix of reverse osmosis water and industrial methylated spirits. The tannic acid was found not to protect the underlying iron, so a two-part zinc rich epoxy anti-corrosion paint was applied to the exposed iron surface (Jotun Barrier® paint). Once dry a further application using Hammerite® anti-corrosion paint was brushed on to seal the metalwork.
34. Through washing in a 2% w/v aqueous sodium hydroxide solution.
35. Where the relative humidity is less than 15%. The conserved gun carriage should be stored or displayed at an optimum relative humidity of between 50–55%, light levels should not exceed 150 lux and the temperature should be stable. The carriage should be examined periodically to ensure the attached ironwork remains stable and is not actively corroding.



Figure 5.13 Gun carriage with concreted bolts and iron staining (© Historic England, photograph York Archaeological Trust)



Figure 5.14 Complete axle and cross-bracing elements (post-conservation) displaying erosion from gribble attack. Note remains of iron bolt (x2) (© Historic England, photograph York Archaeological Trust)



Figure 5.15 The truck and axle assemblage (with cross-bracing members behind) prior to treatment (© Historic England, photograph York Archaeological Trust)



Figure 5.16 Large concreted cross-bolts between the cheeks (x2) (© Historic England, photograph York Archaeological Trust)



Figure 5.17 Post-removal of concretions. Bolt heads only survive as stains on the wood (© Historic England, photograph York Archaeological Trust)



Figure 5.18 Concretion removed from front bolt. The iron remained in situ *to prevent damage to the wood (© Historic England, photograph York Archaeological Trust)*



Figure 5.19 Gun carriage on removal from freeze-drier. The white deposits are the excess PEG (© Historic England, photograph York Archaeological Trust)



Figure 5.20 Gun carriage after removal of excess PEG (© Historic England Archive, photograph Christopher Redgrave)



Figure 5.21 One of the conserved trucks (wheels 3149; © Historic England Archive, photograph James O. Davies)



Figure 5.22 Board re-attached to the internal face of the left cheek with detail (© Historic England Archive, Christopher Redgrave)



Figure 5.23 Treated wrought iron bolt protruding from left cheek (© Historic England Archive, photograph Christopher Redgrave)

Chapter 6
Ship's Parts

Richard Endsor

Contemporary evidence for the structure of the *London*

Naval architecture and shipbuilding methods for the later 18th and 19th centuries are well understood as there are many surviving plans and even a few remaining ships. This is certainly not the case for the 17th century. The *London* was built during a period of many changes in the development of naval shipbuilding and warfare. The lack of archaeological evidence for ships of this period leaves significant gaps in our knowledge, so the best information comes from surviving documentary evidence.

The best contemporary evidence for the appearance of the *London* comes from a volume in the Royal Collection. It contains some of the best surviving architectural drawings of a ship from the 17th century, which happens fortuitously to be the *London* (Fig. 6.1).[1] It includes a list of the guns on board on 13 October 1657 (see Fig. 3.2), and three architectural drawings (Figs 3.1, 6.1 and 6.2).[2] The drawing of the stern includes the Royal arms (Fig. 6.2), which suggests that it must have been drawn after the Restoration of the monarchy in 1660.

The drawing of the midship section illustrates some of the ship's structure (see Fig. 3.1). The drawing is very accurate as the depth of the hold scaled off the recorded breadth of 40 feet equates to the depth of the hold of 16' 6" found in the records of the ship. Although the drawings are not drafts that Captain John Taylor could have used to build the ship, they are convincingly authoritative and were probably copied from the original drafts. The ship is also illustrated in two detailed drawings by Dutch artist Willem van de Velde the Elder, which show the carvings and disposition of the gunports (Figs 1.1 and 6.3).

In 1677 a whole fleet of 30 new ships, including one first-rate of 1400 tonnes, nine second-rates of not less than 1100 tonnes, and 20 third-rates of not less than 900 tonnes (Bryant 1935, 166), was ordered, the second-rates of which were almost identical in weight, dimensions and gunport arrangement to the *London* (Figs 6.4 and 6.5). The only difference was that the *London* had a light unarmed deck connecting the forecastle and quarterdeck. Samuel Pepys oversaw the building of this fleet and because of its importance compiled a considerable archive about the ships. This archive records the 16 major overall dimensions as well as the sizes of nearly all the individual pieces of timber used to build the ships. They provide a good indication of the size of structures which could have been expected to be found on the remains of the *London* (Endsor 2009, 9–16).

The relationship between contemporary evidence and modern archaeology

A study of the ship's parts that have been recovered from the wreck so far can reveal a great deal about the ship's structure, its capabilities and how it functioned, to add to our limited understanding of both the ship and 17th-century ship design and development.[3] Artefacts in this category include a scupper liner, a plank fragment, pulley blocks, deadeyes, cable, rope, bricks and tiles. It is possible to determine from where in the ship some of these artefacts came, both from their position on the wreck site and from their size.

Lead scupper liner

A lead scupper liner (3059) with one flanged end recovered from the site measures 42cm (16.5") long and has an average internal diameter of 70mm (2.75"), which equates to the size of scupper liners on the upper decks of similar-sized vessels (Fig. 6.6). A lead pipe lined the scupper, which

1. https://www.rct.uk/collection/1047387/the-ship-london-on-her-first-voiadge (accessed 26 March 2020).
2. These drawings were discovered during a search of the archives by Dr Douglas McElvogue.
3. With an accurate record of the location from which artefacts have been recovered it should be possible to reconstruct just what the *London* was like. The more accurate the records the more accurate will be any reconstruction.

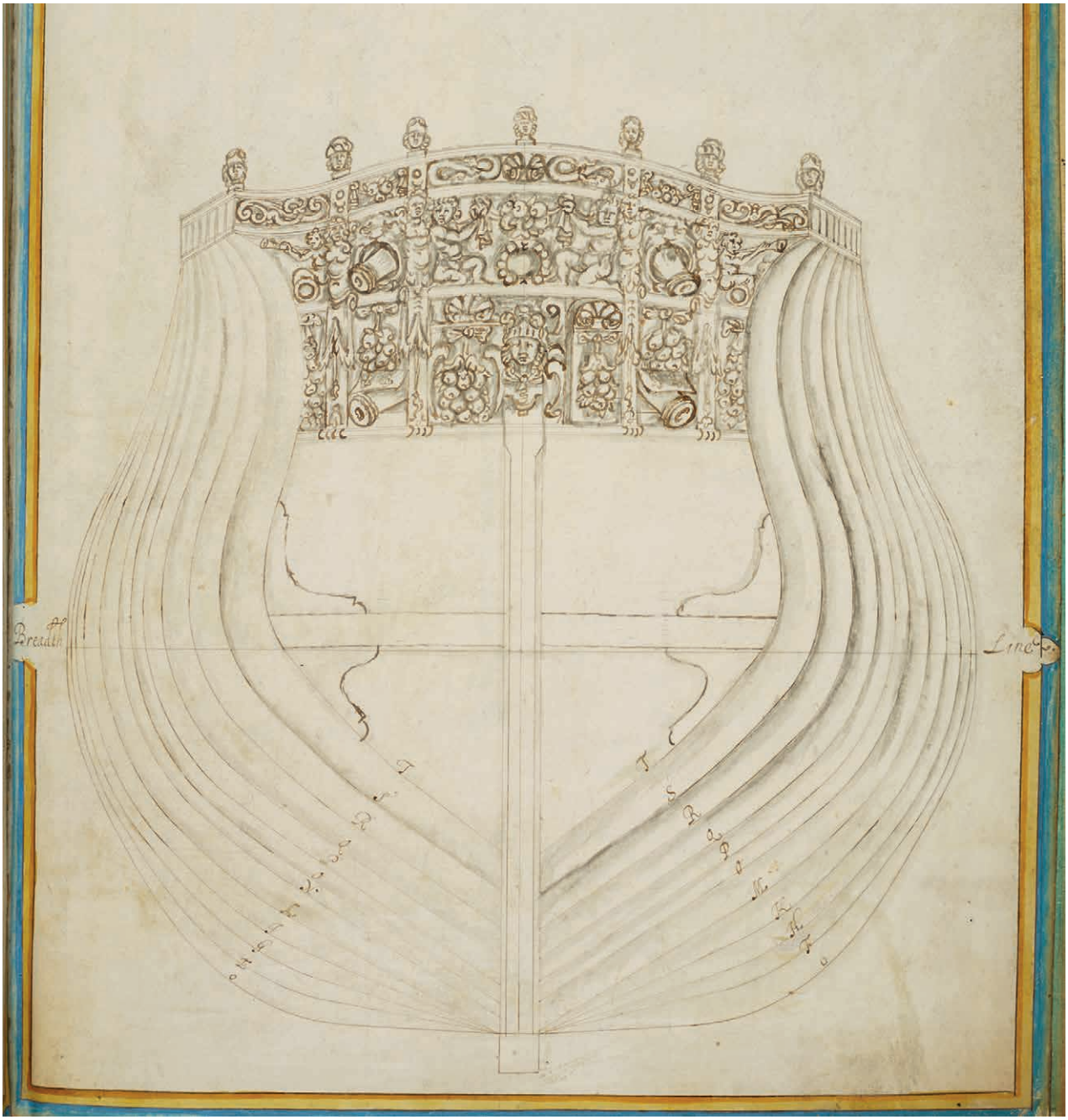


Figure 6.1 Contemporary drawing of the prow decorations on the London *(© Royal Collection Enterprises Limited 2024 Royal Collection Trust)*

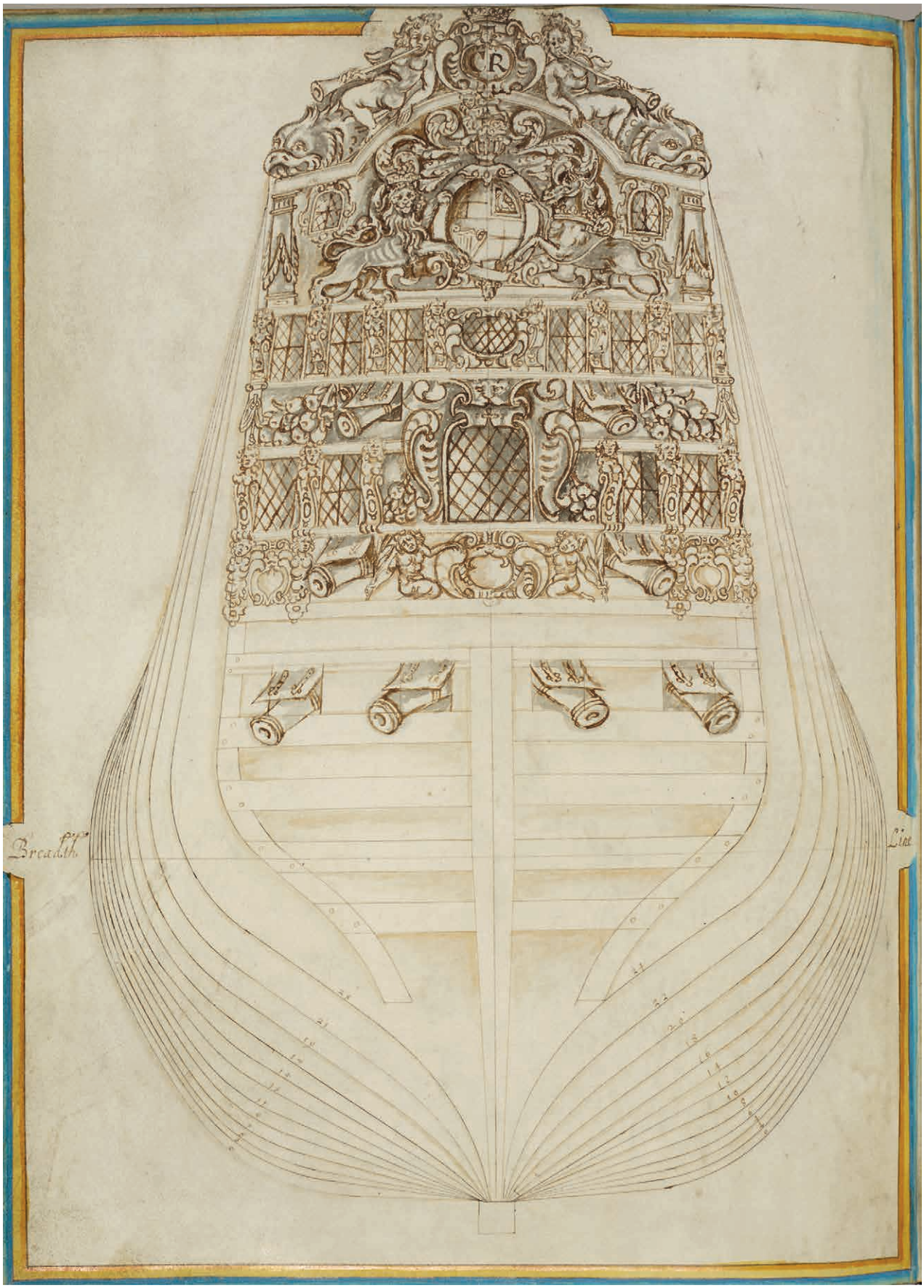


Figure 6.2 Contemporary drawing of the stern of the London *showing the Royal arms (© Royal Collection Enterprises Limited 2024 Royal Collection Trust)*

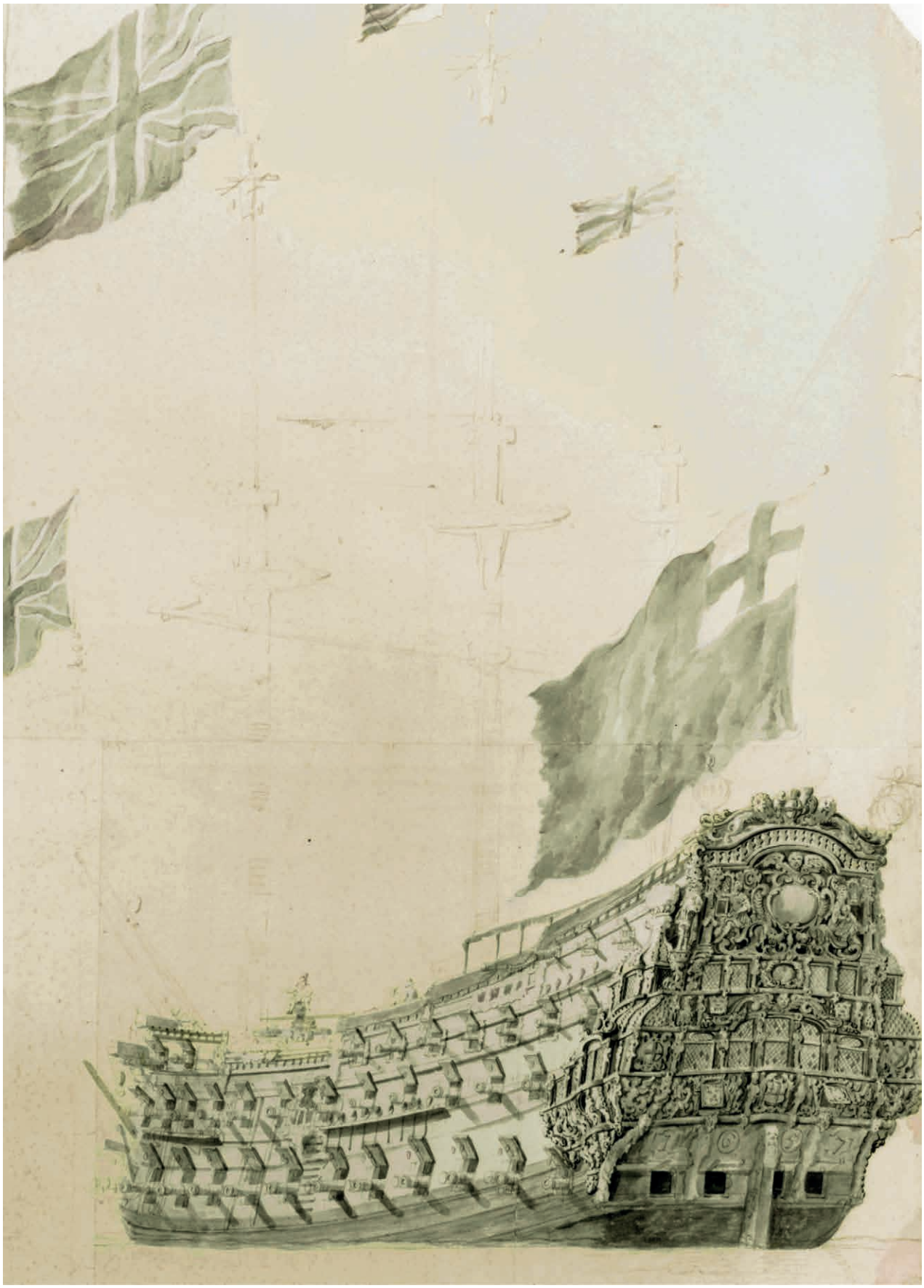


Figure 6.3 Van de Velde the Elder's drawing of the London *(© Atlas van Stolk, Rotterdam)*



Figure 6.4 The main gundeck structure of the London *(© Historic England, drawing Richard Endsor)*

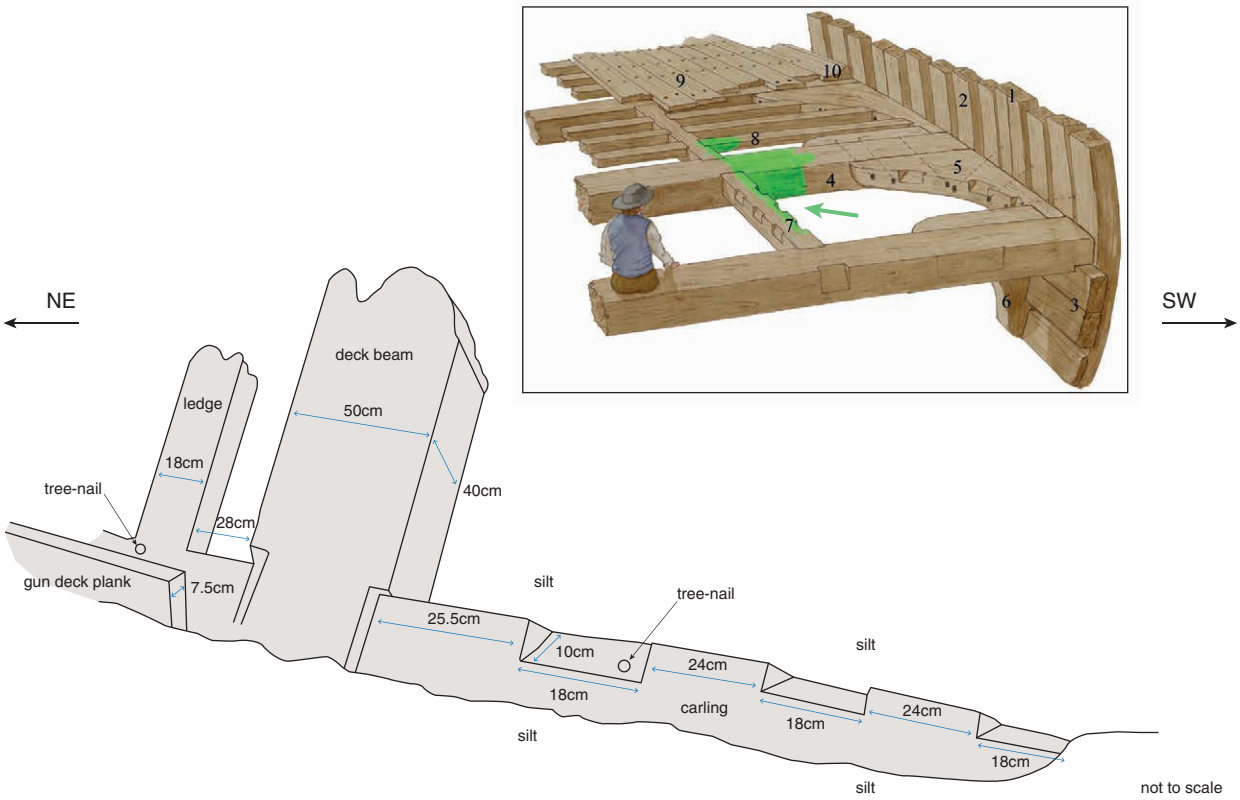


Figure 6.5 Part of the remains of the deck of the London *(based on drawing by licensee). The area surveyed by the licensee is highlighted in green (© Historic England, drawing Richard Endsor, Steve Ellis)*

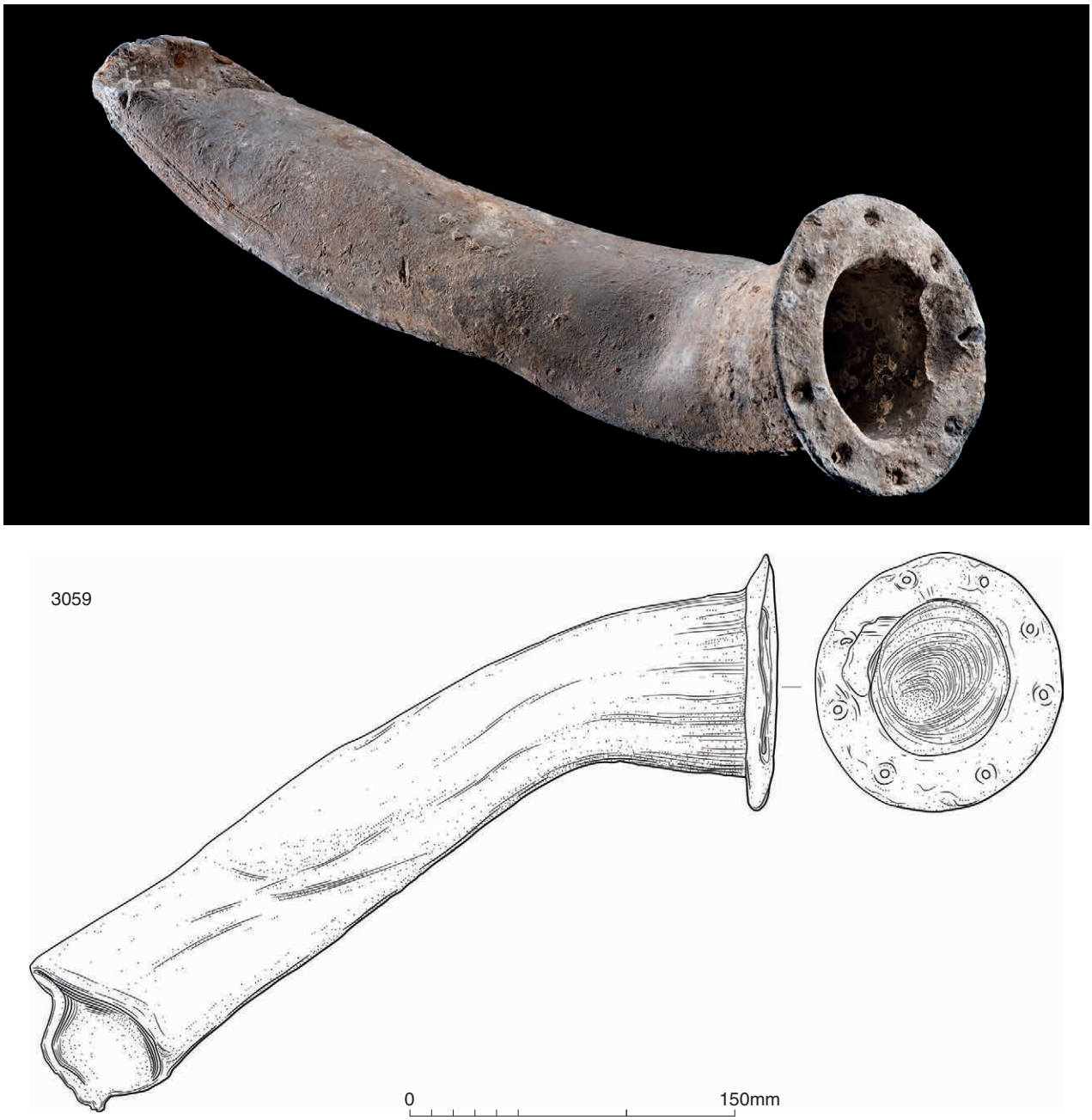


Figure 6.6 Complete lead scupper liner (3059; © Historic England Archive, photograph James O. Davies, © Historic England, drawing Aleksandra Osinska)



Figure 6.7 The recovered plate appears to be a puttock plate used at the lower end of the mast shrouds (© Historic England, photograph Angela Middleton)



Figure 6.8 The topmast shrouds attached to the puttock shrouds by the puttock plate (highlighted in red © Historic England, drawing Richard Endsor)

was a drainhole through the frame timbers of a ship. The flanged end was fixed to the outside of the ship, while the oblique end fitted inside the ship, flush with the waterways at the edge of the decks, to enable water to drain out. In use, lead scupper liners at the level of the main gundeck had leather scupper covers (spouts) nailed to the outside, which fitted over the lead and collapsed when submerged to prevent the ingress of seawater.

Puttock plate and iron-bound deadeye

Two iron-bound deadeyes (3079 and 3315; Fig. 6.7) were attached to plates measuring 160mm (6½") and 200mm (8") in diameter respectively. These are too small to be chain plates that would have attached the lower shrouds to the hull, even for the mizzen mast. Chain plates have an eye at the lower end through which a bolt fitted, whereas the recovered plates appear to have a hook in common with puttock plates. The recovered artefacts are therefore probably puttock plates for the main or fore topmast (Fig. 6.8). The difference in size may suggest that the larger one was for the main mast and the smaller one was for the foremast. They may have been part of the *in situ* rigging or could have been spares from the boatswain's stores.

Double block

Two double blocks (3127 and 3358) may have been two of the 72 blocks of 8" (203mm) or 9" (229mm) supplied by the Ordnance Office in 1664 (Fig. 6.9). They were found in proximity to the recovered gun carriage so were probably the forward blocks of a large gun's train tackle, used to haul the carriage up to the firing position after loading. Gun tackle was attached to each side of the carriage by high-level eye bolts near the second step of each cheek. These were attached to the ship's side by ring bolts that passed through the planking and frame timbers, secured by forelocks to the outside planking.

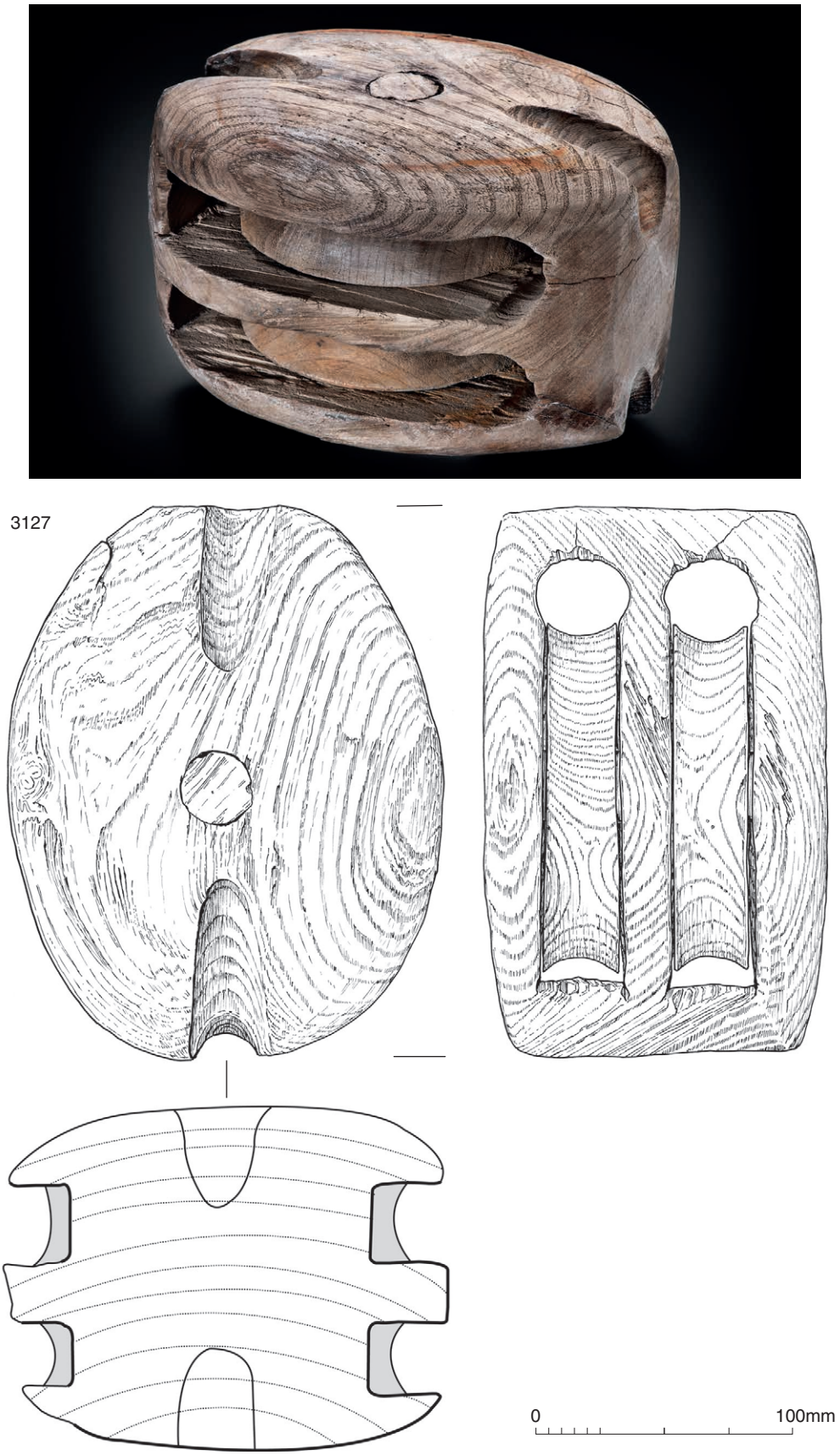


Figure 6.9 Double block (3127) believed to be part of the gun tackle (© Historic England Archive, photograph James O. Davies, © Historic England, drawing Ruth Parkin)

Chapter 7
Gun Equipment and Small Arms

Daniel Pascoe, Alex Hildred, Richard Endsor and Michael Walsh

The excavation of the intact gun carriage revealed that it had been at its gun station adjacent to a gunport on the main gundeck. The excavation uncovered not only the associated gun tackle either side of it, including two double blocks at the front and two single blocks at the rear, but also many more gunners' implements than were needed to operate one gun, including multiples of hand crow levers, linstocks and flexible rammers, only some of which were recovered. Ordinarily this equipment would have been distributed to each of the *London's* 76 guns, that matched the bore and length of the associated gun, to secure, manoeuvre, clean, load and fire it (Pascoe 2017, 52).

Large quantities of equipment for firearms, including powder boxes[1] and leather bandoliers, were recovered from the remains of a wooden chest located to the east of the carriage. Owing to time constraints, the partially excavated chest was left *in situ* and reburied with spoil. The butt of a pistol was recovered from a layer below the chest. The discovery of this chest in the vicinity of a gun station on the main gundeck is unusual, as ordinarily chests of small arms and ammunition, as well as spare gunners' equipment, would have been stowed for safety in the gunners' stores located on a platform below the main gundeck (Fox 2012, 61). The discovery of excess gun equipment and small arms in the vicinity of one gun station sheds light on the last moments of the *London* just before the ship exploded. The ship was not yet ready for the open sea as the crew was still clearly in the process of either stowing the equipment or was distributing it throughout the ship in preparation for battle.

The gun carriage

During excavations in 2014 on S2 the rear sections of two gun carriages were discovered protruding from the seabed silts on the northern edge of the site with trucks (wheels) abutting the main gundeck (Cotswold Archaeology 2014). Oddly, the associated cannon were missing from each carriage; either they had been dislodged during the explosion or removed at a later date. The latter seems more plausible as the remains of the cap-squares and breeching rope were still *in situ* (Pascoe 2017, 34–5).

In August 2015 one of these near-complete carriages (3239) was fully excavated and recovered (Figs 7.1 and 7.2), along with most of the associated gun tackle, furniture and gunners' implements. The excavation revealed that the front of the carriage was abutting the sill of a gunport (Cotswold Archaeology 2017c; Pascoe 2017, 34). This was the largest wooden artefact recovered from the *London*.

An attempt has been made to match one of the salvaged guns to the recovered gun carriage, as the presence of the remains of the cap-squares and breeching rope suggests that the cannon had not been dislodged at the time of the explosion. The photographs of two of the Dutch cannon (see Figs 3.9 and 3.10) recovered by the salvage diver in 2007 show that the muzzle ends are free of marine growth, which suggests that the muzzles had been buried until the time they were lifted. Comparisons of the dimensions of the recovered guns with those of the gun carriage indicate that the Coenraet Antonis (1600) gun most closely fits the dimensions of the adaptions on the recovered carriage.

The gun carriage (3239; see also Chapter 8, Allen) is one of a very small number of known possible 17th-century examples. Gun carriages have been recovered from the *Mary Rose* (1545), the *Vasa* (1628), the Duart Castle wreck (1653) and the *Stirling Castle* (1703); the latter being the most similar in design (Pascoe 2017, 34). It is what is commonly known as a 'truck and bed' carriage, having four trucks attached to two wooden axles (in contrast to the images of the gun carriages in the cross-section of the *London* (see Fig. 3.1), which appears to show carriages with solid half-circular rear skids rather than trucks) below a timber bed, which provided the main strength of the carriage (Lavery 2006, 127).

The partially concreted remains of iron cap-squares were found either side of the deep trunnion recesses cut into the top surfaces of the carriage cheeks. The rear of each

1. The powder boxes held single charges of gunpowder for use in the firing of hand weapons (Hazell and Aitken 2019, fig. 7).



Figure 7.1 The gun carriage emerging from the sea (© Historic England, photograph Dan Pascoe)



Figure 7.2 The gun carriage just after recovery from the seabed (© Historic England, photograph Dan Pascoe)

cap-square was hinged and folded back over the trunnion but had been broken when the guns were removed. An unidentified residue found in the trunnion recesses has been interpreted as the remains of 'pillows' used when trunnions were smaller than the recesses. The remains of iron ring bolts, the breeching rope and other fixtures used to both secure and manoeuvre the guns were also found.

Consistent with the reports that the *London* had been armed with available weapons, the carriage had been adapted to suit a longer and narrower gun that the one it was originally built for. The rear of the bed had been extended, planks of wood had been attached to the inside of the cheeks around the trunnion recesses. Compression marks in the trunnion recesses also indicate the use of a smaller gun (Pascoe 2017). Modifications to gun carriages of this period are unknown so this artefact is unique. Possibly as a result of the wide variety of copper-alloy ordnance with which the *London* was equipped, the modifications indicate that the carriage was carrying a gun for which it had not been designed.

As well as being recorded in its 'as received' state, the gun carriage was drawn by Richard Endsor (Cotswold Archaeology 2016) at the historic Ordnance Office scale of 1½" to the foot (1/8th scale), reconstructed as near as possible to the condition it was in at the time *London* was lost (Fig. 7.3).

Gun-loading equipment

Two flexible rammers (3206 and 3207) comprising round wooden heads, fragments of served rope (3173 and 3208–9)[2] and a flexible sponge (3324) (usually made with a sheepskin nailed to a wooden cylinder, although in this case no evidence of a sheepskin was recovered) were found near the rear truck to the west of the carriage (see also Chapter 8, Allen). Rather than single items attached to wooden poles, a rammer head and a sponge head were attached at each end of one piece of rope and are referred to as rope sponges in contemporary inventories,[3] the remains of which was found inside both the rammers and the sponge. The rammer heads and rope were in excellent condition but the sponge cylinder had been partially exposed and bore signs of biological and physical decay.

A rammer was used to force the charge, shot and wadding down the barrel of the gun to the breech, while the sponge was used to extinguish and clear burning embers after firing (Hildred 2011, 407, 454; Lavery 2006, 142; Padfield 1973, 64). Rope sponges were an essential implement for preparing the gun to fire and by the 1660s the number of flexible sponges and rammers matched the number of guns on board (Lavery 2006, 142).

Flexible rammers

The rammer heads comprise turned conical wooden cylinders that taper from a maximum diameter at the face to form a neck into which the rope was threaded and secured by iron nails. One rammer (3206) has a diameter at the face of 127mm (5") and a rope bore hole of 62mm (2.5") while the other (3207) has a diameter of 115mm (4.5") and a rope bore hole of 50mm (2") (Fig. 7.4). The sizes of these would fit the culverins and demi-culverins stationed on the upper decks. Finding them on the main deck reinforces the notion that at the time of the explosion these had not been distributed to the appropriate place on the ship (Pascoe 2017, 53).

An X-radiograph of one rammer (3206)[4] clearly shows two blacksmith-forged iron nails passing through the sides of the rammer head into the rope core. The nails are rectangular in section and taper to a point; surviving remains measure approximately 60mm by 8–10mm (at their thickest point). Another X-radiograph of this rammer (3206) shows two opposing countersunk holes containing the two horizontally penetrating iron nails. The X-radiograph has also revealed a three-strand hawser-laid rope with a jaw/cant angle of 52°. The strands have been laid together in a Z-twist (Fig. 7.4). The rammer was made from *Populus/Salix* (poplar/willow; Hazell and Aitken 2019, table A2).

An X-radiograph of the other rammer (3207) clearly shows the holes through which three blacksmith-forged iron nails passed through the sides of the rammer head but the remains of only one of these nails has survived passing into the rope core; the remains of this nail measure approximately 40mm by 6–8mm. The other two nails have been lost, most likely through corrosion and the loss of a section of the rope. Another X-radiograph of this rammer (3207) shows three opposing holes through which three diagonally penetrating blacksmith-forged iron nails would have passed. As above, the surviving nail is rectangular in section. The X-radiograph has also revealed a three-hawser cable-laid rope with a jaw/cant angle of 46°. The strands of the hawser have been laid together in a Z-twist and the hawser of the cable has been laid together in a S-twist (Fig. 7.4). This rammer was made from *Alnus* (alder; Hazell and Aitken 2019, table A2).

One flexible rammer (3206) was scanned by X-ray micro-computed tomography (μ-CT) to attempt to determine whether the rope in the centre of the rammer was served,

2. Worming, parcelling and serving rope (referred to collectively as service) provided protection against wear as well as keeping water out. Worming laid rope or line to fill the space between the rope strands to allow tighter, smoother wrapping of the next layers. On ships built later the rope was then parcelled by wrapping the wormed rope or cable in a spiral fashion with long overlapping strips of thin tarred canvas; no parcelling was found on the *London* as it appears to have been introduced at a later date. The rope was then served by tightly wrapping small line or sennit around it. Some of the rope recovered from the *London* had been served without worming, which might indicate further a lack of discipline onboard (D. Pawson pers. comm.).
3. This is illustrated in Falconer's marine dictionary of 1769 (Lavery 2006, 137) and Captain Francis Povey describes in a 1702 publication how the rope should be served and how the rammers and sponge heads should be fixed at the ends with copper nails. The serving stiffened the rope and preserved it from the 'sulphurous matter which remains in the gun' (Povey 1702, 29).
4. The X-radiography of two flexible rammers (3206 and 3207) produced two images of each object, one from above looking down and one showing a side elevation.

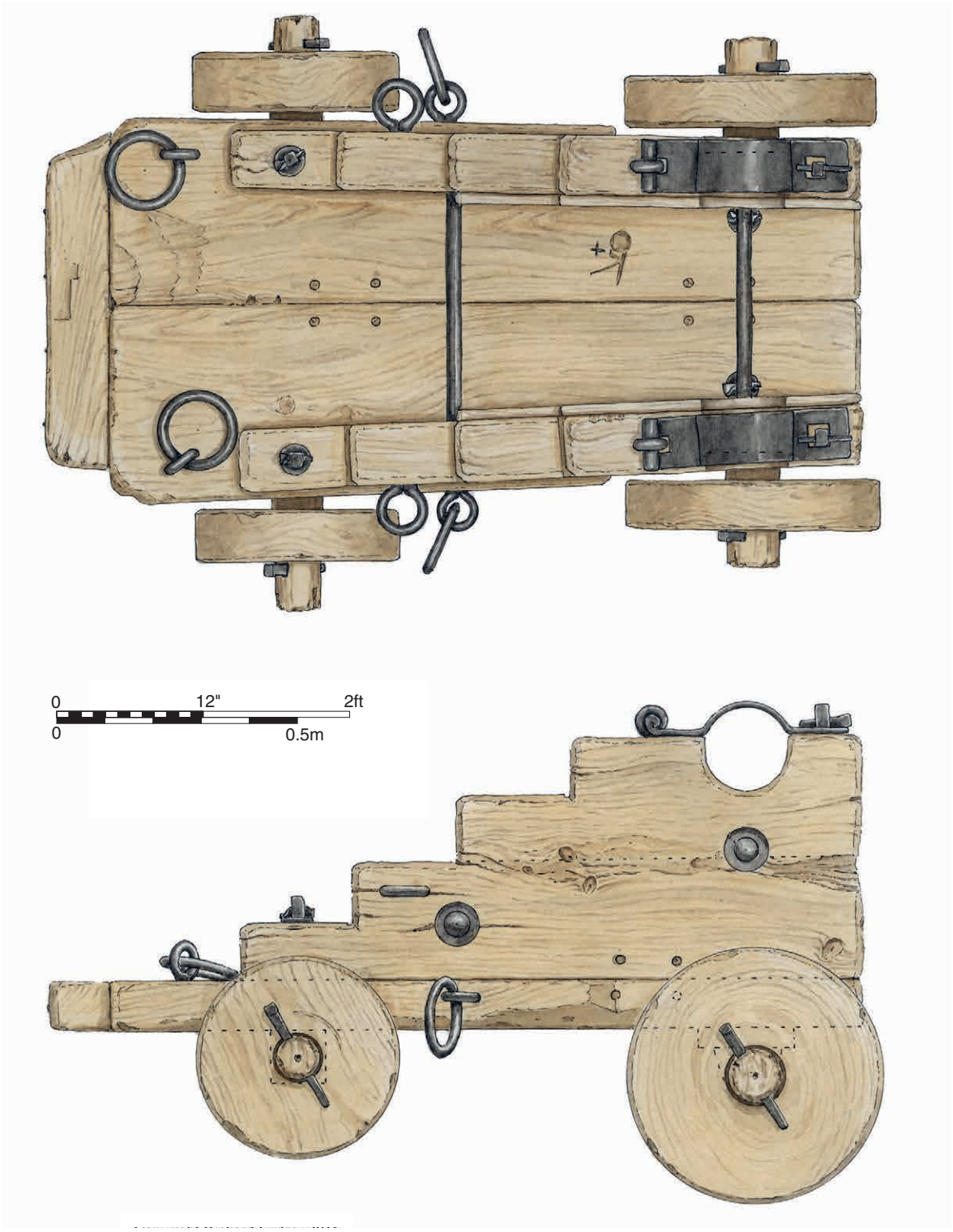


Figure 7.3 Reconstruction of the gun carriage at the historic Ordnance Office scale (© Historic England, drawing Richard Endsor)

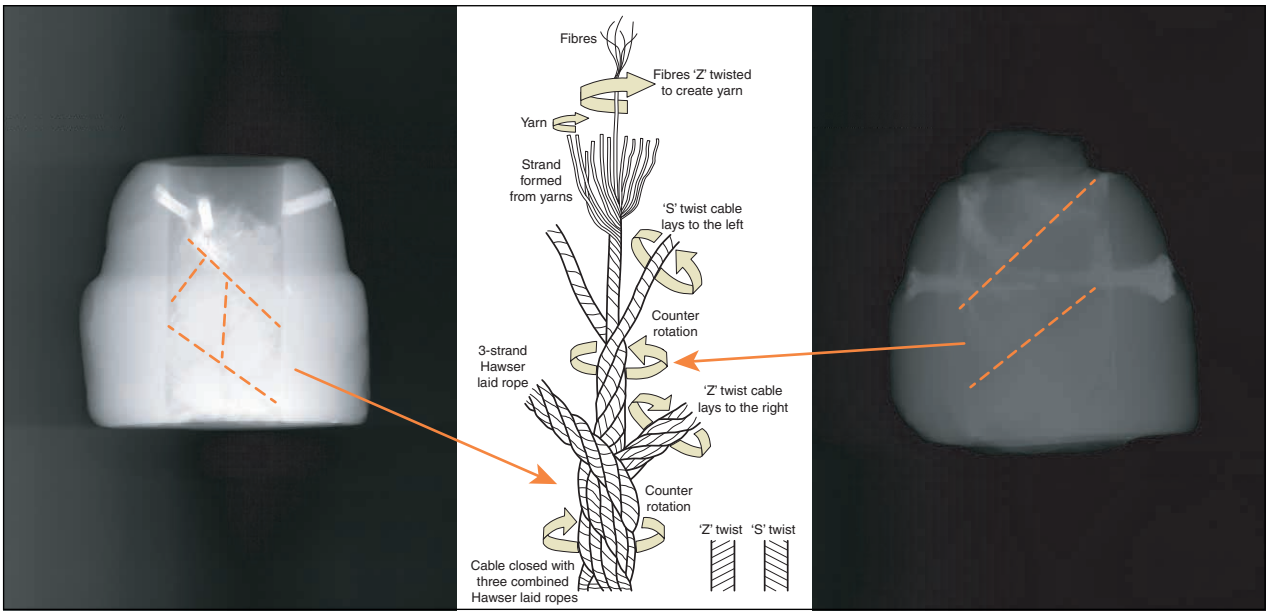


Figure 7.4 An illustration showing rammer 3206 is constructed with a hawser, and rammer (3207) with a cable (© Historic England, radiographs Angela Middleton, drawing Kenneth Lymer)

like the sections of rope (3173, 3209 and 3308) with which it was recovered. From this scan, however, the hawser-laid rope does not appear to be served (Fig. 7.5).

Flexible sponge

The sponge cylinder is conical in shape, tapering from a diameter of 180mm to 116mm, with a slight taper from the shoulder to the neck (Fig. 7.6). Like the rammer heads, a hole running through the centre of the sponge cylinder contains the remains of the rope with a wooden plug at one end.

The X-radiograph of the flexible sponge (3324) shows four blacksmith-forged iron nails, rectangular in section, one of which tapers to a point (see Fig. 5.4). Three nails appear to penetrate diagonally from the top of the sponge into the rope core while the other penetrates horizontally through the shoulder; the best preserved example measures approximately 73mm by 10–11mm. Remains of smaller iron nails, measuring 27mm by 5mm, on the outside face of the cylinder would have secured the sheepskin. The X-radiograph identified a three-strand hawser-laid rope with a jaw/cant angle of 40°, the strands of which had been laid together in a Z-twist. The sponge was made from alder (Hazell and Aitken 2019, table A2).

Served rope

The rope (3173 and 3208–9) has three strands with a yarn of worming laid in the hollow concavity between the strands of the rope, and a layer of serving wrapped around the outside. The served rope varied between 165 and

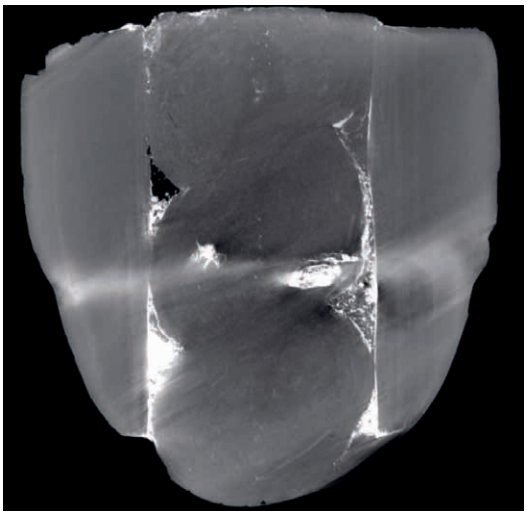


Figure 7.5 CT scan of rammer (3206)



Figure 7.6 Flexible sponge (3324; © Historic England, photograph Dan Pascoe)



Figure 7.7 Fragment of a gunwad (3479; © Historic England Archive, James O. Davies)

178mm (6.5"–7") in circumference and 47 and 57mm (1.8"–2.25") in diameter.

There appears to be a lack of standardisation in the wood and rope types used in the construction of the flexible rammers and sponge. The use of both hawser and cable-laid ropes suggests the possible reuse of old ropes, while the absence of serving on one rammer (3206) suggests that either this rammer was not served at all or the rope was only served up to the rammer head.[5]

Wad or wadding

A recovered fragment of a single gunwad (3479), measuring approximately 100 x 70mm, had been compressed through burial (Fig. 7.7; see also Chapter 16, Gleba, Fig. 16.24). Gunwads were essential elements of a gunner's equipment; without them the guns would not fire effectively. Wads or wadding were made from the yarns of old rope or hay, folded and wrapped into a ball. They were placed in the bore of the gun, one after the powder charge and one after the shot. It was not unusual to have several wads, one before and one or even two after the shot. Wads had several functions, including helping to keep the shot in place during loading, to create a seal in front of the powder charge to help pressure build-up from the burning powder and to absorb moisture.

Several hundred, if not thousand, gunwads were made prior to departure to ensure the ships were capable of engaging the enemy from the moment it left port. Although there appears to be no mention of wadding in the Chatham Ledger it is known from other gunner stores lists that ships like the *London* would have been issued with several tonnes of old rope or 'junk' from which to make wadding. The first-rate *Sovereign*, for example, was issued with 50 hundredweight (cwt) of junk in 1655 (Lavery 2006, 138). The crew would then have picked the yarn from the junk to make the gunwads or wadding to replenish stocks.

The remains of wadding were excavated from the barrel of a loaded 32-pounder gun recovered from the wreck of the *Stirling Castle* (1703). Three samples were recovered, one from in front of the shot and two separate samples from behind. This wadding was made from yarns picked from hawser-laid rope (McElvogue 2008, 41). Several hundred 9, 24 and 32-pounder gunwads were recovered from the wreck of the *Invincible* (1758) during excavations in 2017 and 2018. The wads came from a store in the forward hold, overlying a large quantity of junk (for more gunwads). These wads were also made from individual yarns picked from old rope and wrapped and folded to make a ball. The excavation of several guns from the wreck of the *St George* (1811) revealed several gunwads of similar composition in the barrels (Fig. 7.8).

Manoeuvring equipment

Hand crow levers

Hand crow levers were wooden stakes used by the gun crews to manoeuvre the ordnance into the correct firing position (Manwaring and Perrin 1922, 160) by traversing the carriage from side to side and elevating or lowering the breech (Padfield 1973, 58). Sixty-three hand crow levers and 74 crows of iron were issued to the *London* (Chatham Ledger; TNA WO55/1667). Fifty hand crow lever fragments, representing a minimum of 20 levers,

5. The removal of the rope fragments from the inside of 3207 and 3224 should be considered to be more conclusive regarding the serving.



Figure 7.8 Contents of barrel of gun from the St George*, including double shot, cartridge, wads and tampion (© Dan Pascoe)*

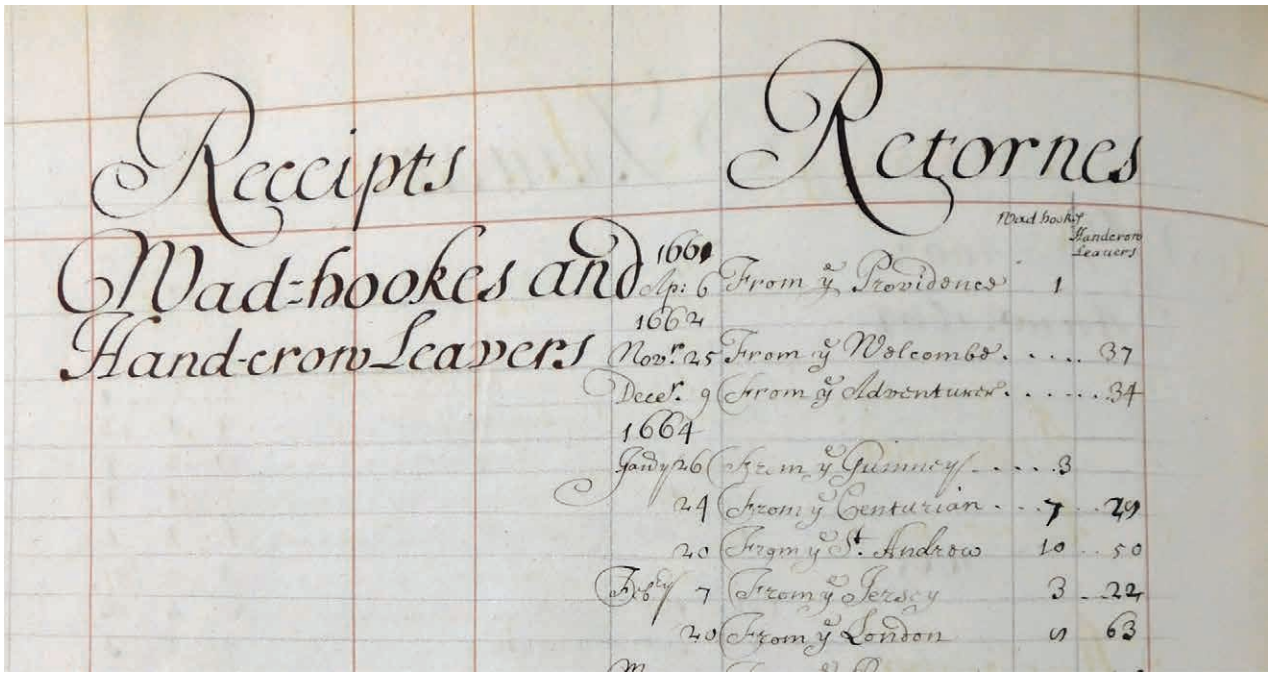


Figure 7.9 Hand crow levers issued to the London *(Chatham Ledger 20 February 1664[5]; TNA WO55/1667; © TNA, photograph Michael Walsh)*

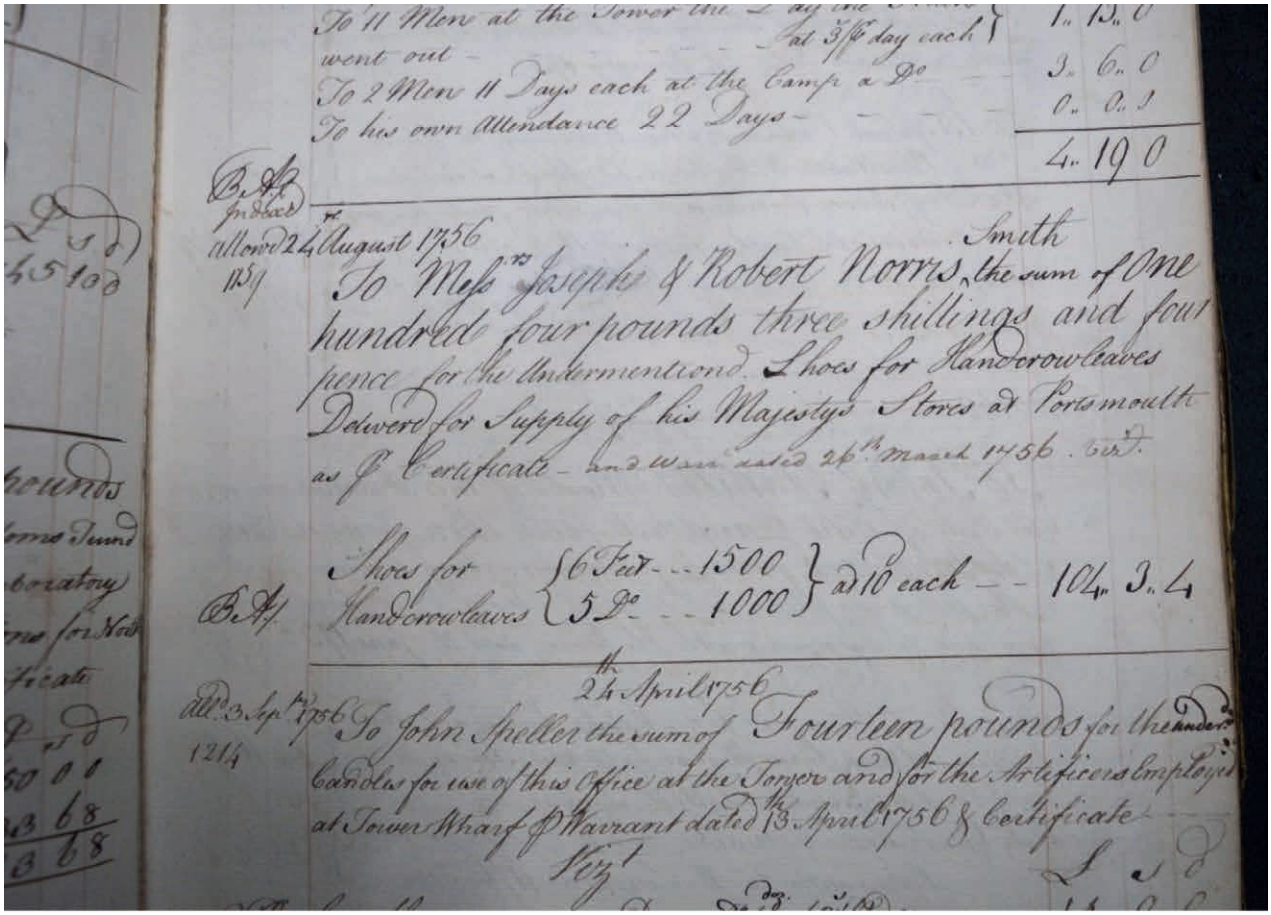


Figure 7.10 A receipt from an Ordnance Board Bill book (TNA WO51/199 f.55; © TNA, photograph Michael Walsh)



Figure 7.11 Hand crow lever from the St George *(© Dan Pascoe)*

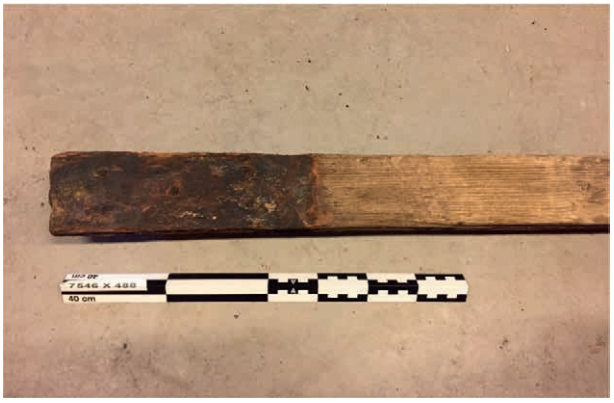


Figure 7.12 Close-up of the remains of the iron shoe and fixings from the St George *(© Dan Pascoe)*

including six complete examples, were recovered during the excavations (see also Chapter 8, Allen).

One of the complete hand crow levers (3333) is 1.53m (5') long (see Fig. 8.18),[6] has a 34mm diameter circular section at the handle and a 70mm by 65mm rectangular section at the head end. The hand crow levers were made from three species, *Fraxinus* (ash), *Betula* (birch) and *Fagus* (beech). Ash was by far the most common species, comprising 38 of the 43 samples (Hazell and Aitken 2019, table A2). Ash is particularly resistant to stress (Gale and Cutler 2000, 120) and therefore ideal for use to manoeuvre heavy objects like guns and carriages.

The head ends of 11 hand crow levers were X-radiographed,[7] and six revealed the fixings for the iron shoes that covered the heads.[8] These shoes were fixed to the heads of the hand crow levers by up to five blacksmith-forged iron nails on the flat surface of the head. There is an obvious pattern to the positioning of these nails, which are in a triangular formation towards the end of the head with two nails in parallel towards the aft end of the head. The side views have also revealed nails hammered into the side of the head to secure the iron shoes. These nails can be seen towards the end of one head (3445) and towards the aft end on five heads (3437, 3559, 3561, 3569 and 3716).

A minimum of 20 individual hand crow levers are represented by all the fragments, which may be one of the largest collections found on a shipwreck. This represents almost one third of the number known to have been issued to the ship (TNA WO55/1625; Fig. 7.9).

There is an extant receipt from 19 August 1756 (TNA WO 51/199 f.55) for supplying shoes for hand crow levers (Fig. 7.10). Several hand crow levers with remains of ferrous shoes were recovered from the wreck of the British second-rate *St George*, which wrecked in 1811 (Fig. 7.11).[9] The locations of the fixings are very similar to those found on the examples from the *London* (Figs 7.11 and 7.12). The historical and archaeological evidence demonstrates that the design of hand crow levers changed little from the time of the *London* through the 18th and into the 19th century.

Gun tackle (single and double blocks)

Each gun had a tackle on each side of the carriage to run the gun out after loading (Lavery 2006, 141). It comprised a length of rope linking a single and a double block which were attached via iron hooks to eye bolts on the side of the hull and the carriage. The *London* was issued with 74 breechings and 148 tackles[10] (Chatham Ledger TNA WO55/1667). The gun tackle was used:

6. The single billet of rectangular timber had been shaped using a draw knife with a chamfered face on the bottom of the head that would have been placed on the deck with the flat upper face against the bed of the carriage. The upper face of the head has a combination of ferrous staining and concretion. Where the concretion has fallen away from the surface of the wood nail holes can be seen. Both concretion and nail holes are present on all the upper faces of the head fragments. This shows that the heads of the hand crow levers were fitted with an iron shoe and also explains why some were concreted together. The shoe was most likely made from a thin malleable sheet of wrought iron which was hammered and fastened into place while still hot.
7. Small find numbers 3437, 3445, 3448, 3455, 3465, 3554, 3558, 3559, 3561, 3569 and 3716.
8. Small find numbers 3437, 3448, 3558, 3559, 3561 and 3569.
9. Now in the Strandingsmuseum St George in Denmark.
10. Plus an additional two breechings and four tackles for the two extra guns that were issued in 1665.

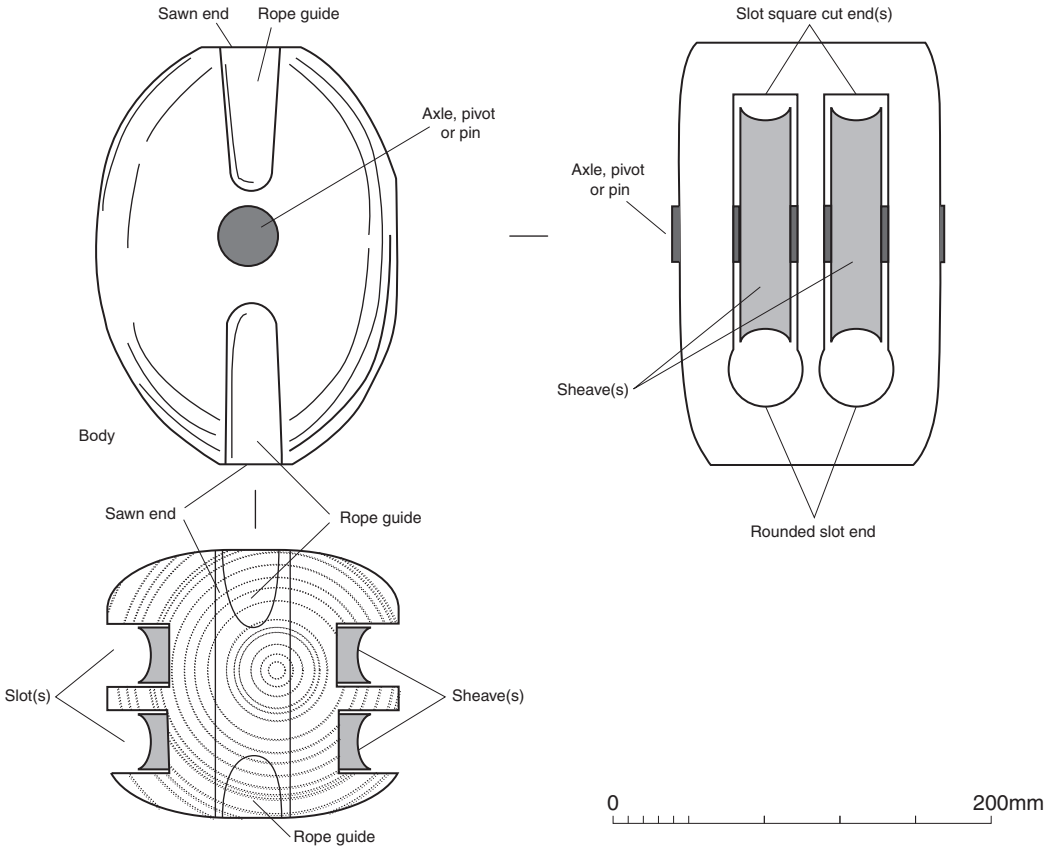


Figure 7.13 Block terminology (double block shown) (© Historic England, drawing Steven Allen)

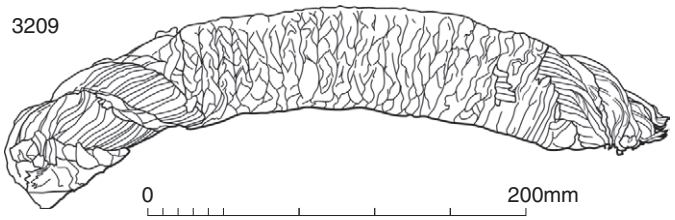


Figure 7.14 Breeching rope (© Historic England, drawing Aleksandra Osinska)

- to secure the gun in place when not in use;
- to prevent the gun moving whilst the ship was in motion;
- to haul the gun inboard for loading;
- to run the gun outboard to fire; and
- to help absorb the recoil when the gun fired.

The double and single blocks have a body carved from a single piece of wood with a slot to house each wooden sheave, which turn on a single wooden peg inserted through the centre of the block (see Figs 5.1, 6.9, 7.13 and 8.12). The body of all the blocks was identified as *Ulmus* (elm; Hazell and Aitken 2019, table A2). The sheaves of one double block (3127) were made of elm and the peg was made of *Ilex* (holly), while the sheaves of another (3358) were made of *Fraxinus* (ash) and the peg from the Maloideae (Pomaceous fruits) family (see also Chapter 8, Allen). The peg of one single block (3052, see Fig. 5.1) was made from holly while on the other (3120, see Fig. 8.12b) was *Fagus* (beech) (Hazell and Aitken 2019, table A2). The sides of the body were routed at each end to enable the rigging to fit flush to the block.[11]

Breeching

A thick piece of rope, known as breeching, was attached by an eye splice to a ring bolt on the inside of the hull either side of each gun to restrain its recoil, which would otherwise have caused tremendous damage. The rope passed through eye bolts attached to the sides of the carriage and was then spliced to the button of the cascabel (Lavery 2006, 141).[12]

11. The routing at the seat or breech end of the sheave extends from one side to the other, while the crown end is flat.
12. The historical record seems to differ in regard to the length of breeching needed for each gun. John Seller (1691, 186) stated the length of the gun tackle was 'as many feet as your piece is in length, so many fathom must your rope be'. Whereas Povey states 'the length of breeching must be twice and half longer than the gun' (Povey 1702, 29). According to Povey the breeching for demi-cannon and 24-pounders was 6.5–5 inches in circumference (Povey 1702, 28).

Some rope fragments recovered from both sides of the carriage, extending from the side of the hull to the centre of the carriage cheeks with broken ends found at the rear of the bed, were identified as possible breeching. This rope is three-stranded hawser with circumferences varying from 150mm (6') to 185mm (7.5') (Fig. 7.14).

Equipment for dressing the guns when not in use

Covers of lead

The *London* was issued 76 'covers of lead' (also known later as gun or lead aprons) (Chatham Ledger TNA WO55/1667), one for every gun. Four covers (or 'aprons'[13]) of lead (small find numbers 3323, 3326, 3341 and 3350) have been recovered from different locations by the licensee team during surveys of the site.[14] These were square or rectangular sheets of lead crudely moulded to the shape of the breech end of the guns to which they were once secured (Fig. 7.15). They were used to cover the vents of cannon to keep the charge dry and to keep the vent hole clean and open (Blackmore 1976, 218).

The recovered covers or aprons are 3–4mm thick and retain the shapes of the guns' base rings and other mouldings.[15] They were compared to some of the guns recovered from the *London* but the only possible match was between apron 3326 and the Tudor Peter Gill gun, cast in 1595 (RA BO1351). This gun was originally a culverin which was later rebored to become one of the eight 24-pounder guns located on the main gundeck. None of the remaining three aprons matched either the George Brown Commonwealth demi-cannon cast in 1656 or the French demi-culverin cast in 1636. The recovered Dutch guns were not available/accessible at the time. The smaller apron did, however, have similarities with the base ring of the French demi-culverin, which suggests it may have related to these guns which would have been located on the upper gundeck.

Firing equipment

Priming iron

A priming iron (3715), also known as a primer (Goell 1970, 88) or priming wire, was found on the west side of trench 3, immediately above but believed not to have been associated with the broken chest that contained the bandoliers (see also Chapter 11, Schuster). Although called a priming iron, it was in fact made of copper alloy; it is 400mm long and 2–3mm in diameter. It has a very simple form with a 24–7mm loop or handle twisted around the shaft at one end and a point at the other (Fig. 7.16).[16]

The 30 priming irons issued (TNA WO55/1667) were essential gunner's equipment (see Seller 1691, 162) and had two functions. The point was used to puncture the powder cartridge prior to firing to enable the finer priming powder to reach the coarser gunpowder (Hildred 2011, 476; Ní Chíobháín 2011, 19) and to clean powder residues and obstructions from the touch hole of the gun between firings. Some primers had a screw thread to remove any debris left in the touch hole (Hildred 2011, 476), although the *London* example lacks this feature (Fig. 7.16).

The use of the term 'priming iron' and its description in 1627 by Smith as 'a small long peece of iron' (Goell 1970, 88) suggests they were made of iron, but archaeological investigations on the *London*, the *Mary Rose* (1545) and the *Hollandia* (1740) have identified only copper-alloy examples. It is possible, however, that examples made from iron have not survived in the archaeological record.

Linstocks

A linstock was a shaped wooden stick that held a slow match or 'lint' (Fig. 7.17), which enabled the gunner to stand at twice arm's length from the gun when he applied the match to the touch hole.[17] The burning match ignited the priming powder in the touch hole which in turn ignited the main powder charge and fired the gun (Hildred 2011, 485).[18]

Fifty-four linstock fragments were recovered, many of which were matched together to form 15 complete or partial linstocks (see Chapter 8, Allen) with evidence for a total of 29 individual linstocks. Along with the priming irons the *London* was issued with 30 linstocks (TNA WO55/1667), almost all of which were found adjacent to the recovered carriage.

The linstocks were found just beneath the surface, close to the top of the stratified deposits, in a neat cluster to the east of the rear truck of the carriage. One linstock (3201) shows signs of biological decay, which suggests it had been exposed at some point. This cluster of the entire issue of linstocks again supports the notion that the ship was still preparing for battle at the time of the explosion.

13. By 1677 they are referred to as 'aprons' (Anon. 1705).
14. One apron (3323) was found in square K8 beyond the north-west edge of the site approximately 2–3m north of trench 3. Another apron (3326) was found in square K9.
15. 1–2m closer to the wreck, while the locations of the other two aprons are unknown. Aprons 3326, 3341 and 3350 are larger than apron 3323. The former have two holes on each side for securing a rope lanyard, while 3323 has only two holes.
16. Secured at its base with a 1 3/5 coil. It has a folding seam visible along most of its length, indicating that it was made by drawing a strip of copper alloy (based on its colour probably brass) through a vice; its diameter ranges between 1.7mm and 2.5mm. 230mm below the loop the priming iron is bent at *c*. 30°, its diameter tapers towards the bend, then becoming thicker again and tapering once more to a long-triangular flattened tip with no indication of a twist or screw thread (J. Schuster pers. comm.).
17. 'Lint stock is a handsome carved stick, more than halfe a yard long, with a cocke at the one end to hold fast his match, and a sharpe pike in the other to sticke it fast upon the deck or platforme upright' (Smith 1627, 68).
18. Keltridge's draft of a fifth rate from 1684 includes an illustration demonstrating linstocks in use (NMM KLT0005).



Figure 7.15a Covers (or aprons) of lead 3326 (above) and 3350 (below) (© Historic England Archive, photographs James O. Davies)

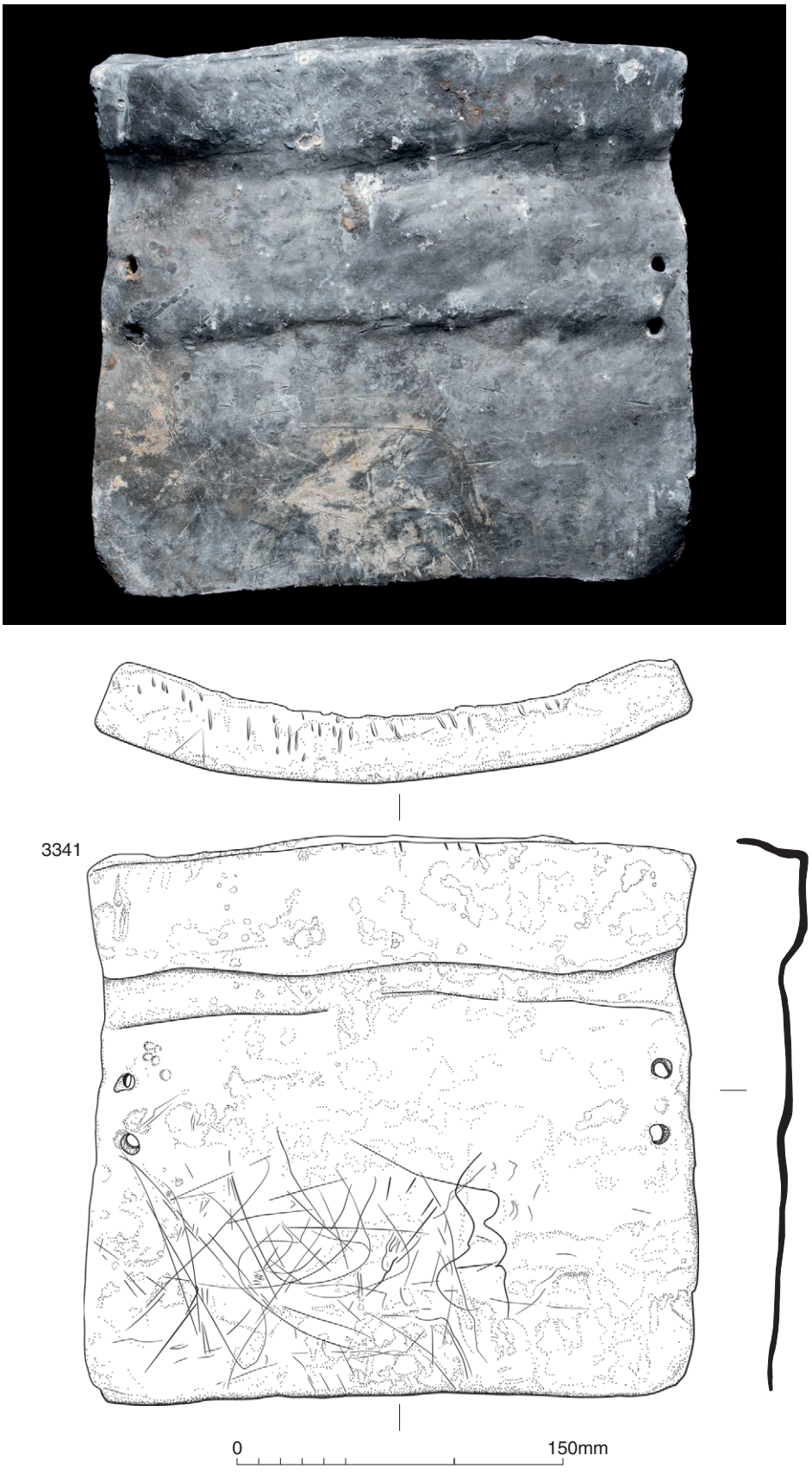


Figure 7.15b Cover (or apron) of lead (3341; © Historic England Archive, photograph James O. Davies, © Historic England, drawing Aleksandra Osinska)



Figure 7.15c Cover (or apron) of lead (3759; © Historic England Archive, James O. Davies)



Figure 7.16 Copper-alloy priming iron (3715; © Historic England Archive, photograph James O. Davies, © Historic England, drawing Aleksandra Osinska)

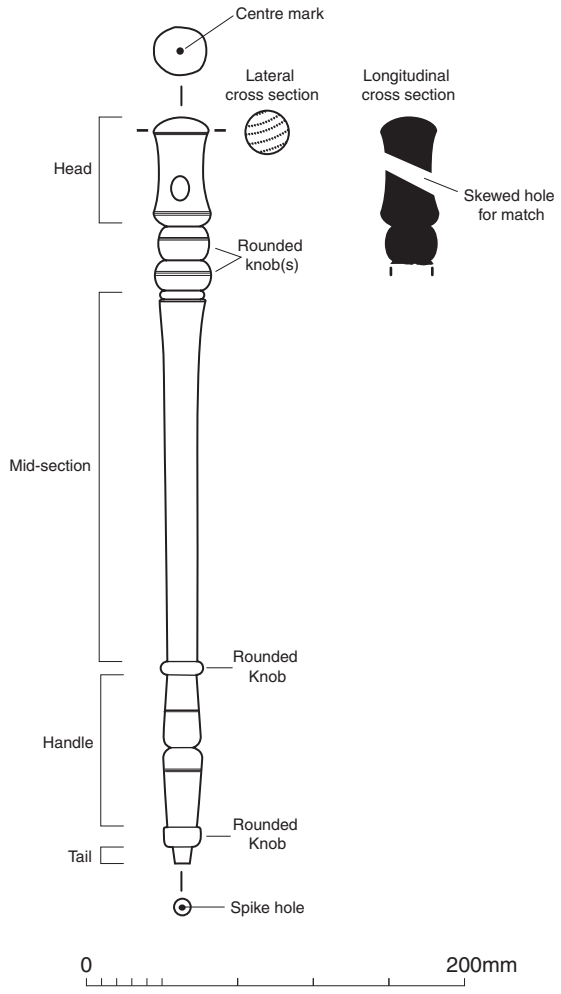


Figure 7.17 Linstock terminology (© Historic England, drawing Steven Allen)

It is possible that the linstocks and the gun carriage may have been located close to a hatchway that led from the main gundeck down to a 'platform' below. At this time, the gunner's storeroom was located on a platform in the hold at the bow (Fox 2012, 61).[19] These stores may therefore either have been in the process of being taken below to the gunner's store or, more probably, were being brought up for distribution around the ship.

The assessment of features such as heads, collars and grips has identified 29 individual linstocks[20] including three that are complete and unbroken, nine complete but in fragments, eight almost complete and 30 fragments. They are not identical in form but the majority are similar; all but one (3310) had been turned from a single piece of wood. The exception (3310) appears to be carved rather than turned and its style is similar to some found on the *Mary Rose*.

Several linstocks bear scorch marks from the match around the hole at the head and along the haft. The latter seems odd as the match should not have burned down towards the haft and there is no continuous scorch mark from the head. The scorch marks could have occurred during the explosion but the absence of other damage does not support this. Alternatively, some of the linstocks may have been placed next to each other while lit, possibly in a bucket of sand prior to being used (Fig. 7.18).

All but one linstock (3310), which seems to have had an open V-shaped end, have a hole drilled at an angle through one end (the head) to hold the match. The head is separated by a collar from the shaft (haft), which is turned to include a hand grip. The end of the hand grip has a square hole with the remains of iron concretion. The concretion represents the remains of an iron spike which was used to secure the linstock to the deck or a bucket of sand (Hildred 2011, 490).

X-radiographs of 25 linstock grip ends and fragments[21] confirmed that, with the exception of one linstock (3186), they contained a ferrous spike driven into them, with a ferrous ferrule used to strengthen the end of the grip.[22] An X-radiograph of the exception (3186) reveals several splits in the wood extending down the grip, which appear to have been reinforced with a lead repair moulded around the grip. Another linstock (3188) has two areas of serving with a fine thread below the collar at a diagonal split in the haft which appears to be a repair (see Fig. 8.17).

Wood species analysis has identified that the linstocks were made from a variety of wood species including ash, birch, *Castanea* (sweet chestnut), *Populus/Salix* (poplar/willow) and *Quercus* (oak) (Hazell and Aitken 2019, 32–5). Wood types were chosen from which the narrow shafts of the linstocks could be turned on a lathe.

Owing to the inherent risks posed by a burning match the number of linstocks was controlled and they were only issued to select members of the gun crew, so that the numbers issued reflect gunnery practice at the time rather than the number of guns carried. During the mid-17th century one linstock was placed between every two guns (Lavery 2006, 143), so the issue of only 30 linstocks for the *London's* 76 guns is not particularly unusual. As this is fewer than one linstock for each pair of guns, priority would have gone to the larger guns on the broadsides.

An inventory suggests that by the turn of the 18th century a 90-gun, second-rate ship should be issued with 20 linstocks (Povey 1702, 36), which equates to one linstock for every four or five guns, so the responsibility for firing the guns had been assigned to fewer crew members.

19. At this time the hold extended down from the bottom of the gundeck, there was no orlop as you see today on HMS *Victory*. Instead there were partial decks known as 'platforms' (Fox 2012, 61). These were located at the bow and stern and around the perimeters; there was not a continuous deck.
20. The assemblage includes 29 grips, 29 upper grip mouldings and 29 collars.
21. Small find numbers 3125, 3183, 3185, 3186, 3193, 3195, 3198, 3199, 3200, 3202, 3213, 3214, 3218, 3219, 3220, 3221, 3252, 3261, 3265, 3268, 3273, 3284, 3286, 3296 and 3309. X-radiographed at Fort Cumberland.
22. The remains of the ferrule can be seen on the X-radiographs of linstocks 3125, 3219, 3265, 3268 and 3198.



Figure 7.18 Scorch marks on the shaft of a linstock (3200; © Historic England Archive, photograph Steven Baker)

Hand weapons

Small arms equipment included bandoliers, leather shot pouches, wooden powder boxes, caps and spouts (caps/lids of primers) and a single pistol fragment.

Bandoliers

Numerous leather and wooden components of the 70 bandoliers issued to the *London* were recovered,[23] including leather shoulder belts with leather shoulder pads, the former punched with regular holes from which wooden powder boxes and a leather shot pouch were suspended, many of which were also recovered (see Mould, Chapter 9, Figs 9.1–9.6). Most of the powder boxes carried a single charge of powder to load a handgun but one on each bandolier was fitted with an open spout rather than a closed cap and carried finer priming powder used to ignite the main charge.

The bandoliers were found in layers in the remains (one side and one bottom) of a broken chest on the west side of trench 3. The chest, lying at an angle of 45 degrees, contained at least two alternating layers of leather belts and wooden powder boxes, many of which were left *in situ* owing to time constraints.

Powder boxes

A total of 137 elements (bodies and caps) of complete and fragmented powder boxes was recovered, eight of which were recorded in detail (see Chapter 8, Allen; Fig. 8.1). The wood species from which the powder boxes were made was chosen for workability; the majority were of *Fraxinus* (ash), *Fagus* (beech) and Betulaceae taxa but also *Populus/Salix* (poplar/willow), *Acer* (maple), *Juglans* (walnut) and Maloideae (Hazell and Aitken 2019, table A2). An X-radiograph of two powder boxes (3515 and 3525) has revealed that they were turned from within and not bored, as their profiles taper from a narrow top to a deep recess flaring out at the bottom. This style matches the specifications of contract books for the New Model Army of Oliver Cromwell, which stated that the boxes should 'be of wood with whole bottoms, to be turned within and not bored' (Roberts 1989, 58).[24] The volumes of 72 of the most complete powder boxes were measured;[25] the volumes of the 12 best preserved boxes range from 15 to 20 millilitres (Hazell and Aitken 2019, table A3).

The *London* was issued with several types of handgun, including 50 matchlock and 30 snaphaunce (an early type of flint lock) 'musquettes' (muskets), 12 blunderbusses and 20 pairs of pistols (TNA WO55/1667; Fig. 7.19).

23. By 1677 the number of bandoliers issued to second-rate ships had increased to 80 (Anon. 1705) but by the turn of the century the number had reduced to 30 as by then another type of shot and charge holder, the cartouche box, was in use (Povey 1702, 33).
24. In contrast, rather than being an integral part of the box the bases of the powder boxes from the Duart Castle wreck were formed by separate wooden plugs (Martin 2017, 173).
25. Seven complete bodies and caps (category 1) and five complete bodies (category 2) provided the most accurate measure of volume.

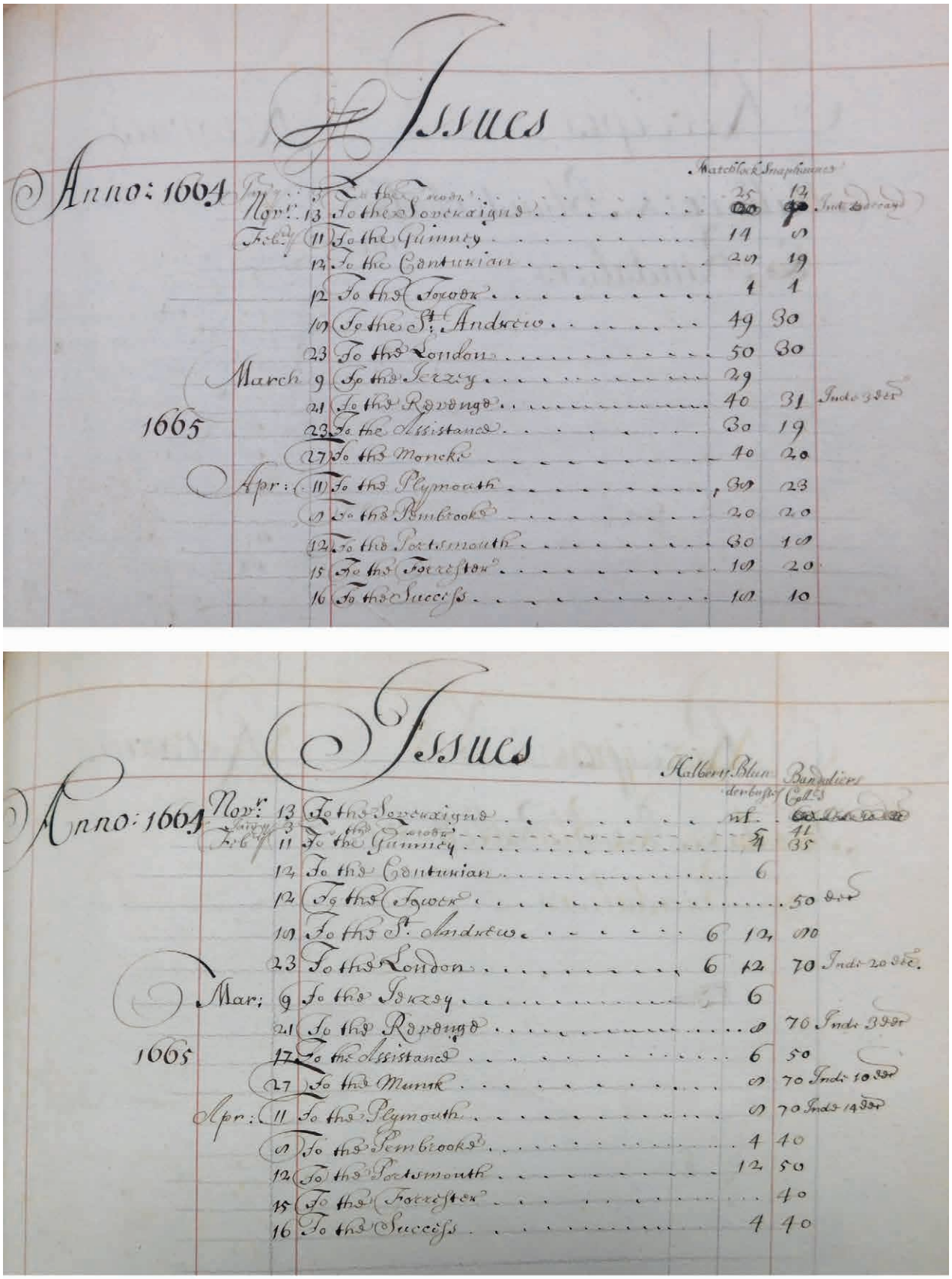


Figure 7.19 Hand weapons listed in the Chatham Ledger 23 February 1664[5] (TNA WO55/1667; © TNA, photograph Michael Walsh)

Each category of weapon would have had a different bore and would have required a different weight of shot and a different powder charge to propel the bullet. Therefore at least three, and possibly four, different sizes of powder box would have been required.[26]

Similar-sized powder boxes were recovered and analysed from the Cromwellian Duart Castle wreck. One from Duart Castle[27] was similar in size to one from the *London* (3581).[28] The internal volume of the Duart Castle box is 250mm^3 which could hold 37g (1⅓oz) of packed gunpowder (Martin 2017, 173).[29] Martin (2017, 173) suggests that this size of box was designed for the larger category of lead shot found on the wreck, the 12-bore calibre at approximately 19mm diameter and 43g (1½oz) in weight. There were two standard calibres for muskets in use from the 1660s, 14 and 12-bore (Foard 2017, 181).

Spout of primer

Three powder box caps (3618, 3655A and 3703),[30] which were different from the others, have been identified as spouts for powder boxes that carried powder (known as primer; for description, see Chapter 8, Allen; see Figs 8.2, 8.9a and b).

Further archaeological evidence for powder boxes comes from the wreck of *La Belle*, a French colonial vessel wrecked in 1686 off what is now southern Texas. Fifty-five wooden artefacts have been identified as either the cap or body of a powder box. They are similar in style to those from the *London* (Bruseth *et al.* 2017, 441).

Although similar to the powder boxes and caps recovered from the Duart Castle and *La Belle* wrecks, those recovered from the *London*, which is the largest known collection, differ subtly in construction. The main difference is that rather than being an integral part of the box the bases of the powder boxes from the Duart Castle wreck were formed by separate wooden plugs (Martin 2017, 173); unlike those from the *London*, the Duart Castle examples had been bored out from the bottom and then plugged.

Pistol grip

A single pistol fragment (3634; see Chapter 8, Allen and Chapter 11, Schuster), comprising the grip and butt end (see Fig. 8.21), was recovered from the west side of trench 3 near the chest of bandoliers. The fragment is 106mm long, 58mm wide across the butt and 31mm wide across the broken end. A recess in the butt end extends partially up the side of the grip. Concretions around the butt and the sides of the grip represent the remains of a butt cap that acted as protection for the base of the pistol. There are concreted remains of a trigger guard on the underside of the grip at the opposite end to the butt.

Two X-radiographs of the pistol grip[31] have revealed that the ferrous butt cap was secured to the butt of the pistol by a single ferrous nail, passing through the centre of the butt (Fig. 8.21). The pistol grip was made from *Juglans* (walnut; Hazell and Aitken 2019, table A2) which is resistant to shock and therefore makes an ideal wood-type for hand weapons and is often used to make gunstocks (Gale and Cutler 2000, 110).

Pistols are a type of handgun that were used at close quarters, for example, when boarding other vessels during fighting. Twenty pairs of pistols were issued to the *London* (Chatham Ledger TNAWO55/1667). By 1677 the number of pistols issued to second-rate ships had increased to 60 pairs (Anon. 1705), which probably reflects not only the increasing size and ability of ships to carry more men but also the naval tactics of the time, which were to come alongside and board the enemy ship. By the end of the century the number of pistols and other close-quarter weapons had been reduced again, to be replaced by longer-range weapons like muskets, as tactics had changed from boarding to longer-range engagements (Endsor 2009, 165). The *London* and its assemblage provide archaeological evidence for the period prior to Samuel Pepys' and Charles II's attempts to standardise all things essential in the supply and fitting out of the Navy. Some of the *London* artefacts appear to demonstrate issues with the production, supply and use of stores and why standardisation was necessary to make the Navy more efficient and effective.

Conclusion

The excavation of trench 3 revealed a gun station with more gunner's implements than were needed for one gun, as well as other weapons. This suggests that the ship's crew was in the process of distributing and stowing the equipment. The chest of bandoliers and pistol, for example, would normally have been stowed in a safe and secure location, not next to a single gun station. The linstocks would normally have been evenly distributed about the gundecks, while the hand crow levers, and rope sponges would have been distributed to other guns. Given that the Chatham Ledger shows that the gun equipment had been returned to the ship on 23 February it should have already been appropriately distributed.

26. Depending on variations between the match lock and snaphaunce muskets.
27. Example DP00/166, 111.085.
28. 3581 has a volume of 19ml (body length of 110mm and a diameter at base of 28mm), while DP00/166, 111.085 has a volume of 25ml (body length of 109mm, extending to 120mm with cap, and a diameter at base of 31mm).
29. If filled to the top, allowing a weight/volume figure for packed gunpowder of 1.5g /cm^3.
30. Example 3618 is 48mm long and 26mm across the lugs. It has an external diameter at the base of 21 mm and an internal diameter of 18mm. The external diameter at the neck is 10mm and the internal diameter is 8mm.
31. X-radiographed at Fort Cumberland.

Indeed the recovered flexible rammers were not appropriate for this gun station, as they were intended for the smaller-bored culverins and demi-culverins which with the exception of the chase guns at the stern end of the main gundeck the culverins would have been on the middle deck and demi-culverins on the upper deck (Fox 2012, 67). The excavation of this small area has therefore provided an insight into what was happening on board the *London* at the moment that the ship blew up. The crew were obviously still in the process of making the ship ready for sea and for meeting their captain.

Both the inventory of guns and the types of guns that have been recovered demonstrate that the *London* was not issued with a standardised set of artillery. The main gundeck, for example, was equipped with three types of gun: demi-cannon, Dutch 24-pounders and culverin chase guns. This lack of standardisation on the main gundeck complicates the supply, maintenance and operation of the guns, especially during the heat of battle when guns potentially could have been supplied with the wrong charges or shot.

This lack of standardisation is reflected in the gunnery equipment; the recovered gun carriage, for example, had been altered to suit a longer, narrower gun. The wood species and type of materials used in the construction of the flexible rammers and the sponge were not consistent, while the use of both hawser and cable-laid rope suggests the recycling of old ropes. The lack of serving on one rammer (3206) suggests that it was either only partially or not served at all.

The assemblage of bandoliers and their component parts, including powder boxes and leather components, is the largest known recovery of such objects and is unique. This seems to be the first site from which all the component parts have been recovered and from their original context inside a chest. This has contributed to our understanding of how the bandoliers were worn, and the number and location of accessories suspended from the belt, including powder boxes, primers and shot pouches.[32]

The assemblage from the *London* provides archaeological support for Samuel Pepys' and Charles II's drive to introduce standardisation in the arming and fitting of naval ships, to produce a more efficient and effective naval gunnery system. This appears to have been lacking at the time of the *London's* loss as evidenced by the collection of equipment found at one gun station. This appears to have been lacking at the time of the London's loss as evidenced by the collection of multiples of equipment found at one gun station, which should have been evenly distributed to the appropriate guns or stored in a safe place. This demonstrates a lack of organisation and discipline on board at the time, as these stores were returned to the ship on the 23 February, 12 days before the ship blew up. Lack of discipline is further evidenced by Lawson's later testimony to the Navy Board (see Chapter 17, Walsh).

32. It is unfortunate that there was insufficient time to finish the excavation of the chest and recover the remaining bandoliers and the chest itself, as this would have helped to identify the size of the chest, the number of bandoliers stored in an individual chest and whether any other objects were stored with the bandoliers.

Chapter 8
Wooden Small Finds: Wood-working Technology, Wood Selection and Use

Steven J. Allen with Zoë Hazell and Emma Aitken

A total of 345 wooden small finds were recorded,[1] the majority of which (160)[2] relate to 'collars of bandoliers' that were worn over the shoulder by a soldier armed with a muzzle-loading long firearm or musket (Courtney 1988). A pipe stopper (3342) could not be examined at the time of writing but has been described in detail by Higgins (Chapter 10).

Powder boxes

Each powder box consists of two parts: a wooden cylinder or bottle, often tapering slightly towards the upper end, and a cap (Figs 8.1–8.3). The top of the powder box was removed, the powder was then emptied into the muzzle of the weapon, followed by wadding and a bullet. Priming powder was then added to the lock via a priming spout (Fig. 8.2); when the trigger was depressed the firing mechanism ignited the priming powder, flashing into the breech end of the barrel via a touch hole, setting off the main charge and propelling the bullet towards its target. Soldiers or marines armed with muskets would have been present on all larger warships of the period. For comparison, a third-rate vessel of 1685 would have been issued officially with 50 weapons for sailors forming boarding parties, plus more for any marines on board (Davies 2008, 144).

Overall, 117 examples of box bodies (see Fig. 8.3 for terminology) (or parts thereof; Figs 8.1–8.6) and 53 examples of caps (or parts thereof) were recovered (see Chapter 7, Pascoe *et al.*). Eight boxes[3] were recovered intact with caps *in situ* and six caps[4] had the remains of broken powder box necks *in situ*. The possibility that the six snapped necks found within their caps are from boxes that were recovered with broken or missing necks, or may be from boxes that are otherwise lost, would have minimal impact on the quantification.

The caps and boxes of five examples,[5] and possibly two others,[6] were made from the same wood species. The wood species of three[7] could not be determined for box body or cap, two (3469 and 3601; Fig. 8.5) had species identifications for the box body but not the cap, while one (3470) was not sampled. One lid with some neck inside it (3587) was identified but it was not sampled (Hazell and Aitken 2019, 22–23, table A1).

Although this is a small sample, in five certain and two probable cases the wood of the powder box matches that of its associated cap and in the remaining nine pieces the wood species was either indeterminate or unsampled. In no case is there a definite mismatch between the wood of the box body and its associated cap. It would appear at the very least that a box body and its cap came from the same wood species and the conversions might suggest they came from the same parent billet.

Of the identified artefacts, 40 box bodies and 16 caps were made from *Fraxinus* (ash). There were 27 box bodies and 13 caps of *Fagus* (beech), 16 box bodies and 10 caps of *Carpinus* (hornbeam), 14 box bodies but no caps of *Populus/Salix* (poplar/willow), 6 box bodies and 2 caps of *Acer* (maple), 4 box bodies and 3 caps of *Betula* (birch), one box body and 2 caps of *Alnus* (alder), one box body of *Juglans* (walnut) and one box body from the Maloideae family. Finally, two box bodies and one cap are from Betulaceae undiff.[8] (Hazell and

1. Linstocks were found exclusively in 2015 and powder boxes were exclusive to 2016.
2. Eight complete examples of powder boxes (3469, 3470, 3472, 3526, 3527, 3581, 3601 and 3687); 103 boxes only (3471, 3473–3475, 3504–3505, 3513–3522, 3525, 3528, 3538, 3567, 3572–3580, 3582–3586, 3602–3604, 3606–3608, 3612–3617, 3619–3621, 3635–3648, 3650–3653, 3654A–G, 3664–3672, 3673A–E, 3678–3686, 3688–3690A–B, 3702 and 3795 neck); 46 caps only (3506–3512, 3523, 3524, 3566, 3587, 3588, 3599, 3609-3611, 3614, 3622, 3630, 3649, 3655B–J, 3656–3662, 3674–3676, 3696–3700, 3712 and 3799); 3 priming spouts (3618, 3655A and 3703).
3. 3469, 3470, 3472, 3526, 3527, 3581, 3601 and 3687.
4. 3506, 3587, 3656, 3657, 3658 and 3700.
5. 3472 ash; 3506, 3658 and 3687 hornbeam; 3656 beech.
6. 3657 and 3700 – hornbeam and Betulaceae undiff.
7. 3526, 3527 and 3581.
8. Betulaceae undiff. is used here as a summary, where the genera from the Betulaceae family (i.e. alder, birch, hazel and hornbeam) could not be differentiated to genus level based on the wood anatomical features preserved. In some cases, however, some level of refinement was possible; see Hazell and Aitken (2019) for further detail.

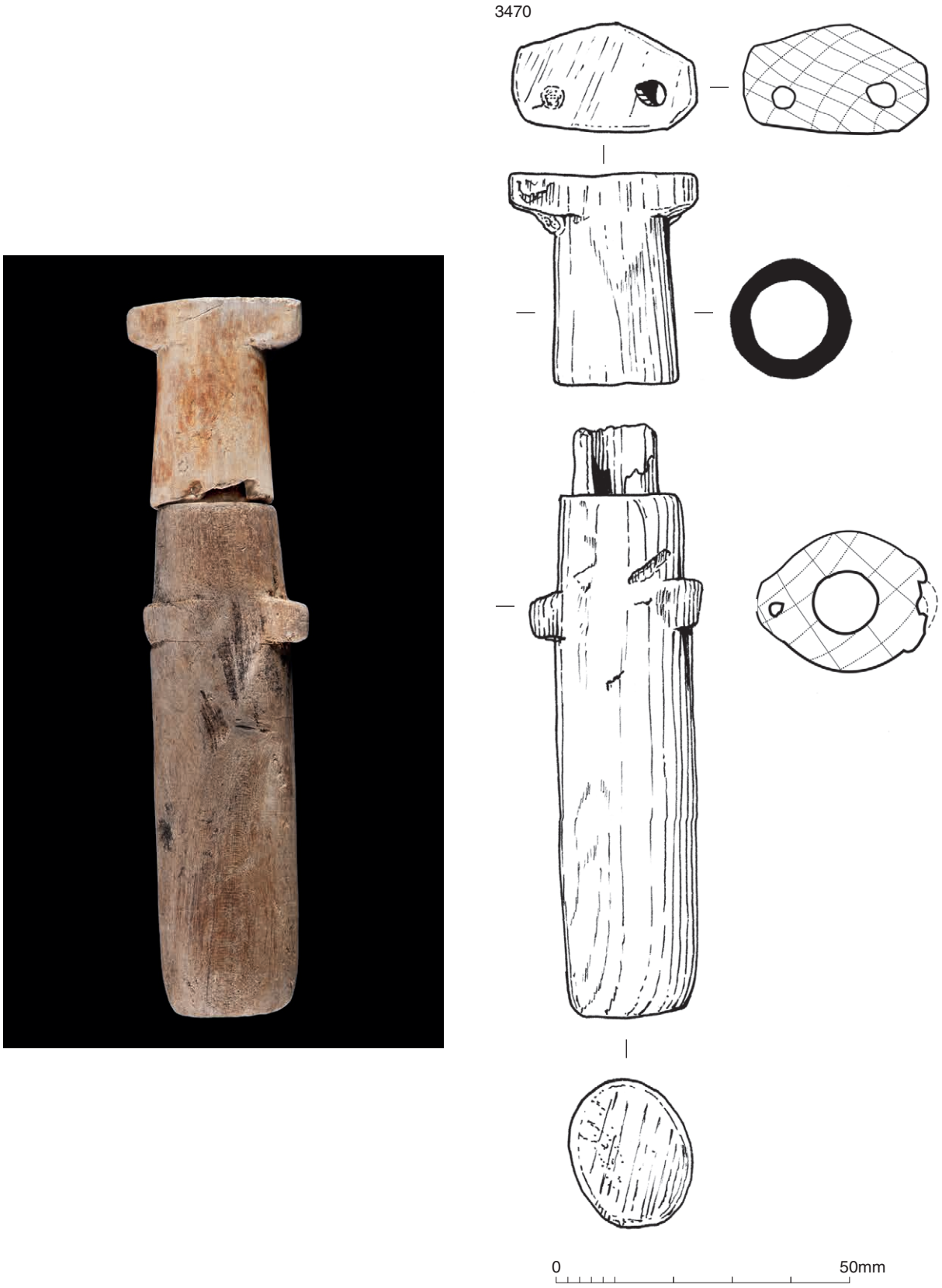


Figure 8.1a Complete powder box (3470; © Historic England Archive, photograph James O. Davies, © Historic England, drawing Ruth Parkin)

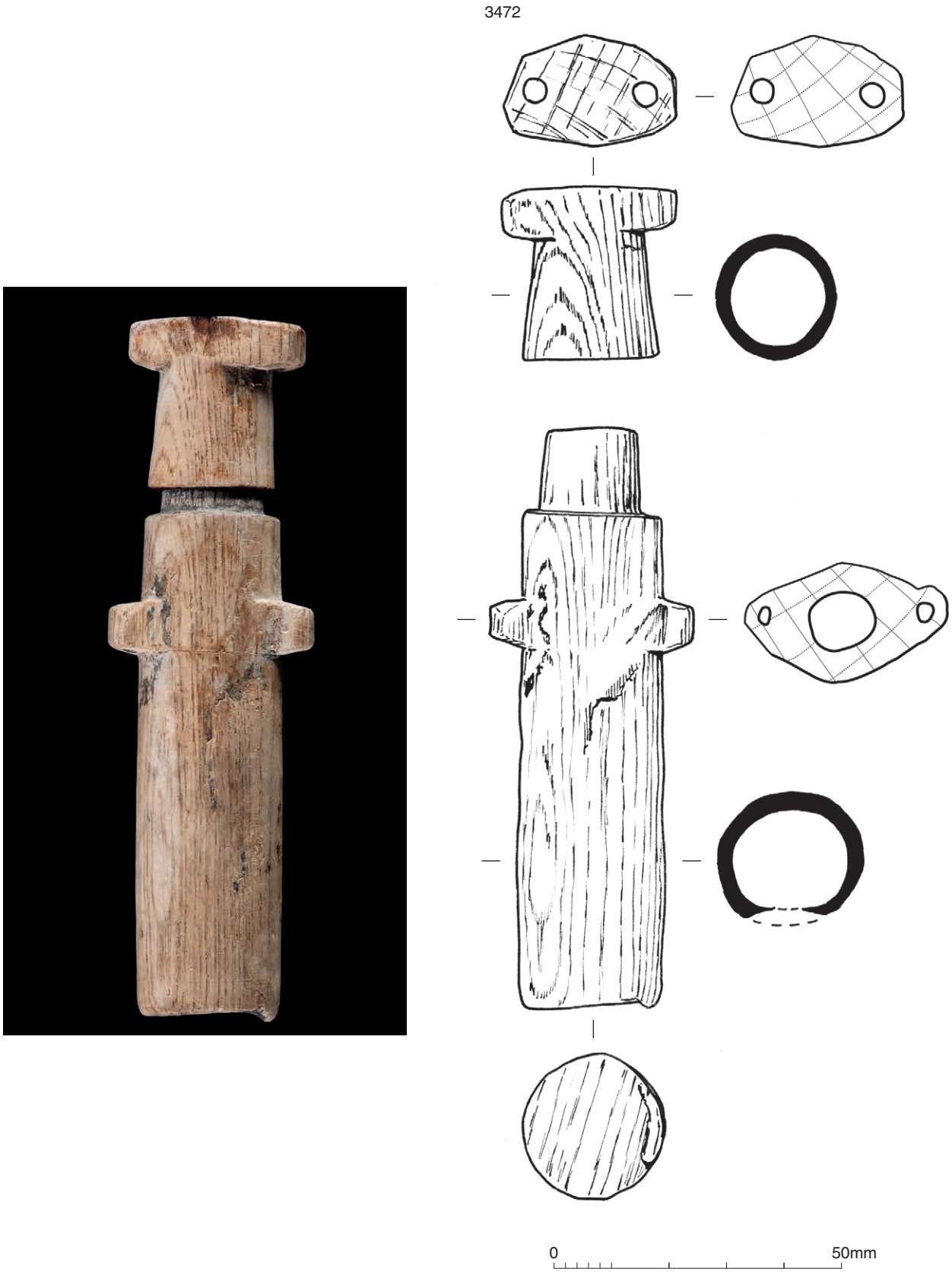


Figure 8.1b Complete powder box (3472; © Historic England Archive, photograph James O. Davies, © Historic England, drawing Ruth Parkin)



Figure 8.1c Complete powder box (3526; © Historic England Archive, photograph James O. Davies, © Historic England, drawing Ruth Parkin)



Figure 8.1d Complete powder box (3527; © Historic England Archive, photograph James O. Davies, © Historic England, drawing Ruth Parkin)

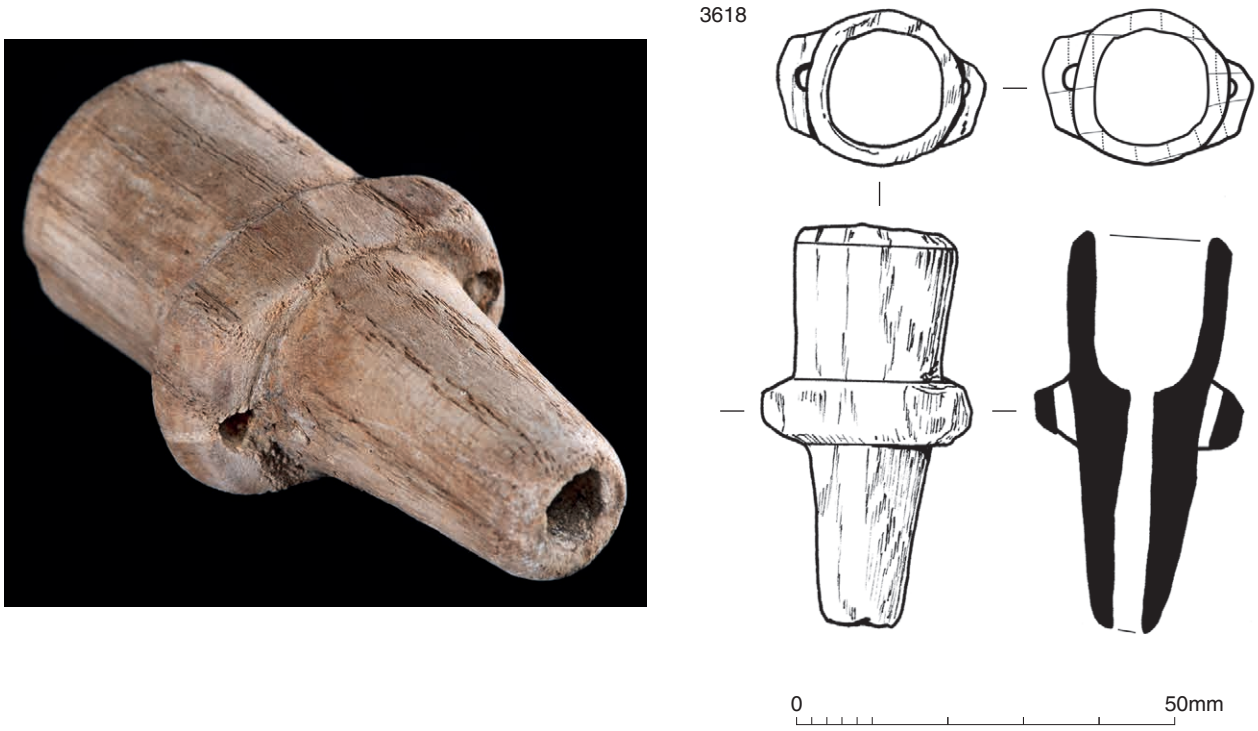


Figure 8.2 Priming spout (3618; © Historic England Archive, photograph James O. Davies, © Historic England, drawing Ruth Parkin)

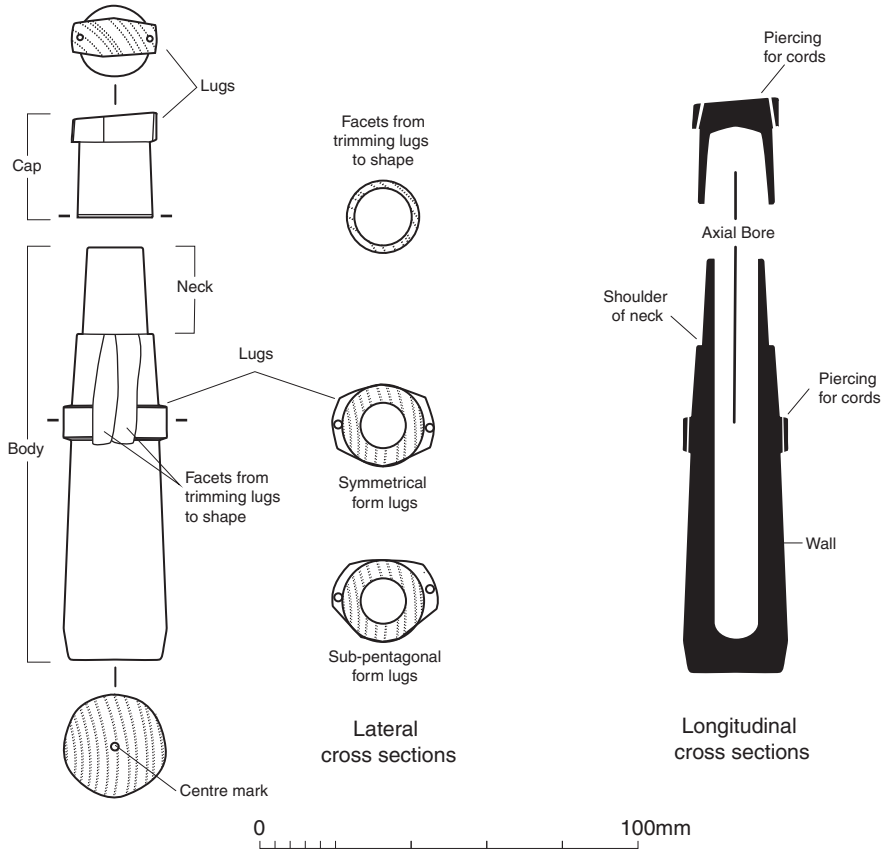


Figure 8.3 Powder box terminology (© Historic England, drawing Steven Allen)

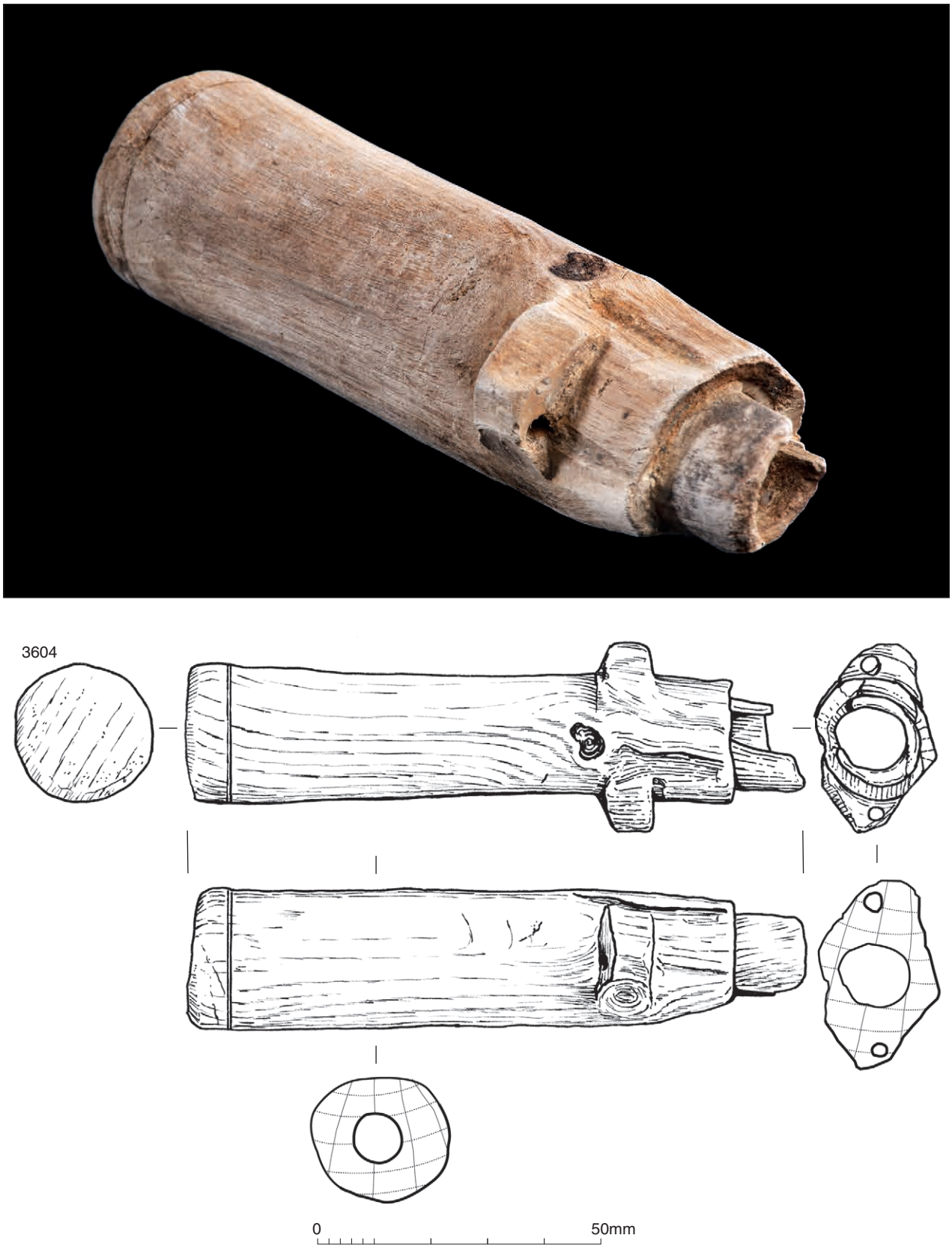


Figure 8.4a Powder box body (3604; © Historic England Archive, photograph James O. Davies, © Historic England, drawing Ruth Parkin)

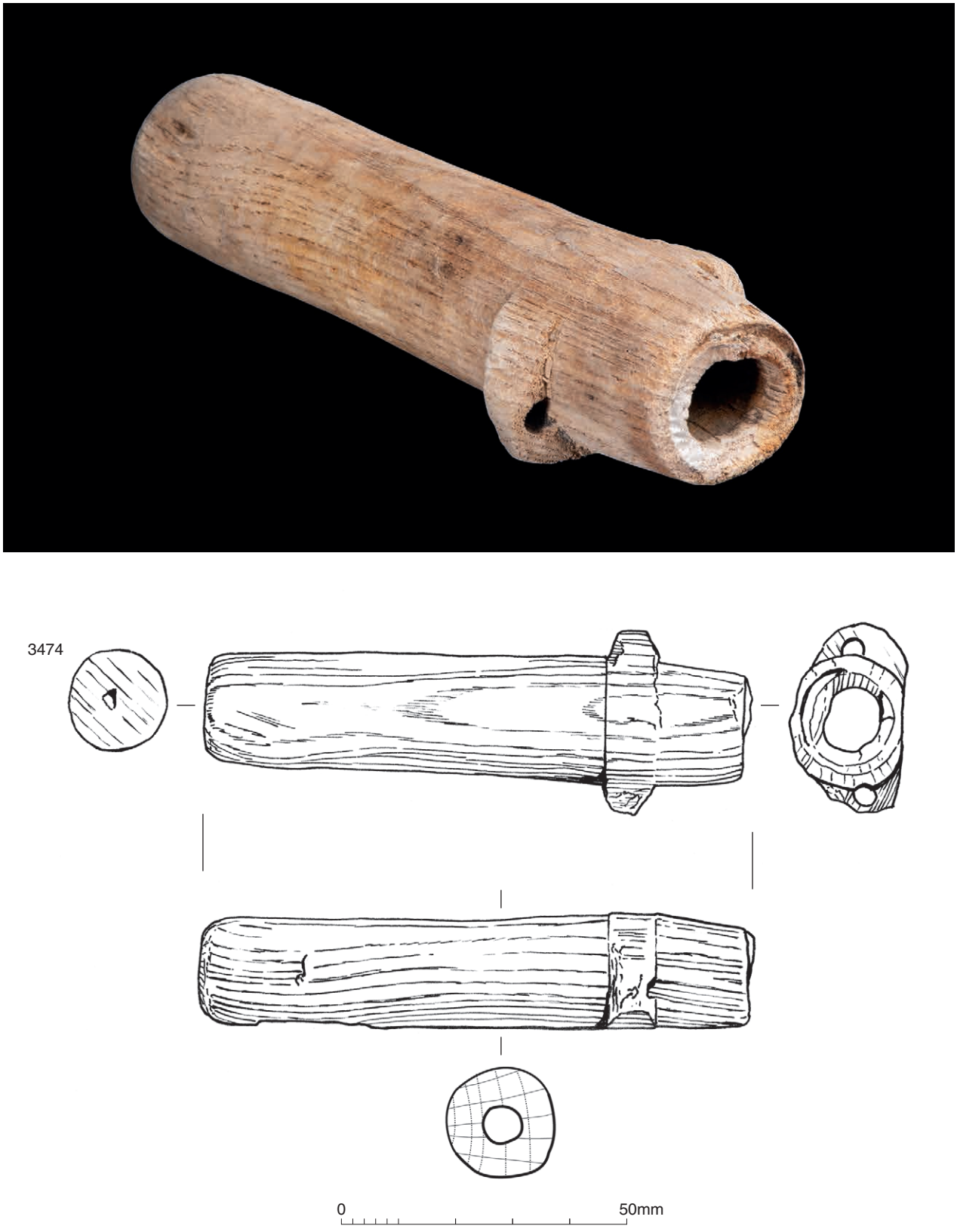


Figure 8.4b Powder box body (3474; © Historic England Archive, photograph James O. Davies, © Historic England, drawing Ruth Parkin)

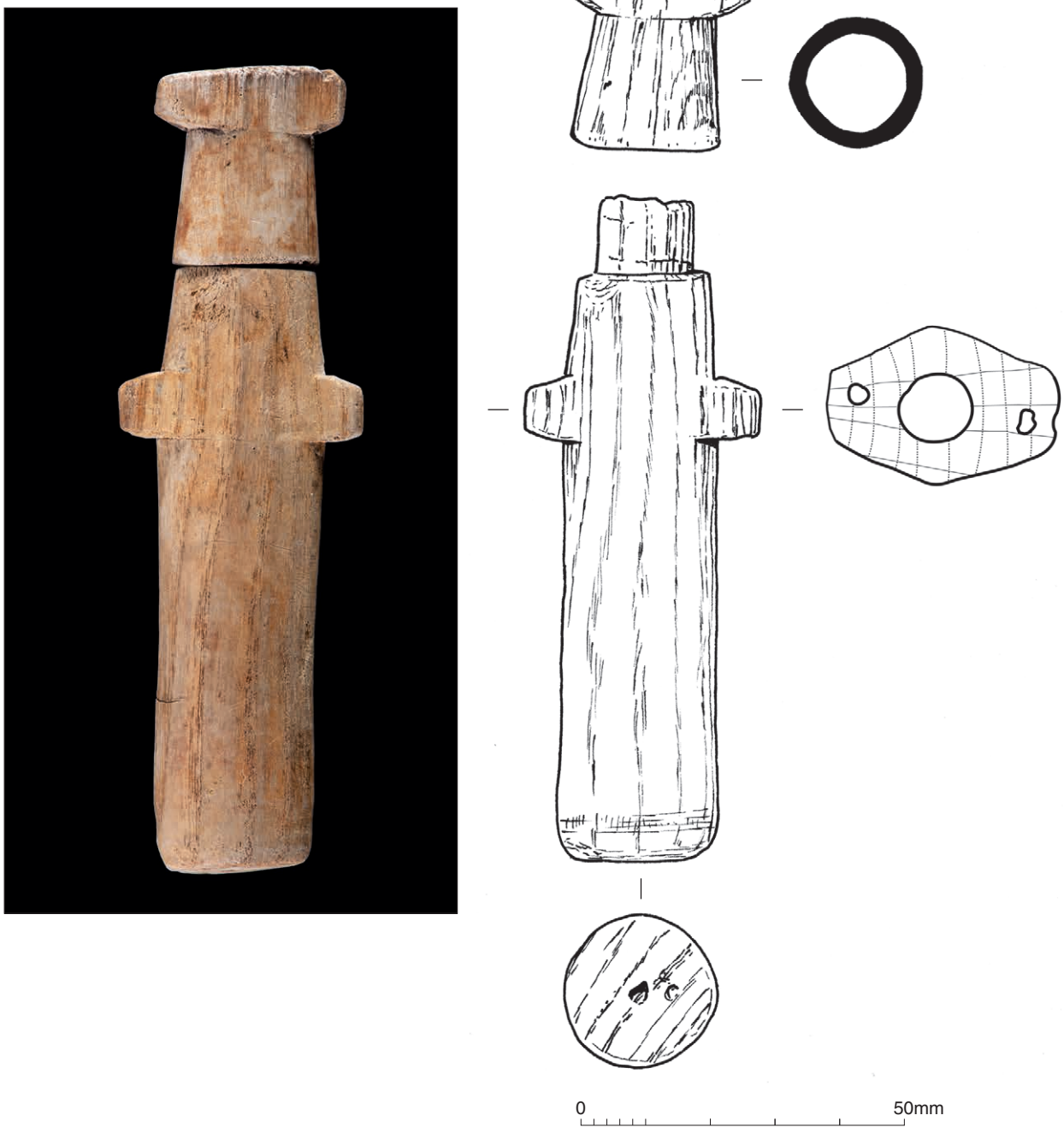


Figure 8.5a Complete powder box (3469; © Historic England Archive, photograph James O. Davies, © Historic England, drawing Ruth Parkin)

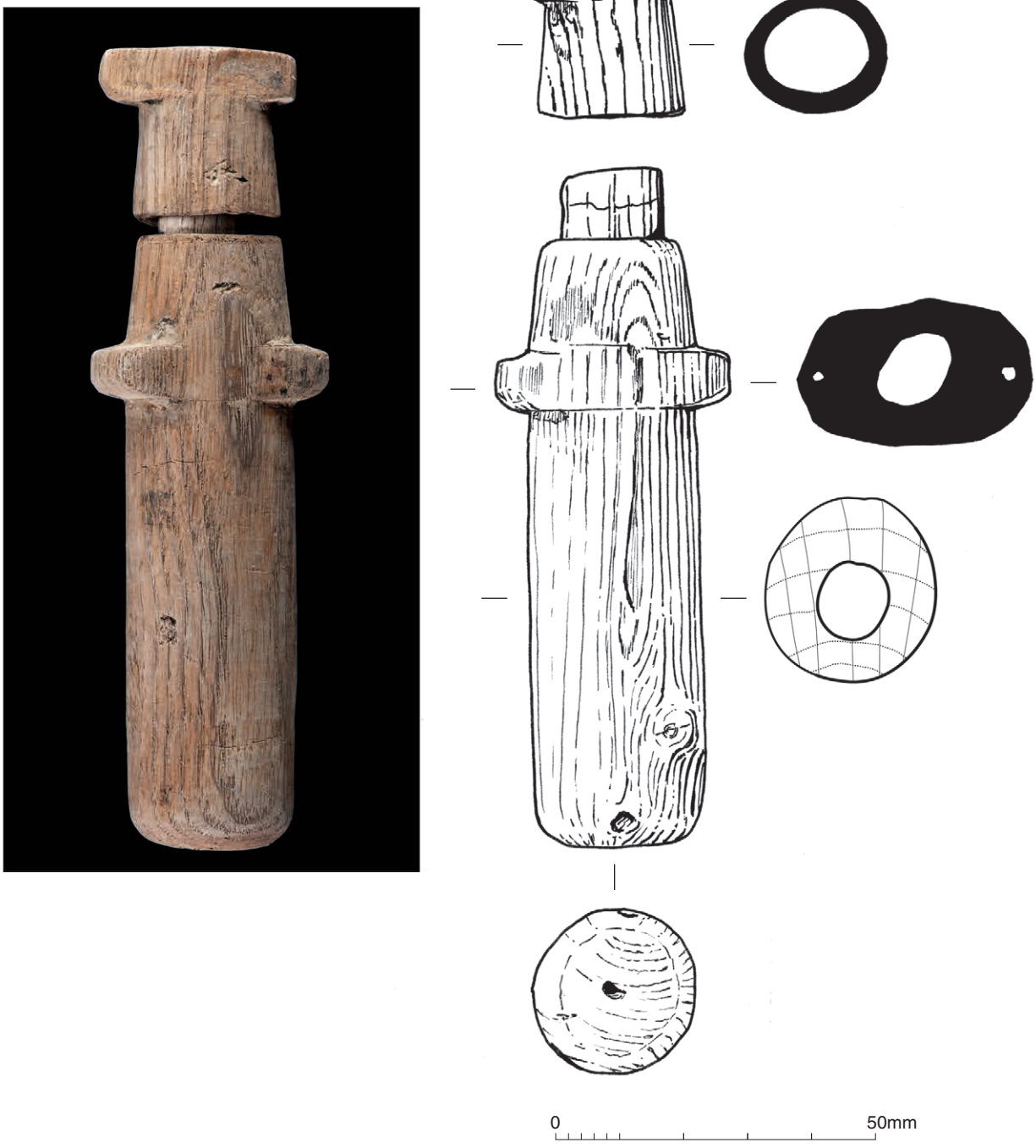


Figure 8.5b Complete powder box (3601; © Historic England Archive, photograph James O. Davies, © Historic England, drawing Ruth Parkin)

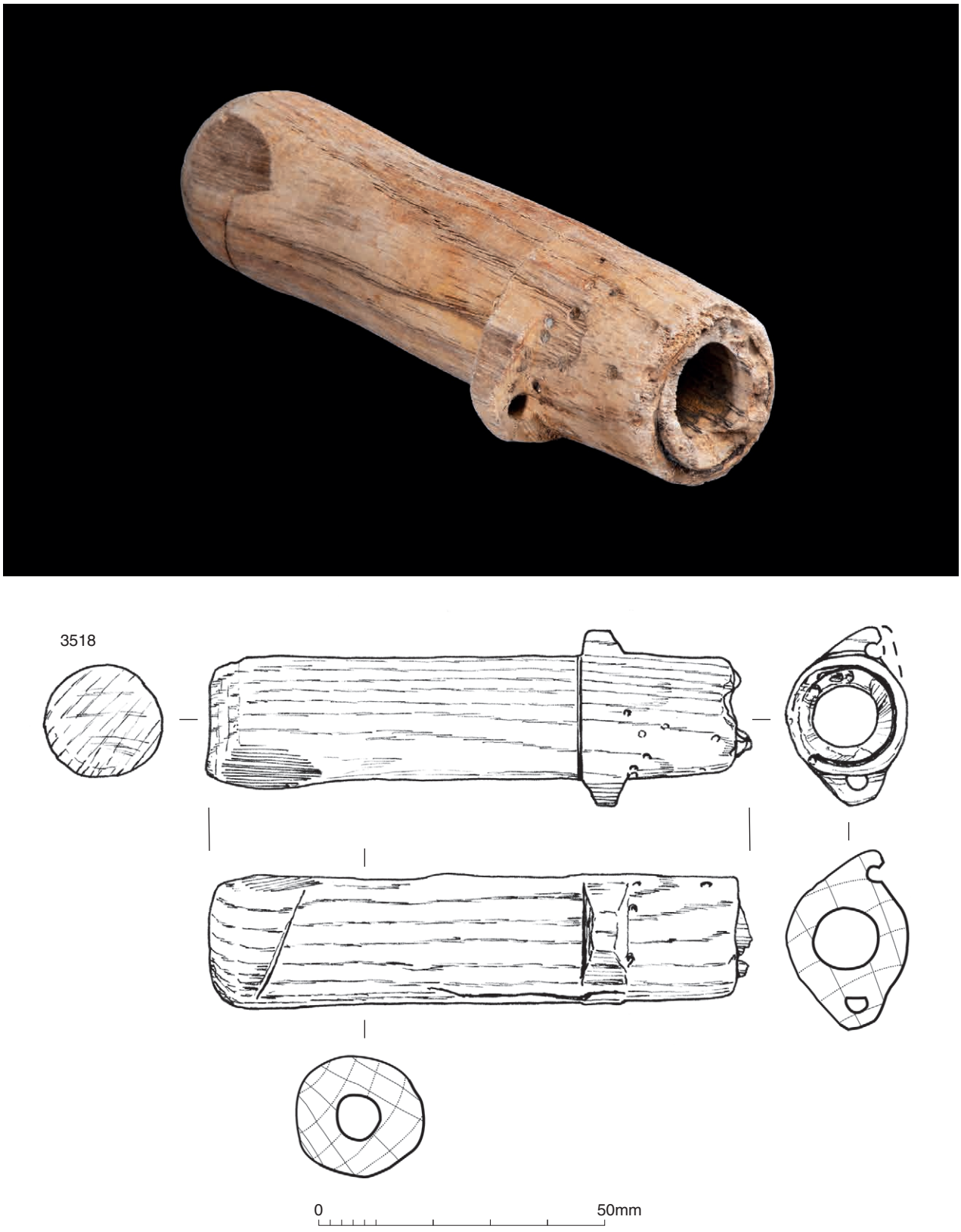


Figure 8.6a Powder box body (3518; © Historic England Archive, photograph James O. Davies, © Historic England, drawing Ruth Parkin)

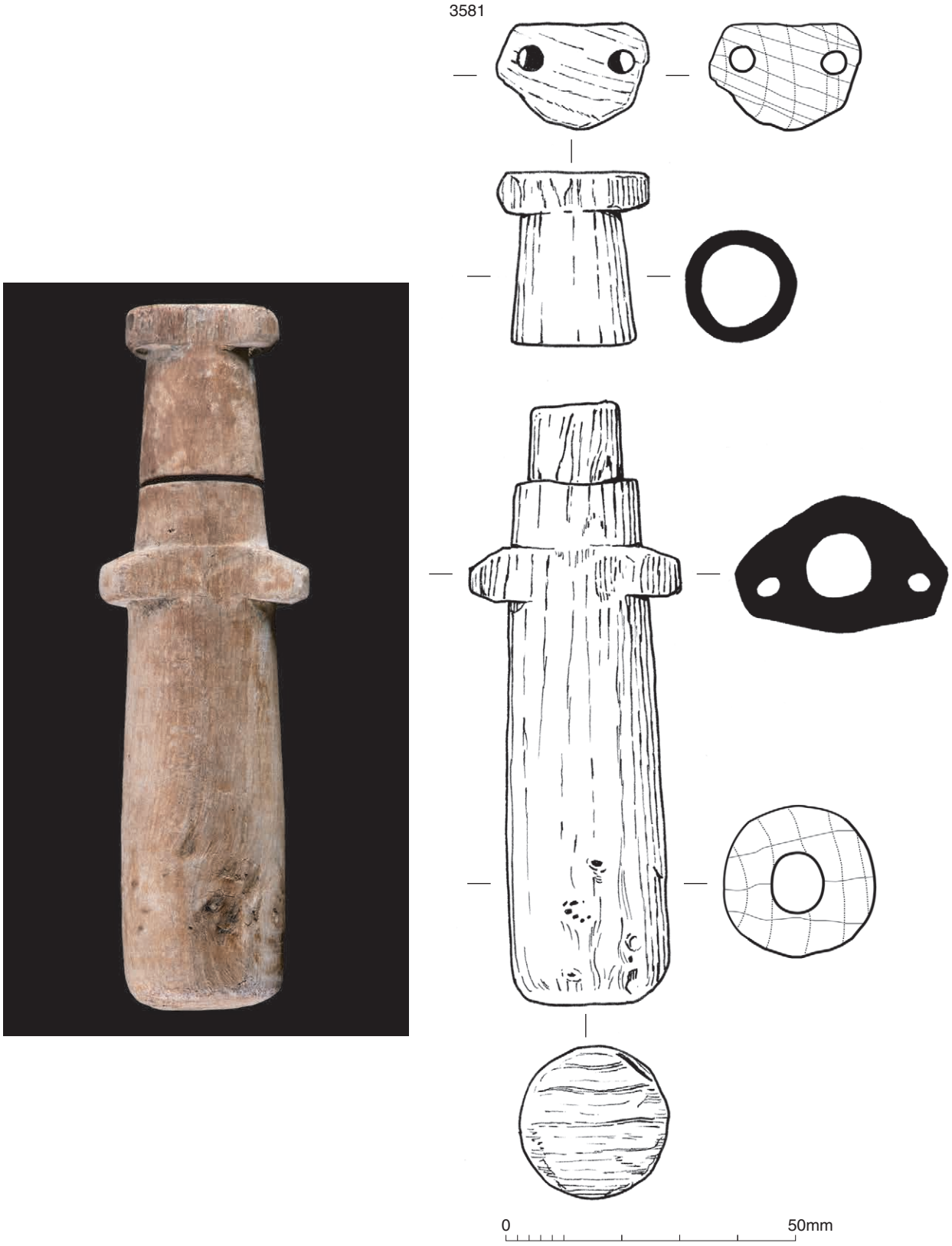


Figure 8.6b Complete powder box (3581; © Historic England Archive, photograph James O. Davies, © Historic England, drawing Ruth Parkin)

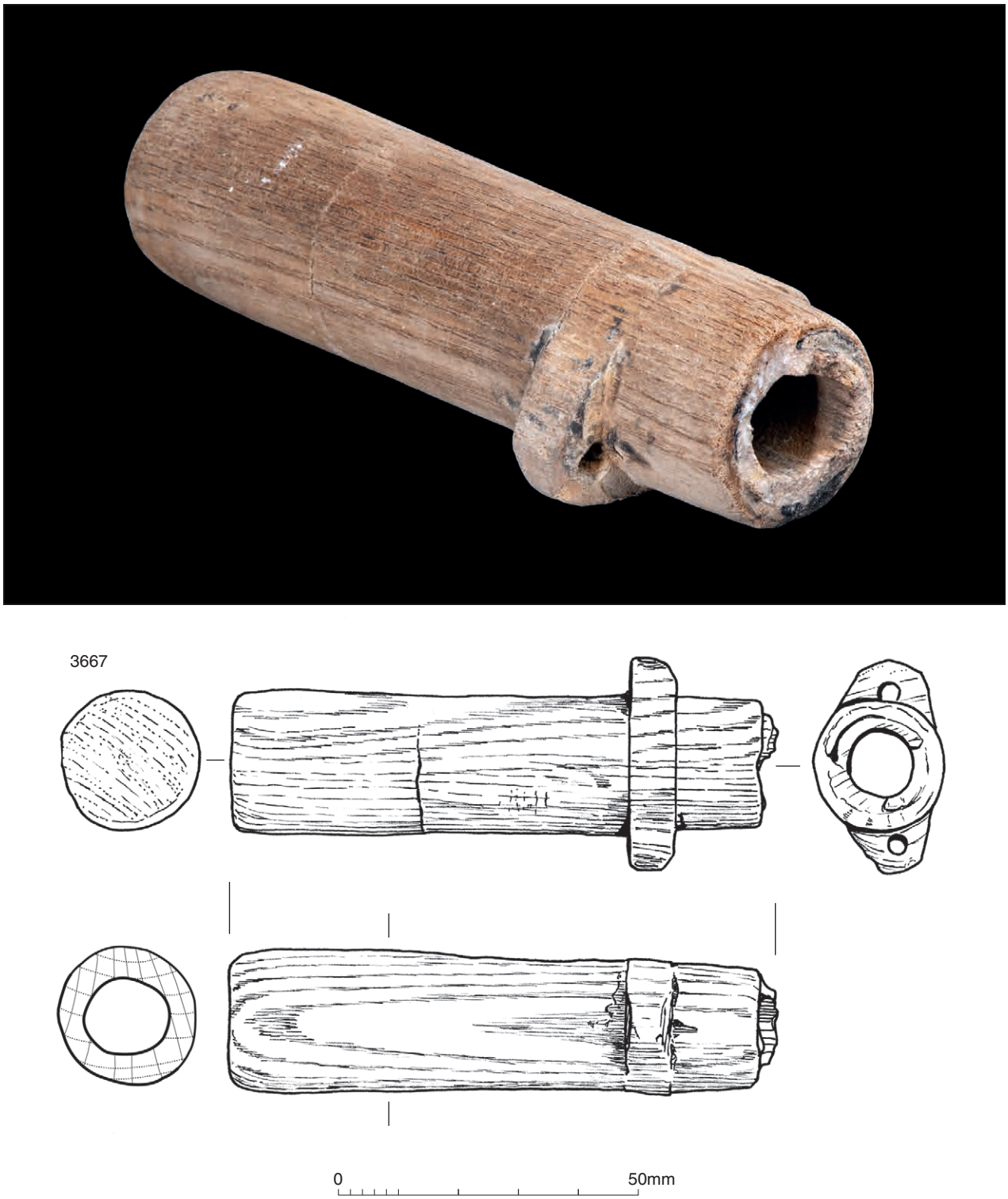


Figure 8.6c Powder box body (3667; © Historic England Archive, photograph James O. Davies, © Historic England, drawing Ruth Parkin)

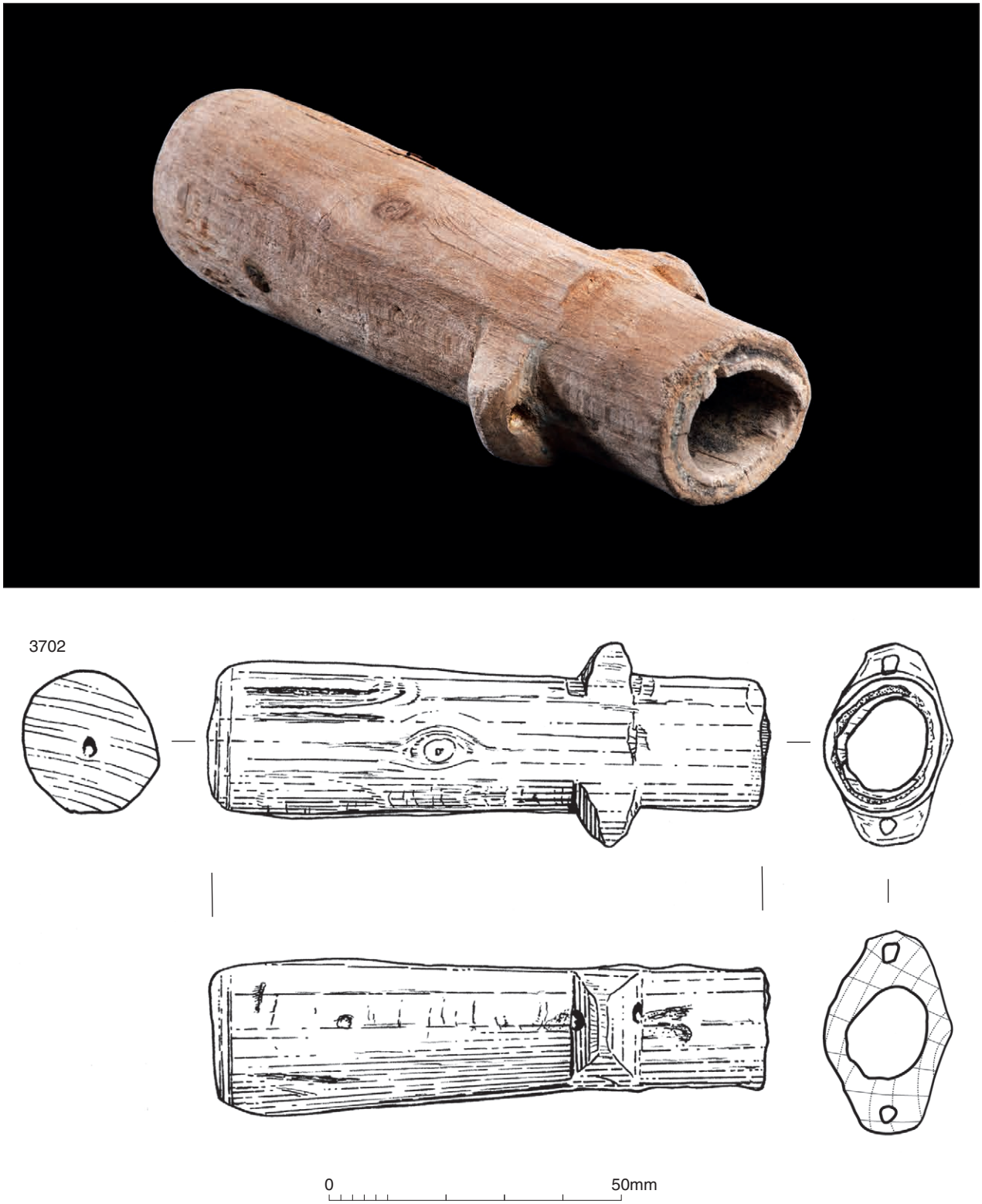


Figure 8.6d Powder box body (3702; © Historic England Archive, photograph James O. Davies, © Historic England, drawing Ruth Parkin)

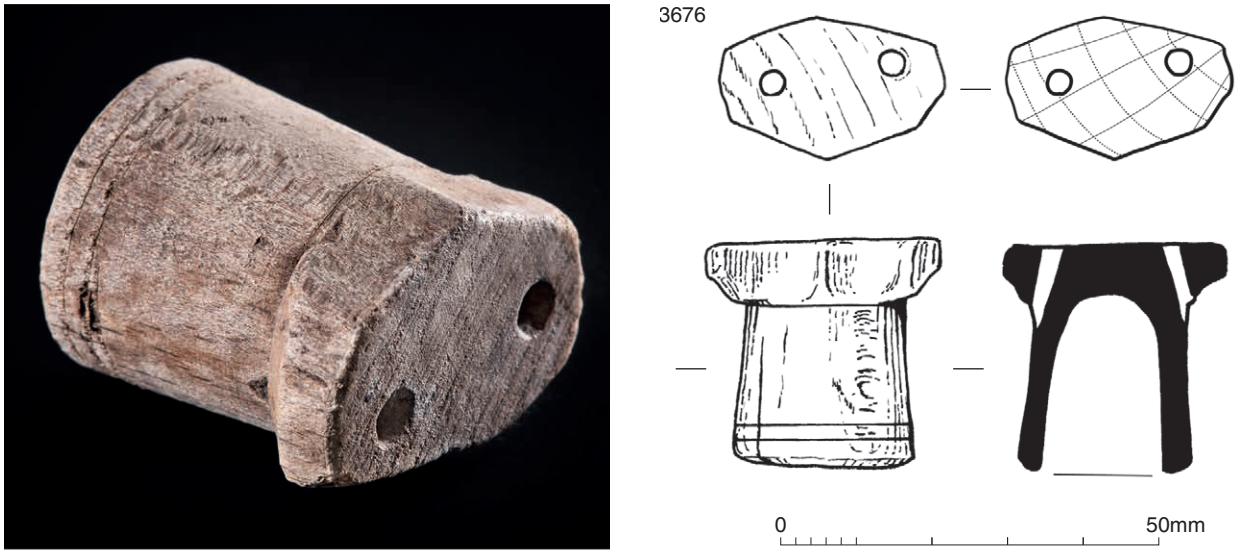


Figure 8.7 Grooved powder cap (3676; © Historic England Archive, photograph James O. Davies, © Historic England, drawing Ruth Parkin)

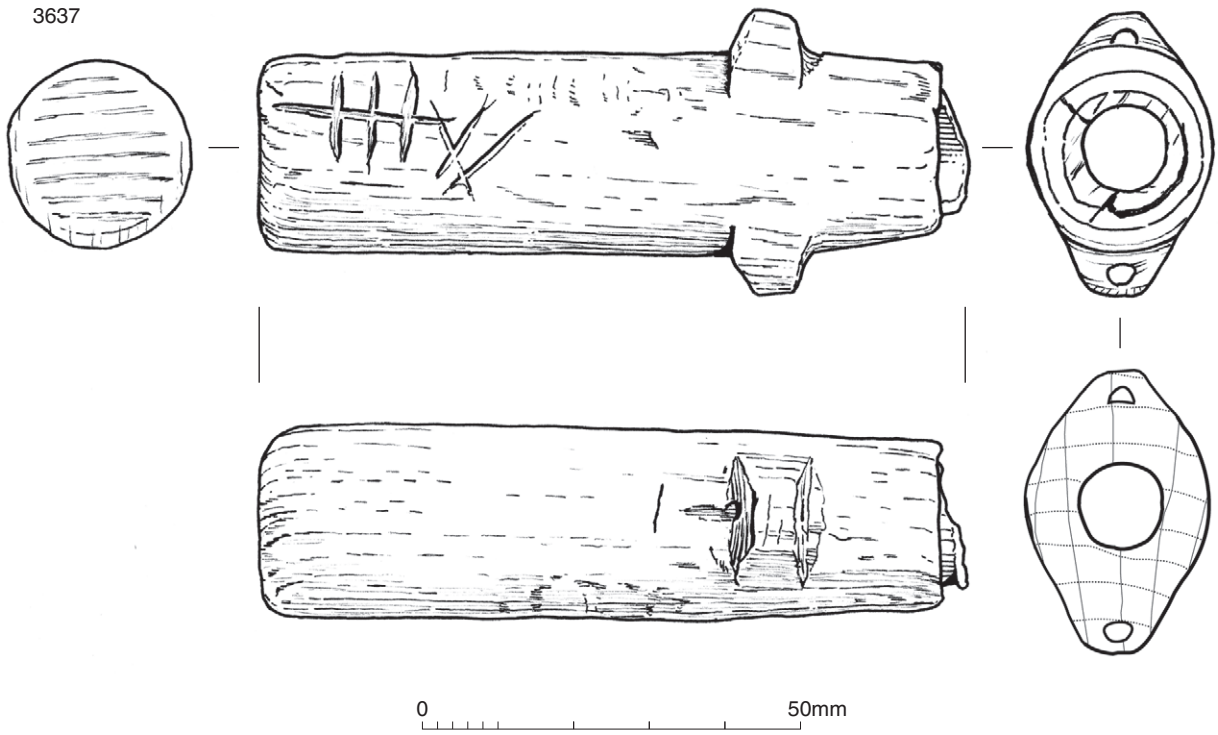


Figure 8.8 Incised mark on powder box (3637; © Historic England, drawing Ruth Parkin)

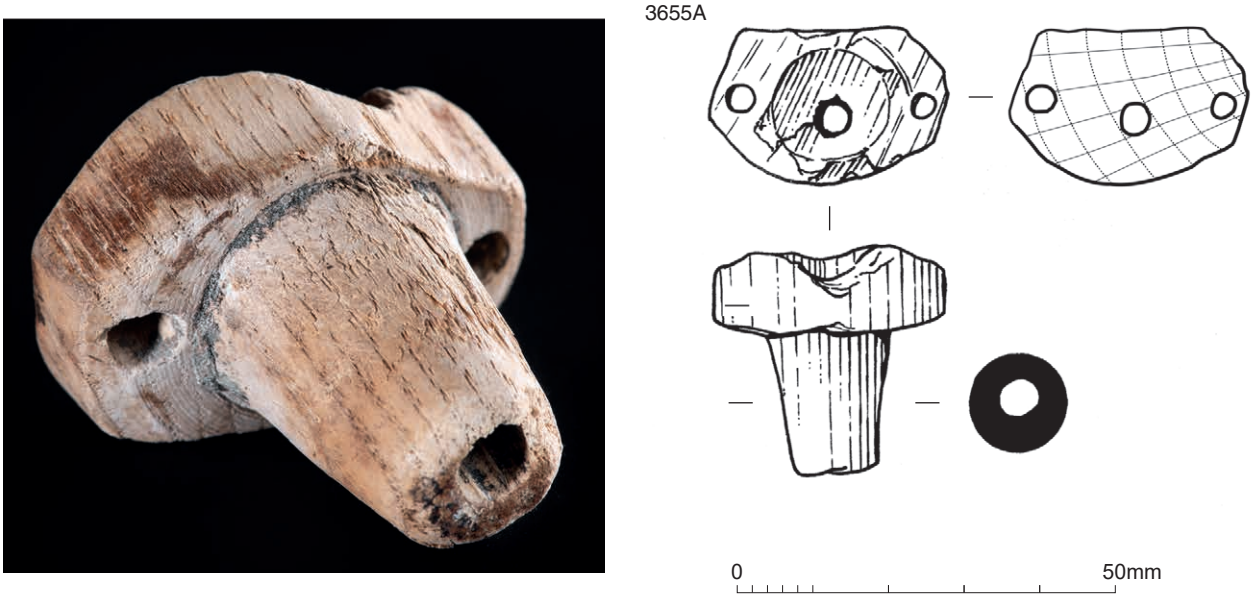


Figure 8.9a Priming spout (3655A; © Historic England Archive, photograph James O. Davies, © Historic England, drawing Ruth Parkin)

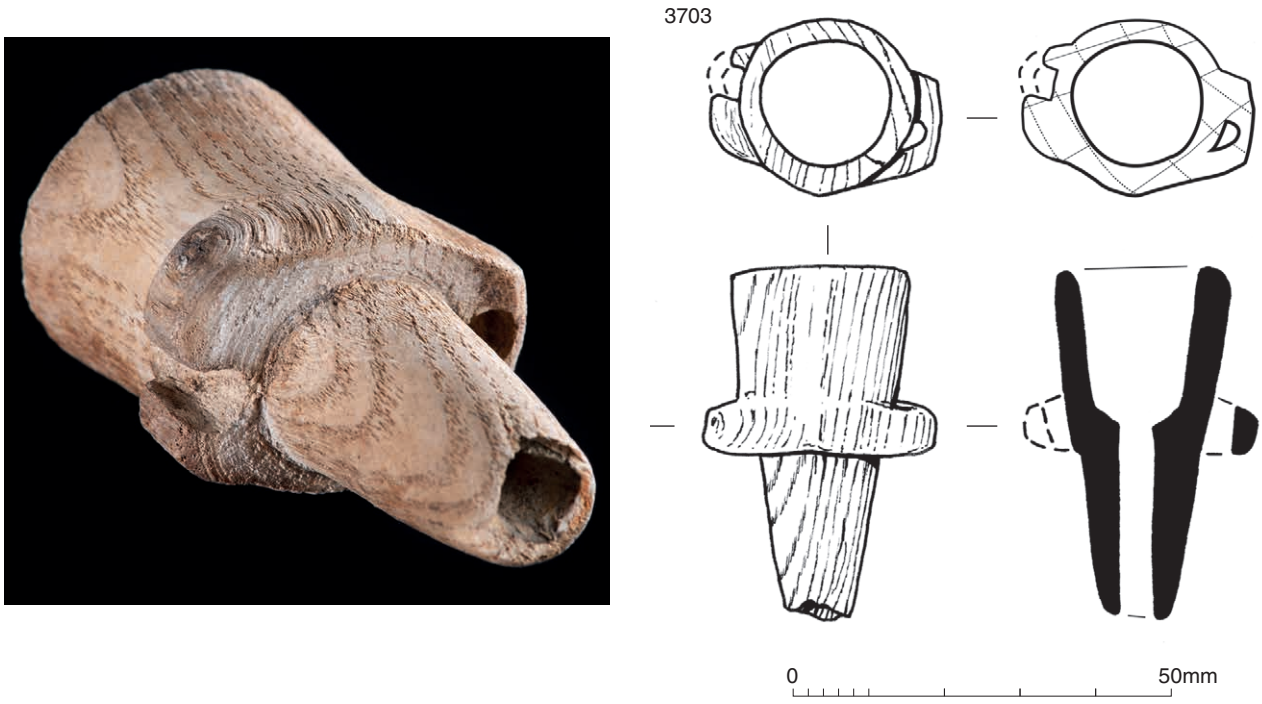


Figure 8.9b Priming spout (3703; © Historic England Archive, photograph James O. Davies, © Historic England, drawing Ruth Parkin)

Aitken 2019, table A2). All of these are popular choices of wood species for producing turned objects as they are relatively dense and do not splinter easily.

The one unusual choice (3519) is cut from a piece of walnut (Hazell and Aitken 2019, table A2), which is a relatively expensive wood and one that would not have been in common supply. A complete bandolier of such powder boxes would have been significantly more expensive than those made from other woods, so this is either a piece from such a set or a stray box body incorporated into another set – perhaps recycled from an older one broken up for reuse.

No two powder boxes are identical (Figs 8.1, 8.4–8.6, 8.8); the eight intact powder boxes measured between 120 and 130mm long, while the width varied according to the amount of trimming that had taken place to form the lugs.

All powder boxes were made from converted heartwood billets; no roundwood rods are present. Each billet would have been sub-rectangular in cross-section, deriving either from a 'radially'-faced (93 box bodies and six caps), a box-quartered (13 box bodies and 41 caps) or a tangentially-faced (three box bodies and six caps) timber. Owing to the rounded cross-section of the finished object it is quite probable that what are recorded as 'radial', 'tangential' or 'quartered' conversions are simply a fortuitous result of the way in which the artefact had been finished, rather than how the original billet may have been cut from the parent log.

Each powder box was spindle-turned on a lathe from its parent billet, having been trimmed roughly to shape with a hewing tool. Some boxes (3579, 3582 and 3645) had been overworked at this stage, so overcut facets, not removed by subsequent turning, were noticeable towards the lower end. A circumferential ridge was left approximately one third down the box body; faint turning marks on some of their upper and lower surfaces show that this was done at the turning stage. This ridge was then partially trimmed almost flush with the side of the box body on opposing faces to leave a projecting 'lug' on each side (see Figs 8.1, 8.4–8.6, 8.8). On approximately 34 boxes these lugs are almost symmetrical and when viewed in plan are almost sub-hexagonal in form.[9] On 45 others one part of the lug has been so heavily trimmed that it looks sub-pentagonal in plan, with an almost flat face on one side.[10] The remaining box bodies are too badly damaged to be certain of their lug form.

The top of each box body was reduced in diameter on the lathe to produce a neck, which was covered with a close-fitting cap. These caps were also lathe-turned to create a short, slightly tapering cylinder ending in a flat-headed button top. The edges of this button were partially trimmed to create projecting lugs corresponding to those on the box body. A single small hole 1.5–2.5mm in diameter was bored lengthwise through each lug, through which a cord was passed to both retain the cap and with which the powder box was hung from the bandolier. This enabled the cap to be slipped off the top of the box when used without it becoming separated from its box body and lost.

Blind holes 10mm in diameter were bored into the length of both the box and the cap using a spoon bit to create the hollow core. The hole in the cap had a slightly larger diameter to enable the cap to fit closely over the neck on the box. On powder boxes with undamaged necks the depth of the bore varies between 95 and 102mm.

Centre marks from the mandrel spike of the lathe survive on the bases of 14 boxes.[11] Marks surviving on the bottom ends of most boxes show that waste was generally sawn away, but one (3651) was detached with a hewing tool, while another (3527) was turned so deeply that the waste was snapped off. The upper end of the caps was sawn away from the parent billet. No mandrel spike centre marks survive on these caps, though the turning marks are often prominent on the lower shoulder of the lugs. One powder box (3683) bears a deep cut mark in the wood, where a tool used at the turning stage jammed in the body.

Decoration on any of the elements of these boxes was at best sparse. One cap (3676) has a pair of narrow-turned grooves around the circumference just above the base (Fig. 8.7). The meaning or significance of an individual incised mark cut into the face of one box (3637; Fig. 8.8) is unknown. One box (3668) has a heavily charred patch on the wall of the vessel towards the base.

Three spouts (3618, 3655A and 3703) were made in a similar way to the caps (Fig. 8.9), being lathe-turned and trimmed with pierced lugs, and drilled to fit over the powder box necks (see Figs 8.1b and 8.2). The upper end, however, was turned to create a long conical top which was drilled out to form a spout, which enabled small amounts of powder to be poured through them. Unlike the caps that sealed the boxes until the contents were poured into a muzzle, these spouts were fitted to powder boxes containing powder (known as primer) for priming a firearm. All three spouts were cut from ash (Hazell and Aitken 2019, table A2) and all are similar in size (see Figs 8.2 and 8.9).

Gun carriage and associated fittings

The gun carriage

The largest wooden artefact recovered from the *London* is a near-complete gun carriage (3149, 3239, 3317, 3318, 3357, 3499, 3503 and 3531; see Chapter 7, Pascoe).[12] The

9. 3469, 3470, 3473, 3475, 3505, 3511, 3515, 3517, 3521, 3522, 3525, 3567, 3575, 3580, 3582–3586, 3602, 3604, 3606, 3608, 3612, 3616, 3620, 3637, 3640, 3650, 3653, 3665, 3666, 3678 and 3682.
10. 3471, 3474, 3504, 3514, 3516, 3518, 3520, 3528, 3572-3574, 3576–3579, 3581, 3603, 3607, 3613, 3617, 3621, 3635, 3638, 3639, 3641–3645, 3651, 3652, 3664, 3667–3669, 3673B, 3679–3681, 3683–3686, 3690 and 3702.
11. 3469, 3526, 3527, 3601, 3603, 3635, 3639, 3643, 3644, 3645, 3647, 3651, 3680 and 3702.
12. This is a composite artefact consisting of a base or bed of two planks butted edge to edge, linked by cross pieces or braces and a pair of axles. Each axle mounts a single truck wheel on each end. The sides of the carriage are formed by left-side and right-side cheek pieces fastened to the upper face of the bed along each edge. Much of the object is articulated but there are a number of separately numbered pieces that are probably from the same carriage and are treated as such here.

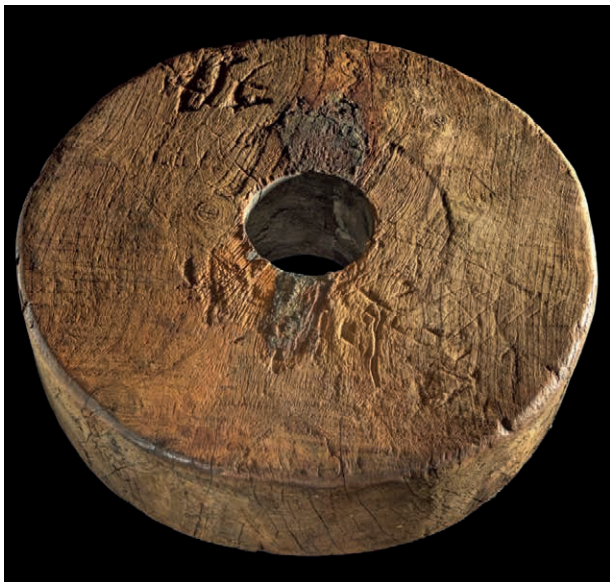


Figure 8.10 Complete gun carriage truck after conservation (© Historic England Archive, Christopher Redgrave)



Figure 8.11 Maker's mark (+Я) on the internal faces of the gun carriage cheeks (© Historic England Archive, Christopher Redgrave)

two planks connected by two tenons, which formed the carriage bed, and one of the two trunnion support cheeks, each made from a single piece of timber, attached to each side of the bed by a single tenon fixed with wooden pegs, are sawn tangentially-faced conversions; the other cheek plank was effectively boxed heart, though this is certainly a fortuitous accident of the positioning of the parent log during conversion, where the baulk is sawn into parallel slices. The two cheeks have four steps which facilitated the adjustment of the elevation of the gun.

All four pieces are of elm,[13] with one of the bed planks having a small sapwood zone surviving. The bed widens at the rear of the carriage to accommodate the breech of the gun; localised axe hewing marks show the edges of the bed were trimmed to create this taper after the cheek pieces had been fastened to the bed. Other evidence of modification is in the form of small tangentially-faced rectangular elm boards or fillets nailed to the inner face of each cheek immediately below the trunnion sockets.[14] Matching markings on the inner face of the left cheek and on the upper face of the left bed plank (the latter truncated by a later through hole) suggest these marks belong to the original construction of the carriage and that the piece had been modified but not disassembled and rebuilt.

The front and rear axle-trees, to which the trucks or wheels were connected, were secured to the carriage by iron bolts. They were cut from box-quartered elm heartwood and retain a sub-rectangular cross-section across the width of the bed to which they are fastened. The ends of each were reduced to a circular cross-section to enable the trucks to be slipped on to the axle and to rotate around the pivot so formed. Single through holes pass through each pivot outside of the truck to house iron lynch pins that prevented the truck from slipping off the pivot whilst in use.

The trucks (Fig. 8.10) were cut from thick tangentially-faced sawn elm planks, probably marked out with a compass and finished with a hewing tool. A slight bevel around the outside helps to reduce stress on the wood at this point and reduces the risk of the truck face splintering in use. Marks on the inside of the piercings for the axle show these were finished off with curved profile gouges rather than entirely drilled out, although it is quite possible that these holes were started with smaller drilled holes to remove most of the waste.

The cross-braces were tangentially-faced or box-quartered sawn lengths of elm fastened to the underside of the bed. Their edges and ends were chamfered and bevelled respectively with hewing tools, perhaps to limit the chances of sharp corners splitting off or catching on obstructions while the carriage was in use.

The X-radiography of the concretions which represent the remains of the two wrought iron cross-bars and assorted bolt heads that connected the two cheeks, revealed that the front cross bar (part of which is still attached to the gun carriage)

13. As stated in Chapter 5 Allen only undertook wood identifications for elements of the gun carriage to enable a conservation regime to be formulated for it; all other wood identifications were undertaken by Hazell and Aitken (2019 and this chapter).
14. It seems likely that this truck carriage had been built for a larger gun and was modified to support a smaller cannon.

was best preserved. The bolt heads and the rear cross bar were poorly preserved, with very little uncorroded wrought iron surviving (see Chapter 5, Panter). An unidentified carriage maker's mark (+Я) is visible on the inside face of both cheeks (Fig. 8.11) and on the bed (Pascoe 2017, 34).

Blocks and deadeyes

The blocks (3052, 3079, 3120, 3127, 3257, 3315 and 3358; see Fig. 7.13 for terminology) (Burney 2006, 41) are formed from a body or shell cut from elm heartwood into which one (single; Fig. 8.12) or two (double) slots had been cut (see Chapter 7, Pascoe *et al.* and Chapter 6, Endsor). Each body had been sawn to length and its rounded edges trimmed to shape with hewing tools. These slots have one square cut end (finished with a 20mm wide chisel) and one rounded end (finished with a gouge greater than 10mm wide) that indicates which end of the slot its rope passed through. The slots house the sheaves, disc-shaped bearings usually cut from radially-faced elm boards, though the pair in the double block (3358) are ash (Hazell and Aitken 2019, table A2). Their round edge has a concave profile to guide the rope around it. This was probably finished with a gouge, though the surfaces are worn and this cannot be confirmed.

Each sheave is mounted on and rotated around a peg (pin or axle) cut from a heartwood billet or roundwood.[15] Each had been trimmed to a circular cross-section passing through each slot at right angles through pre-drilled holes and offset within the slot to allow more space at the rounded end of the slot than the squared end. The end of each axle is trimmed off flush with the surface of the block with a hewing tool. The slots are long enough to enable rope to be passed through and around the sheave. Shallow grooves or rope guides were cut into each face of the block with gouges, around 20mm in width, at each end to enable further rope to pass around the body of the block to hold it to a fixed point.

The deadeyes (3079 and 3315; Burney 2006, 45; see Chapter 6, Endsor) are discs cut from box-halved heartwood (Fig. 8.13). The heavy corrosion and attached iron fittings have precluded the sampling of these objects for species identification. Each disc is pierced by three through holes in the face. Each hole has a shallow groove or rope guide cut into the adjacent face enabling cordage to pass through smoothly. An iron band is fastened around the edge of the deadeye and joins at one end with a fixed chain that in turn would have fastened to a fixed point on the ship's structure.

Loading and firing equipment

Rammer and sponge heads

The heads of two rammers (3206, 3207, see Figs 7.4 and 7.5) and a sponge (3324, see Fig. 7.6) are wooden cylinders made to fit the bore of a muzzle-loading gun, used to load the powder charge and shot (Burney 2006, 380; see Chapter 7, Pascoe *et al.*). Each had been spindle-turned from a block of boxed heartwood.[16] All have turning marks surviving on the circumference and two (3206 and 3207) have a single turned (possibly decorative) line around the outside. Each was bored out to house the end of a length of thick cordage which formed the flexible handle, the bore varying between 51mm and 64mm in diameter. The end of the cordage was secured in place with iron nails. The sponge (3324) had a spindle-turned bung placed in the open bore end.

Rammers used on land-based guns had rigid wooden handles, matching or slightly exceeding the length of the gun bore, with a ram head at one end and a ram head or sponge at the opposite end. The use of such a long implement in the confined space on board a ship was impractical, even with the gun run fully inboard. A thick length of cordage, however, could be bent to enable the insertion and extraction of the head into the muzzle (see Chapter 7, Pascoe *et al.* for further discussion).

Linstocks

Fifty-four linstock fragments[17] were recovered (Figs 4.2–4.3, 5.2, see 7.17 for terminology, 7.18 and 8.14–8.17),[18] including 15 complete or near-complete examples (see Pascoe *et al.*, Chapter 7). The complete or near complete linstocks (15 no.) vary in length from 412 to 626mm although most are between 465mm and 525mm long with maximum diameters of 34mm to 40mm. All are taken from converted heartwood billets – there are no roundwood rods present. Each billet would have been sub-rectangular in cross-section, deriving from a 'radially'-faced (36 no.) or boxed-heart (18 no.) timber. Owing to the rounded cross-section of the finished object it is quite probable that what are recorded as 'radial'-conversions might equally be tangential-conversions. If so, then all the billets could have been obtained from tangentially sawn parent timber.

15. Those on blocks 3052 and 3217 are *Ilex* (holly), 3120 (beech) and 3358 Maloideae/Pomoideae (Pomaceous fruits) but that on 3257 is an undetermined diffuse porous hardwood (Hazell and Aitken 2019, table A2).
16. Two are alder (3207, 3324), one is poplar/willow (3206; Hazell and Aitken 2019, table A2).
17. 3164/3193/3217, 3170/3218, 3181/3185/3191, 3182, 3183/3190, 3184, 3186, 3187/3189, 3188, 3192/3245/3268, 3194, 3195/3203, 3197/3202, 3198, 3199, 3200, 3201, 3213/3310, 3214, 3215/3223, 3216, 3219/3270, 3220/3251, 3221, 3224, 3225/3229/3262, 3226, 3227, 3228, 3230, 3231, 3246/3258/3273/3275, 3247/3265/3267/3288, 3248, 3252, 3254/3281, 3255/3269, 3256, 3259/3287, 3260, 3261/3264/3280/3282, 3263/3266/3277/3279, 3271, 3272/3283, 3274, 3276, 3278, 3284, 3285, 3286, 3296, 3309, 3312 and 3362; see Fig. 7.17 for terminology.
18. A linstock was a rod used to apply a lighted match to the touchhole of a gun to ignite the powder and fire the weapon at a safe distance for the operator. It is evident that these pieces were carefully shaped and possess certain features unnecessary for that simple function suggesting they were important to the user. Of the 29 species identifications, 14 of the linstocks are birch, 10 ash, 2 *Castanea* sp. (sweet chestnut), one alder, one poplar/willow and one that might be alder or birch. Twenty-five were not sampled for identification (Hazell and Aitken 2019, table A2). Several separately numbered fragments were found to refit. These are grouped together and for ease of reference will be referred to by the first small finds number assigned. Though some of the remaining pieces may similarly be parts of a smaller number of original objects they have suffered so much damage while buried that this can no longer be tested.

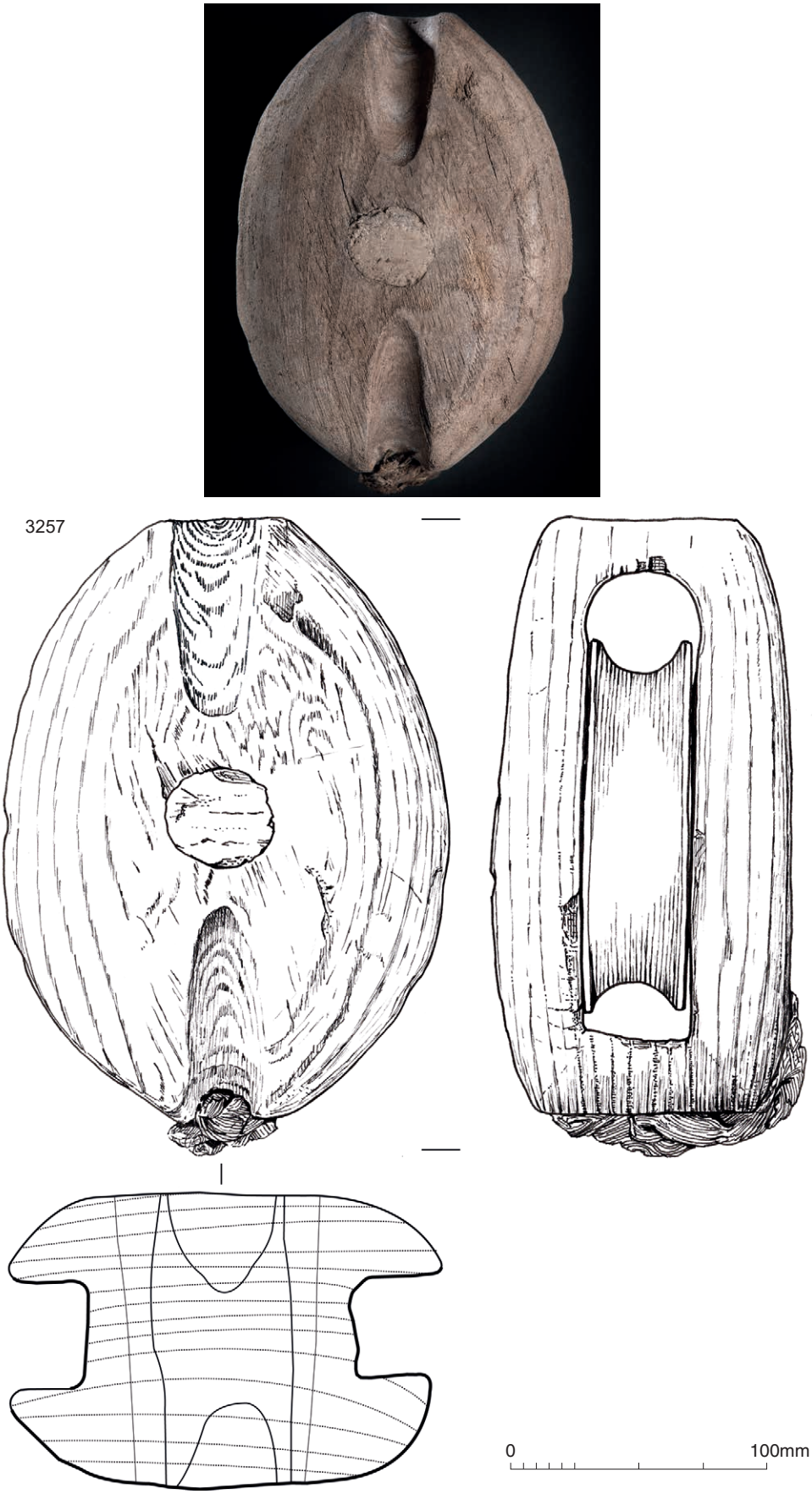


Figure 8.12a Single pulley block (3257; © Historic England Archive, photograph James O. Davies, © Historic England, drawing Ruth Parkin)

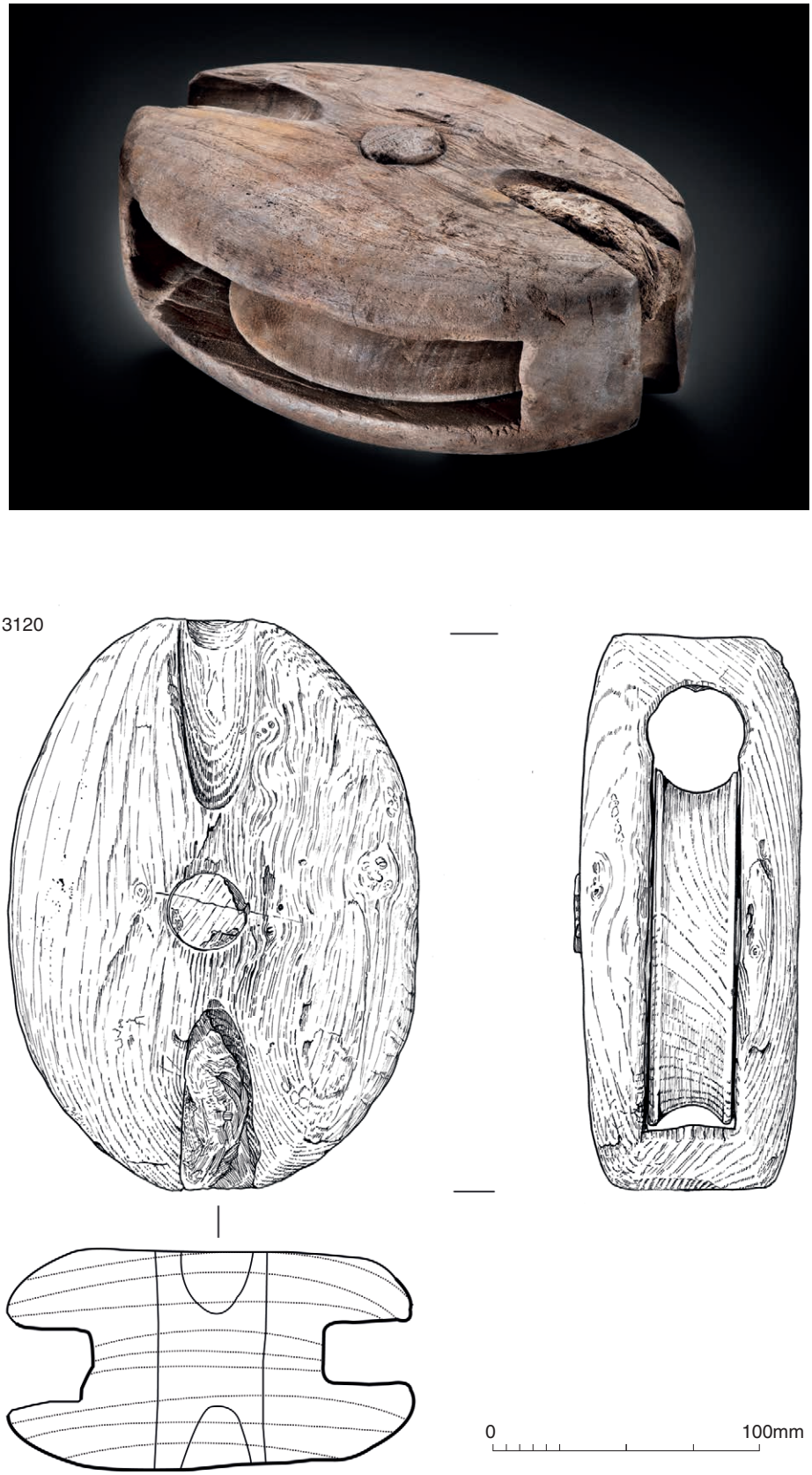


Figure 8.12b Single pulley block (3120; © Historic England Archive, photograph James O. Davies, © Historic England, drawing Ruth Parkin)



Figure 8.13 Deadeye (3079; © Historic England, photograph Angela Middleton)

The billets may have been roughly trimmed to remove their corners and to partially round off their cross-sectional shape before being mounted on a lathe; the mandrel spikes of the lathe are evident in the end grain of each billet. The small residual hewn facet on the mid-section behind one head (3164) may be explained by overcutting while trimming. Another example (3246) shows the wood was turned while still green or unseasoned. A small patch of bark on the handle of this linstock indicates that it was turned from a billet very close to the outer edge of the parent tree; had this piece been in use for any length of time this should have detached and fallen away. This suggests that this linstock had been recently supplied to the ship.

As well as producing a consistently round cross-section, this process created what can be described as three distinct zones and occasional decoration. These zones include a distinct head; a cylinder, sometimes straight-sided, sometimes slightly concave. The head was completed by turning deep grooves below it and rounding off the wood just leaving one (Fig. 8.15),[19] or more usually two rounded knobs.[20] These knobs in turn transition to a mid-section (a long straight section, often flared along its length) widened out at the head end and tapering down towards the handle. The mid-section terminates in a rounded knob that marks the transition to the handle. The handle was typically symmetrical or nearly so; a narrow circumference at the mid-section knob end, widening out midway along the length of the handle before narrowing again and ending in another knob just before the tail. Halfway along the handle a rounded groove might be turned dividing the handle into two zones. The terminal knob of the handle had a short shaft projecting along the axis.

Apart from the knobs, turned grooves were used as decoration. Twenty-three had individual grooves exclusively.[21] These were combined with paired grooves on 11 examples (Fig. 8.14).[22] On four examples they were combined with a triple groove elsewhere on the object (Fig. 8.15).[23] The grooves are usually positioned to define or emphasise transition points along the profile. One groove was usually placed at either end of the cylindrical head and sometimes a third at its mid-point (frequently interrupted by the through hole which must therefore have been cut later). The knobs sometimes had grooves around their widest circumference. A groove could also be present just behind the start of the mid-section at the head end. Further grooves can often also be found either side of the handle mid-point where the handle is widest.

Once the turning stage was complete, the linstock was removed from the pole lathe. Any remaining waste core at the head end was either snapped away,[24] sawn away[25] or, very rarely, cut away.[26] At the tail end, the mandrel spike hole was often quite deep, passing well into the terminal knob. Any evidence of trimming at this end was frequently obscured by corrosion deposits. These appear to derive from an iron ferrule placed around the tail,[27] or the presence of an iron spike to secure the linstock to the deck when awaiting use. A metal casing around the tail that partially encloses one terminal knob (3186) may be the only evidence of a possible ferrule.

To secure the slow match used with the linstock, a single through hole, 12–17mm in diameter, usually at a skewed angle to the axis of the linstock, was drilled through the head.[28] Almost all the linstocks are in very good condition

19. 3186, 3200, 3219 and 3309.
20. 3164, 3170, 3181, 3184, 3187, 3188, 3192, 3195, 3198, 3199, 3201, 3216, 3220, 3225, 3246, 3247, 3255, 3259, 3261 and 3312.
21. 3164, 3170, 3181, 3183, 3184, 3186, 3188, 3195, 3197, 3199, 3200, 3201, 3214, 3215, 3216, 3221, 3246, 3248, 3252, 3263, 3272, 3278 and 3312.
22. 3187, 3192, 3198, 3219, 3220, 3225, 3228, 3255, 3261, 3296 and 3309.
23. Handle of 3310, heads of 3247, 3259 and 3260.
24. If the head had been turned deeply enough at this point – a small scar around the remaining imprint of the mandrel spike attests to this practice (3192, 3198, 3199, 3200, 3201, 3216, 3219, 3220, 3225, 3246, 3259 and 3260).
25. 3164, 3170, 3184, 3195, 3247, 3255 and 3312.
26. With a heavy knife or small axe and the surface trimmed smooth (3181 and 3188).
27. Such as the imprint left on 3286.
28. This would have secured the lit end of the slow match, allowing it to be applied to the cannon touch hole while still leaving enough play to pull a length of match through as it burned down.

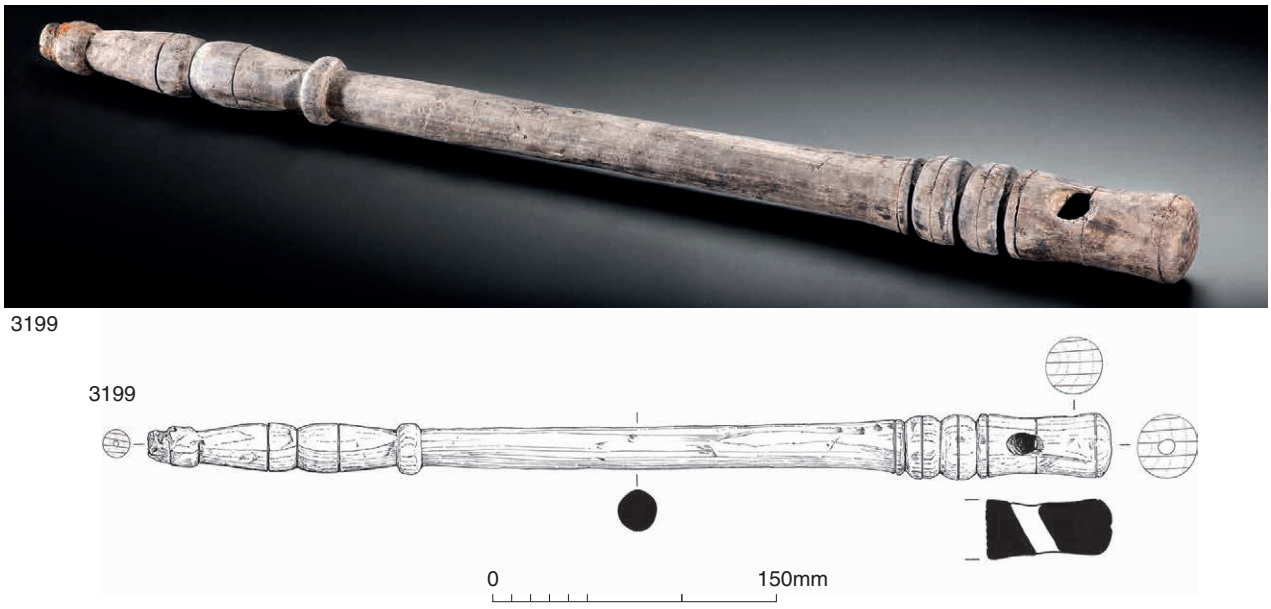


Figure 8.14 Linstocks (3199 and 3201; © Historic England Archive, photographs James O. Davies, © Historic England, drawing Judith Dobie and Helena Munoz-Mojado)

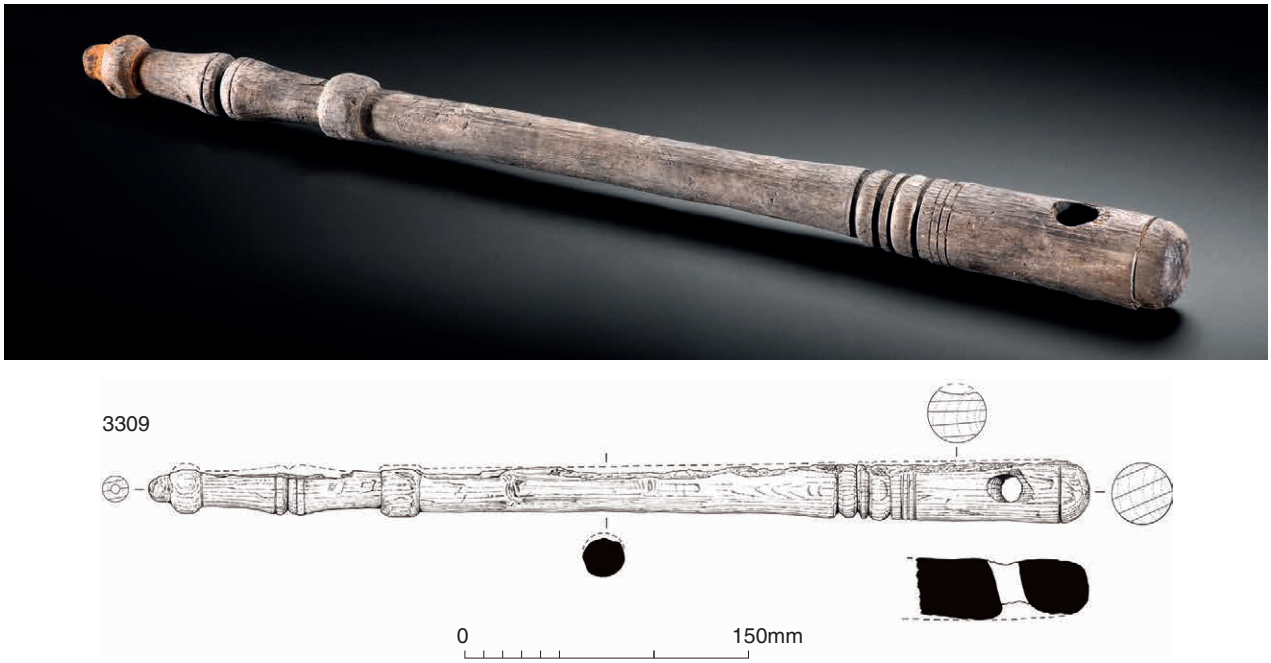


Figure 8.15 Linstock (3309; © Historic England Archive, photograph James O. Davies, © Historic England, drawing Ruth Parkin)

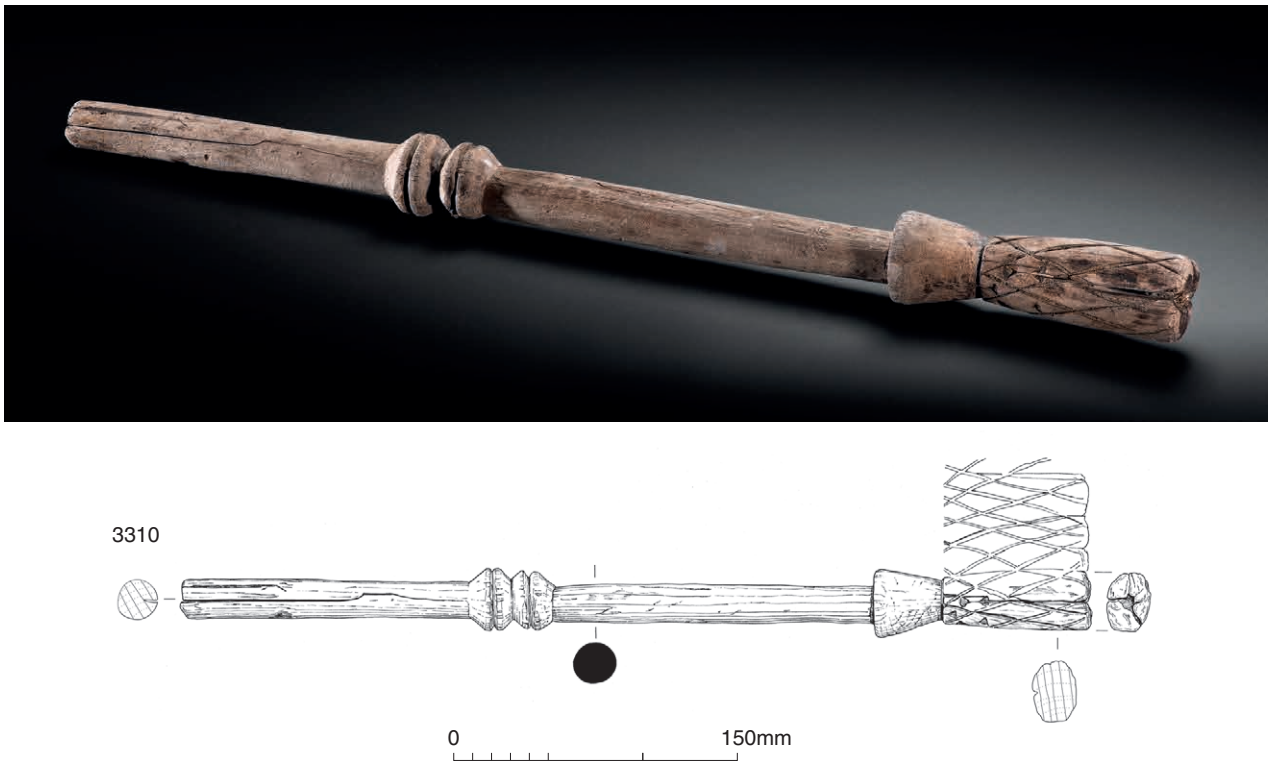


Figure 8.16 Linstock showing the decorated head (3310; © Historic England Archive, photograph James O. Davies, © Historic England, drawing Ruth Parkin)

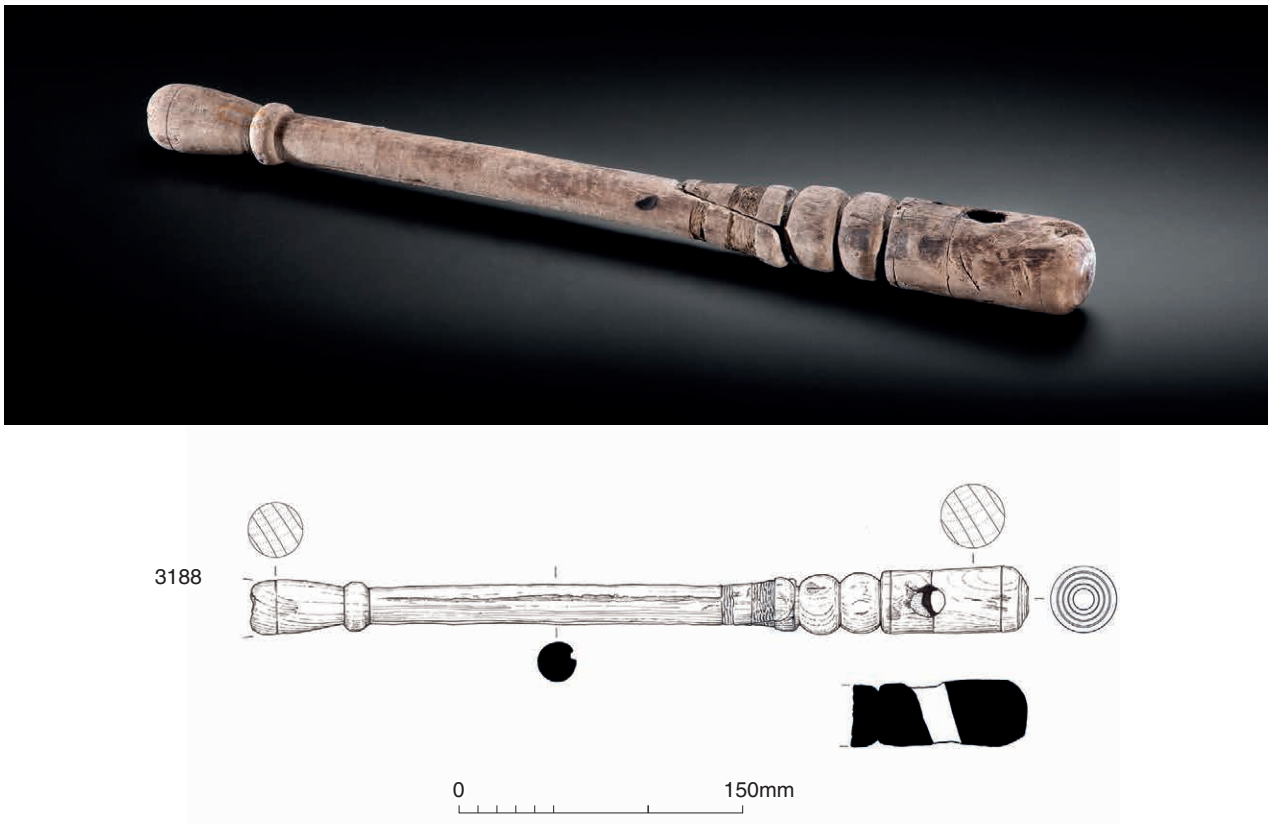


Figure 8.17 Repaired linstock (3188; © Historic England Archive, James O. Davies, © Historic England, drawing Ruth Parkin)



Figure 8.18 Near-complete hand crow lever (3333) (© Historic England, photograph Angela Middleton)

with clear turning marks present in the deeper recesses where protected from abrasion. Their very fresh appearance suggests they may have been fairly new when the ship sank, as few show evidence of wear from extensive use. Evidence for use is confined to localised charring of surfaces where the slow match secured in the head hole has burnt down and charred the adjacent area of the head and/or mid-section.[29] There is, however, much less charring than might have been expected in objects which had been used extensively. This may be an accident of survival as badly burned linstocks may have been discarded as potentially dangerous to the user and the ship.

Two linstocks have atypical features of note. The head of one (3310) has a carved flattened sub-rectangular cross-section with rounded edges. Decoration has been applied to the head in the form of a shallow diamond or lattice made from incised lines cut all the way around the head, both faces and both edges (Fig. 8.16). Some of the diamond panels have small triangular nicks within them and the very end has been deeply scored with a cross. In addition there is no hole cut for a slow match and there are no knobs between the head and the mid-section, although there are two knobs halfway along its length. While prepared mostly by turning, the mid-section has been finished with a drawknife. The uncompleted decoration on the head and the absence of a hole for the slow match suggest this linstock is either unfinished or was in the process of being reworked at the time of loss.

Another linstock (3188) was found in two refitting sections, having split diagonally along the grain just below the head (Fig. 8.17). There are two shallow 10mm wide grooves around the circumference of the mid-section at this point, initially thought to be decoration. On closer inspection, these grooves were found to contain fibre from strips of cloth. Their position, around the break in this linstock, does not appear coincidental as it appears to have been an attempt to repair a developing split in this artefact.

At least one linstock would have been required for each pair of guns on the *London* (assuming that a single gun crew was responsible for one gun on each side of the ship, as was common practice later, cf. Burney 2006, 238). So, given the number of guns (76 no.; see above) the *London* would have required a minimum of 38 linstocks.[30] The mass production to a common pattern of such a utilitarian object required in such numbers does not appear to have occurred. While many are very similar in appearance and might therefore have come from the same workshop, no two linstocks are the same, varying in proportions, dimensions and decoration. This might suggest they were produced individually for specific gun captains, either as their personal property or to make them readily identifiable. This seems highly unlikely given the Chatham Ledger records 30 linstocks reloaded on 23 February 1665 (see Fig. 3.3). More plausible is that they were mass produced but not to a set template. It may be that the ship was fitted out in an emergency (and the outbreak of the Second Anglo-Dutch War with the need to recommission and prepare dozens of warships would have been such an emergency) with a combination of lots of similar but not identical examples combined with older stock.

Hand crow levers

Fifty hand crow lever fragments were recovered,[31] wooden bars or levers tapering along their length which could be used for a variety of purposes but perhaps predominantly to help manoeuvre a gun carriage to point at the target and to raise the gun breech to allow quoins to be positioned when adjusting the elevation. Six of these are complete or near complete; 3311, 3333, 3558 (three examples) and 3559 (see Chapter 7, Pascoe *et al.*). Several others are missing only minor details and it is possible that some of the smaller broken sections would refit to make more complete objects.[32] Twenty-six pieces are radially-faced, 13 tangentially-faced, 8 box-quartered and 3 boxed-heart conversions. The wood used is knot-free heartwood and, while not necessarily very straight-grained, has few irregularities along its length. The most

29. Scorch marks around the hole and adjacent areas of the head (3164, 3170, 3181, 3184, 3186, 3187, 3188, 3192, 3198, 3199, 3200, 3213, 3216, 3220, 3246, 3247, 3255, 3259, 3260 and 3261) while additional scorch marks on the mid-section, where the match has burned out while still wrapped around the that part of the linstock, might suggest a match was left smouldering for some time before being properly extinguished (3164, 3170, 3181, 3184, 3186, 3187, 3188, 3192, 3195, 3198, 3199, 3200, 3201, 3215, 3216, 3219, 3221, 3246, 3247, 3252, 3254, 3255, 3259 and 3263). Scorching on one linstock (3260) may possibly have burned away part of the head.
30. Nominally built for 64 guns, fitted in 1665 with 76 (and perhaps actually carrying 80, according to Samuel Pepys' diary for 8 March 1665; Latham 1996b, 138) the *London* would need at least 38–40 linstocks.
31. 3142, 3159, 3160, 3174–3176, 3196, 3204, 3205, 3235–3237, 3253, 3293, 3305–3308, 3311, 3327, 3333, 3435, 3437, 3438, 3443, 3448, 3449, 3459, 3465, 3487, 3489, 3490, 3532–3536, 3555–3559, 3561–3564, 3569–3571 and 3716.
32. Of the 42 pieces sampled, 36 were ash, 5 birch and one beech (Hazell and Aitken 2019, table A2). Ash was clearly the wood of choice for hand crow levers although birch and beech were also acceptable.

complete examples (3333: Fig. 8.18 and 3559) have damage to the tail end. These pieces suggest an overall intended length of 1.48–1.55m (approximately 5 feet). The head ends vary between 64–83mm wide and 58–80mm thick, the tail ends are consistently 40mm diameter.

All are tapered along their length, from a 'D'-cross-section broader head end transitioning to a tail end with a fully rounded cross-section. Surviving faint saw marks show that these were prepared from sawn billets of timber, bevelled and chamfered at the head with hewing tools. A pair of splayed chamfers was cut into the flat face behind the head to start the transition from 'D' to rounded cross-section. Long narrow facets show this shaping was finished off with a shaving tool, such as a drawknife or similar. Some wear damage indicates that the objects have been used but they are not sufficiently worn or damaged to suggest heavy usage or having been broken in use. The tail on one example (3333) has an eight-pointed cross incised into the end grain; it is the only hand crow lever identified with any form of personalisation.

Cask pieces

There are ten staves from casks (3455, 3781–9). All the staves were cut from radially-faced *Quercus* (oak; Hazell and Aitken 2019, table A2), the most common wood used for this purpose. The end of one stave (3455) is of fairly robust appearance and although it is not possible to calculate the actual size or volume of the cask from one fragment, it appears to have come from a vessel of some appreciable size. In contrast there are six staves (3781–7),[33] one fragment of *Corylus* (hazel) (Hazell and Aitken 2019, table A2) hoop (3789) and one cant piece (3788)[34] from the same small coopered vessel. Only around half of the vessel seems to be present but sufficient to establish that it was a small vessel. Based on a belly diameter of 400mm, a head end diameter of 250mm and a belly-croze height of 163mm it is estimated that this cask held 70 litres. One stave (3781) has a 35mm diameter bung hole, while this and another stave (3786) both have tapping holes. The surviving cant stave (3788) was pegged to its middle piece with two 6mm diameter dowels and the curved edge is bevelled on both faces.

The V-sectioned croze groove, bung hole and tap holes indicate it was probably made to contain liquid. It was fastened together with wooden hoops made from split roundwood rather than metal hoops. No marks were present on any of the surviving components and there is no indication of the cask contents, whether water, beer, wine or spirits. It is likely, given the size of the cask, that the vessel contents were for decanting and use on board or locally rather than long term storage in the hold.

Stoppers

Three bottle stoppers or 'bungs' (3112 in bottle 3436, 3155 and 3157) were each cut from cork bark with the hard outer crust removed. Fine shaving-marks demonstrate the use of a knife or similar to create the lengthwise taper along the cylinder, while light hewing marks show the ends were trimmed to length. All three were found *in situ* in the necks of glass bottles but one (3112) had become loose by the time of Allen's inspection (see Chapter 5, Middleton, Fig. 8.19).

Handles

Six artefacts (3233, 3361, 3466, 3634, 3764 and 3792) are classified as handles as they appear either to have been shaped to be gripped in the hand, have the remains of iron tangs *in situ* or are still attached to tool heads.

A 'D'-shaped handgrip (3233) comes from a spade or, perhaps more likely in this context, a shovel or scoop (Fig. 8.20). It was carved from a radially-faced beech board (Hazell and Aitken 2019, table A2) and appears little worn but without the shaft the overall size or the tool's function cannot be determined. Handgrips like this are indicative of tools used with two hands rather than one. Part of the blade of a scoop or small shovel is present at one end of a shaft (3466). The conversion of this piece, the shared wood species, the dimensions and cross-section strongly suggest that these objects may have been part of the same object although the ends of the shaft are too degraded to confirm.

An octagonal cross-sectioned piece of wood (3361) tapering towards each end with a 2mm square axial hole in one end, which may have housed a tang, is a possible tool handle. It had been carved from a radially-faced board but was not sampled for species identification.

A cylindrical handle (3764) with a distinct waist turned from a radially-faced ash billet (Hazell and Aitken 2019, table A2) has some worm damage and erosion (worm damage is used in this report to describe where the wood has been eaten away by colonising invertebrates). The surfaces of one end have a thin layer of concretion while the other end has an iron tang in a circular axial socket. It is similar in form to a belaying pin, although somewhat shorter than expected, while the socket in the butt end seems intended for connection to something else.

Part of the handgrip from a pistol (3634; Fig. 8.21; see Chapter 7, Pascoe *et al.*) is missing the butt and stock. Part of the housing for the breech end of the barrel is present and there are concretions where the lock would have been. It cannot be determined whether this was a wheel lock or flintlock mechanism. Pistols were a relatively common weapon, being part of the standard armament of the cavalry of the period as well as a personal sidearm used by officers. In the confined space aboard ship a pistol could have been

33. Although 3781 and 3782 are separately numbered they are from the same cask stave.

34. Cant stave (oak) from head of cask, cut from radially-faced board. One straight planed edge with two blind 6mm dia holes 185mm apart to house dowels attaching this edge to the rest of the head. Remaining edge and both ends cut to form a continuous curved plan. Both faces bevelled around the curvature of the latter edge/ends. Abraded surfaces. Slight curvature along longitudinal cross-section. 251mm l, 95mm w, 15mm th. From a cask head of at least 250mm diameter.



Figure 8.19 Glass bottle neck with in situ *cork (3155; © Historic England Archive, James O. Davies, © Historic England, drawing Aleksandra Osinska)*



Figure 8.20 D-shaped handgrip (3233) from a spade, shovel or scoop (© Historic England Archive, photograph James O. Davies, © Historic England, drawing Ruth Parkin)



Figure 8.21 Handgrip (3634) from a pistol (© Historic England, photograph and radiograph Angela Middleton)

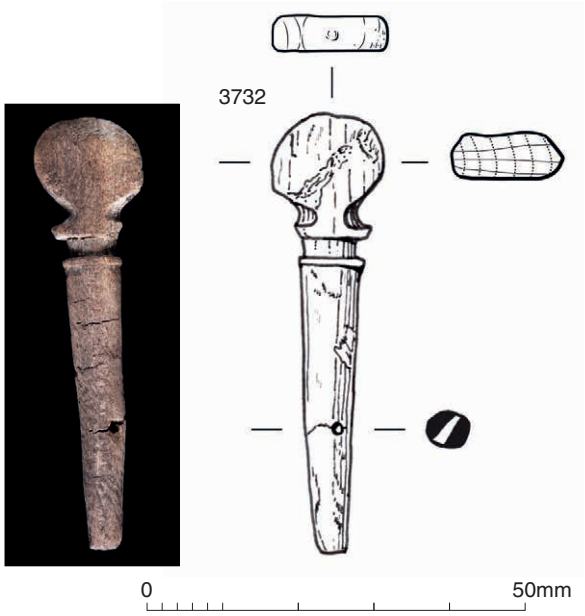


Figure 8.22 Key or tuning peg (3730) from a stringed instrument (© Historic England Archive, photograph James O. Davies, © Historic England, drawing Ruth Parkin)

useful where using a musket or similar would have been difficult. A third-rate vessel of 1685 would have been issued officially with 48 such weapons (Davies 2008, 144). The example here is carved from walnut (Hazell and Aitken 2019, table A2), a relatively rare and expensive wood in this period, principally selected for its aesthetic quality rather than any innate physical properties, so it is likely that the owner of this weapon was someone of status aboard the ship.

The shaft of a hammer (3732) still has most of the heavily concreted iron tool attached to the head (see Fig. 5.5). It is oval in section, transitioning to a sub-rectangular cross-section to fit through a socket in the metal head. Post-conservation the hammer head was identified as a claw hammer (see Chapter 11, Schuster). The wood species can be identified only as some kind of Betulaceae i.e. alder/birch/hornbeam/hazel; Hazell and Aitken 2019, table A2).

Tuning peg

A key or tuning peg (3730) from a stringed instrument (Fig. 8.22) was made by turning a billet of wood (*Prunus* sp.; cherries group) on a lathe to create a tapering cylindrical shaft with a knob at the head end; a small decorative cone of *Pinus sylvestris* (Scots pine) group was inserted into the head end (see Rankin *et al.* 2021). The knob was then trimmed to create two opposing flat faces of approximately the same thickness as the widest diameter of the shaft. A small (1.5mm diameter) hole was then pierced through the shaft towards the narrower tail end. The artefact is most similar in size and form to those found on modern violins, though it is entirely possible that it came from another form of stringed instrument. This may be one of the few wooden items which is a personal possession rather than ship or fighting equipment.

Fire logs

Three objects (3132, 3463 and 3537) are somewhat out of place in the assemblage. Each is a short length of roundwood with the stumps of several side branches present, two of which retain bark. Neither has any immediate evidence of woodworking other than the fact that they have been cut to length. The current interpretation is that they are pieces of firewood, fuel to feed a fire or brazier somewhere on the ship, but this suggestion cannot be verified.

All are different wood species, one being alder (3132), one birch (3463) and one *Taxus* (yew; 3537; Hazell and Aitken 2019, table A2). The only common factor is their poor quality for woodworking, having a knotty appearance with several side branch stumps surviving. Much branch wood would have been used as fuel and it is likely these pieces would have served as kindling. Sources of fire would have been kept under careful control on wooden ships; the galley would have been the only place for cooking purposes. It is quite possible these three pieces are stray objects from the fuel store but it is not known how far they may have been displaced when the ship sank.

Boards and panelling

Twenty-seven pieces of board (less than 50mm thick), one plank (3138 more than 50mm thick) and one detached moulded strip were recovered.[35] The one plank is cut from tangentially-faced elm heartwood (Hazell and Aitken 2019,

35. 3138, 3144, 3297, 3298, 3299, 3300, 3301, 3389, 3434, 3444, 3445, 3446, 3447, 3451, 3453, 3456, 3464, 3467, 3468, 3478, 3485, 3486, 3492, 3500, 3502, 3554, 3623, 3694 and 3714.

table A2) with saw marks from the conversion surviving. The object has been sawn to length and as elm is not typically associated with ship planking it is possible this piece had a specific purpose aboard ship.

Most of the remaining boards were not sampled for species identification, though macroscopic observation suggests most are oak (Allen 2019). Eleven simple boards or fragments thereof exhibit limited woodworking evidence. Some have saw marks from through and through sawing used during conversion (3138, 3444–one face, 3478, and 3623). One piece (3478) in particular has two intersecting sets of saw marks showing the parent baulk of timber was placed across a trestle and sawn through from two directions by a two-person sawing technique. All but one of the boards are tangentially-faced conversions that would derive from such cutting.

Several boards[36] exhibit planed surfaces that have removed any evidence of sawing but leave very long, very smooth, shallow facets with tiny, almost imperceptible, ridges between them. The additional care with which these surfaces were prepared suggests a decorative or higher-quality finish was required.

The presence of moulded strips would tend to support this interpretation as five pieces either are,[37] or have attached to them,[38] thin strips of board with a quarter-moulded edge. The one detached piece that was sampled for identification (3144) was Scots pine group (Hazell and Aitken 2019, table A2), though whether this is representative of all the moulded pieces or something unusual is uncertain. The moulding was produced by a specialist moulding plane to produce a consistent, even decorative common edge to thin pieces of wood that were attached to thicker boards by iron tacks (see Pleiner 2006), and possibly an unidentified form of adhesive, to judge from the surface deposits present on surfaces of three[39] that conform to the shape of now missing applied strips. Carefully mitred corners on some of the moulded edges show these pieces formed raised edges to recessed panels producing a decorative relief. Deposits of possible white lead primer on the surfaces of three[40] indicate that at least some of these surfaces were painted.

That these boards were part of larger structures now broken up and disarticulated can be shown by the tongue and groove edging on three pieces.[41] Three pieces (3444–6) are almost certainly part of the same board, split longitudinally into three refitting sections. Sawn ends show where particular boards were cut to length or in one case (3444–6) to butt against an angled surface. Nails in five pieces[42] demonstrate they were fastened to other timbers (or had other timbers fastened to them separately from the moulded strips).

One board (3389), cut from tangentially-faced walnut (Hazell and Aitken 2019, table A2), is also part of a composite object, with four transverse grooves cut into the same face. These all have the appearance of housings for the edges of other boards and the object may be one side of a box with internal compartments or a shelf or rack. Walnut was a relatively expensive wood favoured for decorative elements of larger objects and a board of this size suggests it came from a high status object. None of these boards or the plank fragment have any obvious place in the structure of a ship's hull. Their relative lightness and decorative aspects suggest a secondary function within the vessel, perhaps parts of the walls of a cabin shattered in the accident.

Unidentified objects

The function of five objects has, as yet, to be identified (3111, 3234, 3431, 3551 and 3705). They are included here in the hope that future researchers may be able to identify similar objects. A partial object (3111) was cut from a tangentially-faced board made of oak (Allen 2019). It appears to be part of a handle and blade from a single piece shovel or similar, though the 'handle' is generally rectangular in cross-section and there is no indication of any thinning toward the intact edge as might be expected in a shovel.

The function of a bar (3234), made from ash (Hazell and Aitken 2019, table A2) with roughly worked 'reel' terminals at each end, is not yet understood. Although the form could have been readily produced on a pole lathe, all the tool marks show the finished shape was completed with a drawknife and the 'reel' knobs were bevelled with a hewing tool, such as a small axe or perhaps a heavy knife. It has the appearance of something intended to join, but maintain a fixed space between, two separate objects. It is unlikely that these missing objects were rigid, such as wood, as it is difficult to see how the terminals could have engaged with holes. So perhaps the object is associated with cordage, either spanning a gap between two related lengths of rope or acting as a guide for two ropes worked in parallel.

A shaft (3431), made of ash (Hazell and Aitken 2019, table A2) with a rounded cross-section, could be part of the tail of a hand crow lever but the diameter is significantly smaller than the identified examples. It could be part of a handle but there are no features that demonstrate its attachment to any tool head or blade. The shaving marks indicate that it was not part of a linstock, as all the known examples were turned.

Two shafts (3551 and 3705) with octagonal cross-sections and a turned knob terminal are clearly related and were cut

36. 3444-one face, 3445, 3446, 3468-one face, 3485, 3492, 3500 and 3694.
37. 3144, 3464 and 3694.
38. 3444 and 3502.
39. 3444, 3445 and 3502.
40. 3144, 3297 and 3299.
41. 3453, 3467 and 3486.
42. 3300, 3389, 3446, 3453 and 3714.

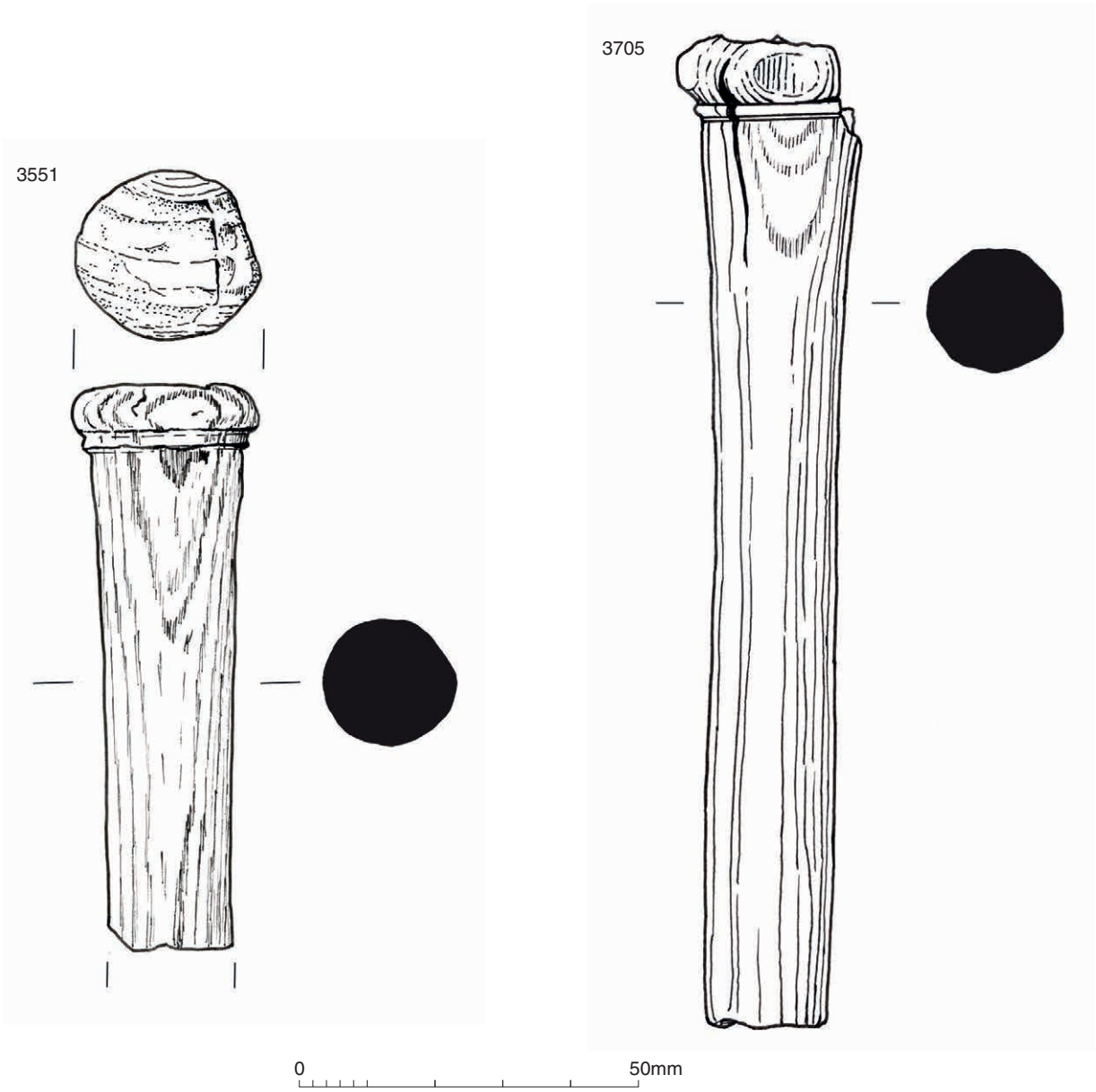


Figure 8.23 Shafts (3551 and 3705; © Historic England, drawing Ruth Parkin)

from the same wood species (ash) (Hazell and Aitken 2019, table A2), though they are evidently not two rejoining parts of the same object (Fig. 8.23). An iron tang is present in one of the knob terminals (3705) and its other end had been sawn away rather than broken. Both ends of the other artefact (3551) are broken and the shaft evidently continued beyond the knob. It is not possible to assign a function to these objects; the cross-sectional form would seem to rule out handles or tools so it is possible they are bars from a piece of furniture.

Timber fragments

Only one timber fragment appears complete (3631); it has a rectangular housing cut into one face across the width at its mid-point but its exact function is not known. Little can be said of the other nine badly damaged and/or worm damaged timber fragments.

Wood selection and use

by Zoë Hazell and Emma Aitken

Of 700 small finds recovered, almost half were made of wood, on which almost 300 wood identifications were undertaken;[43] wood identifications on the gun carriage were undertaken by Steve Allen at York Archaeological Trust (see above). Rather than sub-sampling, two rare artefacts, a tuning peg from a musical instrument (3730, Fig. 8.22) and a pipe stopper (3342, Fig. 10.7) were subjected to

43. The majority of the identifications were undertaken using a combination of destructive sampling (taking thin sections for high power microscopy) and examination under low power magnification.

micro-focus computed tomography (μ-CT) scanning, the methods and results of which are presented in Rankin *et al.* (2021). The results of the wood types identified and used for each artefact type are presented, by group category, in Table 8.1.

In total 16 taxa/taxonomic groups were recorded including 14 hardwoods[44] and two softwoods.[45] Of these, neither sweet chestnut nor walnut are native to the British Isles (Stace 2010). As both would have been growing in the British Isles by this time, and considering the context in which they were found (aboard a sea-going ship), it is not possible to determine where the wood, from which these artefacts were made, was sourced.

Most identifications were made on the small arms (powder boxes) and gunners' equipment which together dominated this assemblage in terms of numbers.

Wood selection preferences

Examination of the material recovered has revealed certain preferences for the wood used for particular artefact types. Some emerging patterns of systematic wood selection include:

- ash – for the hand crow levers and some of the worked shafts/handles;
- elm – for the body and truck of the gun carriage (Chapter 5, Panter), and the pulley block cheeks;
- oak (heartwood) – for the cask components;
- ash and beech – dominant for the powder boxes (both bodies and caps); and
- birch and ash – preferred for use for the linstocks.

Wood selection would most likely have been influenced by the physical characteristics of the wood types themselves, related to either practical and/or aesthetic reasons (ultimately affected by the anatomical structure of the woods):

- durability: the gun carriage and many components of the pulley blocks were made from elm, as it copes well with repeated wetting and drying (oak would crack and probably fail if subjected to the same conditions);
- handling comfort: many of the shafts/handles were made from ash, which is flexible and absorbs impact/stresses, making it comfortable to use. Walnut is also shock-resistant and resilient, and was used for the pistol handle (3634, Fig. 8.21) just as it is now commonly used for gunstocks (Gale and Cutler 2000, 146);
- attractiveness of the wood grain: walnut is used both for the pistol handle (3634, Fig. 8.21) and for the possible box panel (3389, not illustrated). It is also a durable wood;
- ease of working: the linstocks are each turned individually, some with fine detail, and many of the wood types selected for them are easy to work (e.g. ash, poplar/willow). Beech (used for powder boxes too) can be split even when seasoned, as it 'has a straight, even grain' (*ibid.*, 110), characteristics which would make it amenable for working. What is thought to be a cask hoop (3789, not illustrated) is made of hazel, a flexible wood; and
- availability: oak heartwood is used for the cask staves (3455, 3781–7, not illustrated). This wood is commonly used for such objects due to its strength and widespread availability, while the presence of tyloses makes it impermeable (*ibid.*, 205).

Other characteristics

Additional information about the tree element from which the wood originated can sometimes be inferred from the growth characteristics; for example, some of the ash linstocks have strongly curved growth rings which, together in some cases with the presence of the pith, indicates the use of the central part of the tree. The examination of the hand crow levers, which are much larger in size than the linstocks, shows that most have weak ring curvatures, indicating that they were made from the outer margins of larger calibre (diameter) trees. The presence of tyloses makes it possible to infer the use of heartwood (although damage to a tree will also result in these features); as with the oak cask staves, a plank of elm was recorded with tyloses; features that help make wood impermeable.

Some evidence of insect damage was recorded on fragments of ash and birch. This damage aided the refitting of multiple hand crow lever fragments from the birch example, where it is clearly visible macroscopically.

The pulley blocks show evidence for possible running repairs using what was both suitable and easily obtainable; the wood used for two of the pegs (3052 (probable holly, see Fig. 5.1) and 3358 (Maloideae), not illustrated) still has some bark attached, indicating that twigs of approximately the appropriate dimensions (hence requiring no/minimal working) were used.

Comparisons with other shipwrecks

This analysis of wood identifications is one of the most comprehensive and systematic undertaken on material recovered from a wreck in British waters. Although there are European wrecks of similarly aged warships that would make suitable comparisons in terms of wood types used

44. Deciduous, angiosperms: *Ilex* sp. (holly), *Alnus* sp. (alder), *Betula* sp. (birch), *Carpinus* sp. (hornbeam), *Corylus* sp. (hazel), *Castanea* sp. (sweet chestnut), *Fagus* sp. (beech), *Quercus* sp. (oak), *Juglans* sp. (walnut), *Fraxinus* sp. (ash), Maloideae/Pomoideae (Pomaceous fruits; including hawthorn, apple, pear, whitebeam), *Populus*/*Salix* spp. (poplar/willow), *Acer* sp. (maple) and *Ulmus* sp. (elm). Betulaceae undiff. is used here as a summary, where the genera from the Betulaceae family (i.e. alder, birch, hazel, hornbeam) could not be differentiated based on the wood anatomical features preserved. In some cases, however, some level of refinement was possible; see Hazell and Aitken (2019) for further detail.

45. Coniferous, gymnosperms: *Pinus* sp. (pine) and *Taxus* sp. (yew).

Table 8.1 Results of the wood identifications from the London *by artefact group (gunners' equipment, small arms, rigging, and other)**

Class	Artefact type	(cf) *Acer*	Betulaceae undiff.	(cf) *Alnus*	(cf) *Betula*	*Alnus/Betula*	(cf) *Carpinus*	(cf) *Corylus*	(cf) *Castanea*	(cf) *Fagus*	(cf) *Fraxinus*	(cf) *Ilex*	(cf) *Juglans*	(cf) Maloideae	(cf) *Pinus sylvestris* group	(cf) Populus/Salix	(cf) *Quercus*	(cf) *Taxus*	(cf) *Ulmus*	Ring porous	Diffuse porous	Totals
Gunners' equipment	Flexible rammer	–	–	2	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	77
	Gun carriage truck	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–
	Handspike (incl. handspike part)	–	–	–	4	–	–	–	–	1	38	–	–	–	–	–	–	–	–	–	–	–
	Linstock	–	–	1	14	1	–	–	2	–	9	–	–	–	–	1	1	–	–	–	–	–
	Ram rod shaft	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–
Small arms	Powder box body	6	3	1	4	–	16	–	–	26	39	–	1	1	–	14	–	–	–	–	2	**166**
	Powder box lid	2	1	2	3		9			13	17	–	–	–	–	–	–	–	–	1	1	–
	'Flask' stopper/spout	–	–	–	–	–	–	–	–	–	3	–	–	–	–	–	–	–	–	–	–	–
	Pistol grip handle	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–
Rigging	Pulley double block: cheek	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	**17**
	Pulley double block: sheave	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	2	–	–	–
	Pulley double block: peg	–	–	–	–	–	–	–	–	–	–	1	–	1	–	–	–	–	–	–	–	–
	Pulley single block: cheek	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3	–	–	–
	Pulley single block: sheave	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3	–	–	–
	Pulley single block: peg	–	–	–	–	–	–	–	–	1	–	1	–	–	–	–	–	–	–	–	1	–
Other	'Fire log'	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	**28**
	Bar	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–
	Branch wood	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Bung	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–
	Cask: cant stave	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–
	Cask: hoop	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Cask: stave	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7	–	–	–	–	–
	Hammer handle/shaft	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Handle	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–
	Moulded strip	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–
	Pipe stopper	–	1*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Plank	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	1	–	–	–
	Plank – ?box edge	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–
	Shaft (incl. shaft part)	–	–	–	1	–	–	–	–	1	1	–	–	–	–	–	–	–	–	–	–	–
	Shaft/handle	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–		–	–	–
	Spade handle	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–
	Timber with notch	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–

*Betulaceae undiff. is used where the genera from the Betulaceae family (i.e. alder, birch, hazel and hornbeam) could not be differentiated based on the wood anatomical features preserved. * is where the identification has since been refined

(including the *Vasa* (1628) and the *Kronan* (1676)), no such data are readily available.[46]

Research on the wood types used on the earlier *Mary Rose* (1545), which were identified using a combination of microscopic and macroscopic examination (A. Hildred pers. comm.), provides some comparison (see Hildred 1997; 2011; Gardiner with Allen 2005; Marsden 2009). Although there is little overlap in the artefact types recovered and/or analysed from the two ships, there are some similarities between wood types used (although not necessarily exclusively) for the same purpose:

- elm was used for the gun carriage bed and truck(s) (Hildred 1997, 54; 2011, 39, 135); one of the three pulley blocks (Marsden 2009, 265–6) and for structural (deck planks (*ibid*., 143) and cabin partitioning (*ibid*., 178)) and decorative (*ibid*., 231) components of the ship itself;
- oak was used for the storage casks and tubs (Hildred 2011, 409, 433);
- beech was used for many shovels recovered from the *Mary Rose* (*ibid*., 511);
- walnut was used for gunstocks (*ibid*., 546) and storage boxes, including the barber-surgeon's chest (*ibid*., 189, 387) and the base of a compass box (*ibid*., 269); and
- ash was used for handles and shafts of multiple functions (including hand crow levers) recovered from the *London*, with birch and beech also identified, which reflected findings for handles/shafts (including those of rammers) from the *Mary Rose*. Although the identification of the artefacts as hand crow levers was less confident for the *Mary Rose* they were also attributed to ash and birch (Hildred 2011, 504, 508).

The range of wood types used for the linstocks recovered from the *Mary Rose* (eight types) is more diverse than those from the *London* (six types), of which only three types, ash, birch and poplar/willow, were the same. This suggests that the wood type used might have been more personal preference than suitability for performing a particular function. Sweet chestnut, which is not native to the British Isles, was used for two of the linstocks from the *London*. Although recorded on the *Mary Rose*, it was used for handles of domestic-use knives rather than for linstocks (which were predominantly of ash; see Hildred 1997, 65).

Conclusion

The work on the wooden remains from the *London* clearly demonstrates the potential information gained from detailed scientific analysis of the wood types and as a strand of investigation in its own right. As well as wood type, additional evidence from the character of the wood growth itself has also provided further insights into the tree elements and size.

46. Whether this results from an absence of such analysis, or is a matter of publication, remains to be established. It should be noted that no scientific wood identifications were undertaken for the study of the *Vasa*'s wooden treen (wooden tableware) by Gandulla (2014, 17) and no similar artefacts were recovered from the *London*.

Chapter 9
Leather

Quita Mould

Bandoliers

A group of bandoliers (Fig. 9.1) was recovered from the remains of a broken wooden chest located at a gun station adjacent to a gunport on the main gundeck.[1] At least two layers of belts, with layers of wooden powder boxes between, were recovered from the chest, while many more, including the wooden chest, were left *in situ* owing to time constraints (Cotswold Archaeology 2017d, 13). A 'collar of bandoliers' was a leather belt or strap from which containers (boxes) for powder and a pouch for musket balls were suspended, to load a musket (Blackmore 1990, 72).[2]

The bandolier was worn across the left shoulder, with the majority of the powder boxes distributed across the chest, and a musket ball or shot bag and priming powder box suspended from the lowest point where the ends of the belt joined. A smaller number of powder boxes hung from the rear of the belt, lower down the body around the hip area. Most commonly 12 (hence the apocryphal name 'apostles') or 13 powder boxes were carried, although examples with more or fewer boxes are known (K. Dowen pers. comm.).



Figure 9.1 Recovered bandolier with two powder boxes and a primer (centre) (© Historic England, photograph Dan Pascoe)

At least 20 pieces of bandolier belt were recovered with characteristic paired-suspension holes for the strings that held the powder boxes (Table 9.1), with a further 16 pieces of plain strap of similar width (Table 9.2).[3] Seven semi-circular shoulder pieces (or pads) were also recovered. Such items were generally made of either leather or felt and were sewn to the bandoliers to protect the shoulder and to support the weight of the musket when being carried (K. Dowen pers. comm.). The remains of three shot pouches were also recovered. The pouches, made of thin leather, are fragile; one (3719) is in good condition while the other two (3605 and 3633C) are fragmentary. The better-preserved pouch (3719) has a pierced strap by which it had been suspended by strings in a similar manner to the wooden powder boxes (see Tables 9.1–9.4).

Belts

A complete but now-fragmented bandolier belt (3633D) measured approximately 1.32m long;[4] while two lengths of belt (3501 and 3633G), with string holes at both ends but lacking their terminals, may be considered near complete (Fig. 9.2). Others are highly fragmentary so, where possible, strap fragments have been matched, with joining pieces reunited. One example with two matching terminals and several joining pieces of belt and strap is also substantially intact.[5]

All the belt and strap fragments were made from cattle hide; some are heavily 'grained' while others have a smoother surface. They vary little in thickness, between 3.5 and 5mm. All have plain cut edges and are of similar width, being predominantly 19–22mm (0.75") wide, none exceed 24mm, with some slight variation of up to 3mm along their length owing to stretching. One fragmentary bandolier is thinner being 12–15mm (0.5") wide and has the string

1. On the west side of trench 3 during the 2016 season.
2. Alternative spellings include 'bandoleers' and 'bandeliers' (Blackmore 1990, 72).
3. All proved to come from bandoliers rather than other types of belt or strap. In the following text the term 'belt' is used for a length of leather strap with string holes and 'strap' for those without.
4. When wet, before any conservation treatment had taken place, it was recorded as being 1.365m (November 2016, Cotswold Archaeology 2017d, 14), so this current measurement is an approximation of the original length.
5. Small find numbers 3691, 3593, 3591, 3626 and 3625.

Table 9.1 Bandoliers and belt fragments (measurements in mm)

Object no.	Length	Width	Thickness	Belt ends	String holes pairs	Shoulder st.	Long/short
3476	143+	18–21	5.17	no	5p	no	long
3496.1	896+	20–21	4.13	no	1p+1	yes	–
3501	1005+	19–21	3.44	1	8p &1p+1	yes	long+short
3589	446+	19–20	3.59	no	5p+1p	yes	long
3590	365+	20	3.46	no	5p+1	no	long
3592	355+	18–20	1.61 del	no	5p	no	long
3593/3591	590+	20	4.82	1	9p	no	long
3594	492+	19–20	2.28 del	?	8p+1	no	long
3595	375+	18–19	3.13	?	9p	no	long
3627.1	81+	12–15	3.84	no	1p+1	no	–
3627.2	85+	13	3.70	no	4p+1	no	long
3633A.4A	84+	20–22	1.05 del	no	2p+1	no	–
3633A.4B	39+	19	1.97 del	no	1p	no	–
3633B	475+	20	3.61	1	4p	no	short
3633D	1320*	21–24	3.5	2	9p & 4p	yes	long+short
3633F.1	160+	15	3.56	no	5p+1	no	long
3633F.2	245+	15	3.32	no	1+1	no	–
3633G	1135	21	4.27	1	9p & +1	yes	long+short
3691	138+	20	4.34	1	3p+1	no	short

+ indicates measurement of an incomplete dimension; st. = stitching; del = leather delaminated; string holes p=pair/s; +1 = 1 hole from a pair; &=second group of string holes;*1365mm when wet

Table 9.2 Bandolier strap fragments (measurements in mm)

Object no.	Length	Width	Thickness	Shoulder st.
3496.2/3597/3624.1	537+	19–20	3.44–5.00	yes (120 long)
3598/3624.2	134+	19–20	2.08 del	no
3625/3626	121+	20–21	4.57	yes
3629	27+	19	1.46 del	no
3633A.1	635+	19	3.59	yes
3633A.2A	190+	21–22	3.45	no
3633A.2B	142+	22	3.98	no
3633A.3	160+	19	2.47 del	no
3633A.4C	62+	21–22	1.71 del	no
3633A.4D	79+	20–22	1.57 del	no
3633A.4E	31+	22	3.38	no
3713	85+	14	2.20 del	no

st. = stitching; + = measurement of an incomplete dimension; del = leather delaminated

Table 9.3 Bandolier shoulder pads (measurements in mm)

Object no.	Length	Width	Thickness
3529.1	128	51	8
3529.2	131	50	3
3529.3	117	52	4
3628	130	50	3.5
3633E.1	120	49	2.5
3633E.2	115+	57	4
3633E.3	70+	53	3.5

+ = measurement of an incomplete dimension



3501 3633D

Figure 9.2 Complete bandolier straps (3501 and 3633D; © Historic England Archive, photographs James O. Davies)

Table 9.4 Shot pouches (measurements in mm)

Object no.	Back panel	Front panel	Strap length	Leather	Thickness
3605	L 129+, W 72+	L 107, W 67+	–	Sheep/goatskin	0.61 del
3633C	L 58+, W 120	L 125, W 112+	–	Sheep/goatskin	0.42 del
3719	L 148, W 91	L 130, W 118	75 folded	Sheep/goatskin	1.00

del = leather delaminated; L = length; W = width; + = an incomplete dimension

holes more evenly spaced and not so obviously paired.[6] One of these belt fragments (3633F.2) has a series of six small shallow scallops 5mm in diameter, spaced 32mm (1.25") apart, running along one edge (Fig. 9.3). This narrower bandolier appears to have been made from another wider belt, the scallops being the remains of former buckle pin holes that had originally run down the centre. The belts were made from a single strip joined at their ends with a butted seam.

The string holes, running in pairs along the middle of the belt from which the powder boxes and shot pouches hung, were made by a circular hollow punch, 4 or 5mm in diameter. Some, particularly those at the terminals, have been distorted by the weight of the items suspended from them. While most of the paired holes are well executed, those on one (3590) are misaligned and off-centre, suggesting a rather rushed job. The more even, rather than paired, spacing of the string holes on the narrower belt (3633F.1 and 3633F.2) supports the notion that this belt had been made quickly using leather recycled from a wider belt.

Maker's or owner's marks

Two pieces of belt are stamped on the flesh side. One (3633B) is stamped with a serif 'P' or 'd' and a 'comma' or wedge-shaped motif (Fig. 9.4). The other partial stamp (3595) has the circular section of a 'P' or 'd' stamp, together with the diverging arms of a second letter or numeral, possibly a 'V'. The stamps are deep and well cut using a heavy punch, which suggests official marks rather than secondary, personal marks of ownership. These stamps suggest that these were standard issue, presumably from the Navy. Currently these are thought to be the only stamps found on bandoliers.

Later modifications

A series of stab holes, seemingly made using the point of a knife blade, extend from the line of string holes on two fragments of stamped belt (3595 and 3633B) and on another belt fragment (3589; Fig 9.5). None of these secondary stab holes appear to have been stretched by strings used to suspend additional powder-boxes or other items, so their purpose is unclear.[7]

Shoulder pads

A small semi-circular shoulder pad was attached midway along the length of each belt (Fig 9.6). They are sewn along the straight edge of the panel to one edge of the bandolier strap with the same seam used to join the belt terminals. This seam used small paired edge/grain stitches, each stitch appearing as two small paired stitch holes on the grain surface and as a single stitch hole in the edge of the leather. Each pair of stitches is widely spaced from the next with a thread impression running clearly between the groups on the grain side (Fig. 9.7). The ends of the shoulder pad seams are usually finished off with two or three larger grain/flesh stitches. The leather of the shoulder area of the strap is often in poor condition, the grain side having split from the flesh side, so that in some cases the remaining stitching in this area has the superficial appearance of a grain/flesh seam on the strap and as a single large (but broken) stitch hole on the matching length of seam on the shoulder piece (e.g. 3529). The shoulder pads are of uniform size, 117–131mm long and 49–57mm wide (Table 9.3). One example (3529.1) differs from the others as it was made of notably thicker leather (8mm-thick cattle hide). This example (3529.1) bears the curvature of the wearer's shoulder, which shows that it was placed grain side down to the shoulder with the flesh side upward to prevent the musket slipping when being carried.

Shot pouches

Shot pouches were suspended from the lowest part of the bandolier at the terminals. One near complete pouch (3719) and the remains of two others (3605 and 3633C) were recovered (Table 9.4; Fig. 9.8). The pouches were made of thin skins, the flesh side of which has delaminated so only the grain surface remains. The grain pattern of one pouch (3605) appeared to be of sheep/goatskin and the others (3633C and 3719) of sheepskin but in each case the grain pattern was too poorly preserved to be certain. Hairs were present in the skins of two of the pouches (3633C and 3719) but only hairs from one (3633C) were sufficiently well preserved to confirm the identification of sheepskin (Fig. 9.9; Cameron 2019, 2). The pouches are made of two panels with small vertical slots for a drawstring running along the top edge. The rear panels of two of these soft, flexible pouches (3605 and 3719) are teardrop-shaped, while the third (3633C) is semi-circular. All have wider semi-circular front panels with small vertical slots for a drawstring running along the top edge. The back and front panels are joined with a

6. Small find numbers 3633F.1/3633F.2/3627/3713 (matching of pieces from the same item that had been allocated separate numbers has resulted in some items having multiple numbers).
7. The purpose of similar holes located close to the shoulder pad on a bandolier in the collections of the Royal Armouries (RAXIII.1028) is also unknown.



Figure 9.3 Bandolier strap (3633F; © Historic England Archive, photograph James O. Davies)



3633B



3595

Figure 9.4 Detail of stamp on bandolier (3633B; © Historic England Archive, photograph James O. Davies) and partial stamp (3595; © Historic England, photograph James O. Davies)



3589



3595

Figure 9.5 Stab holes and stamp on belt fragments (3589 and 3595; © Historic England Archive, photographs James O. Davies)

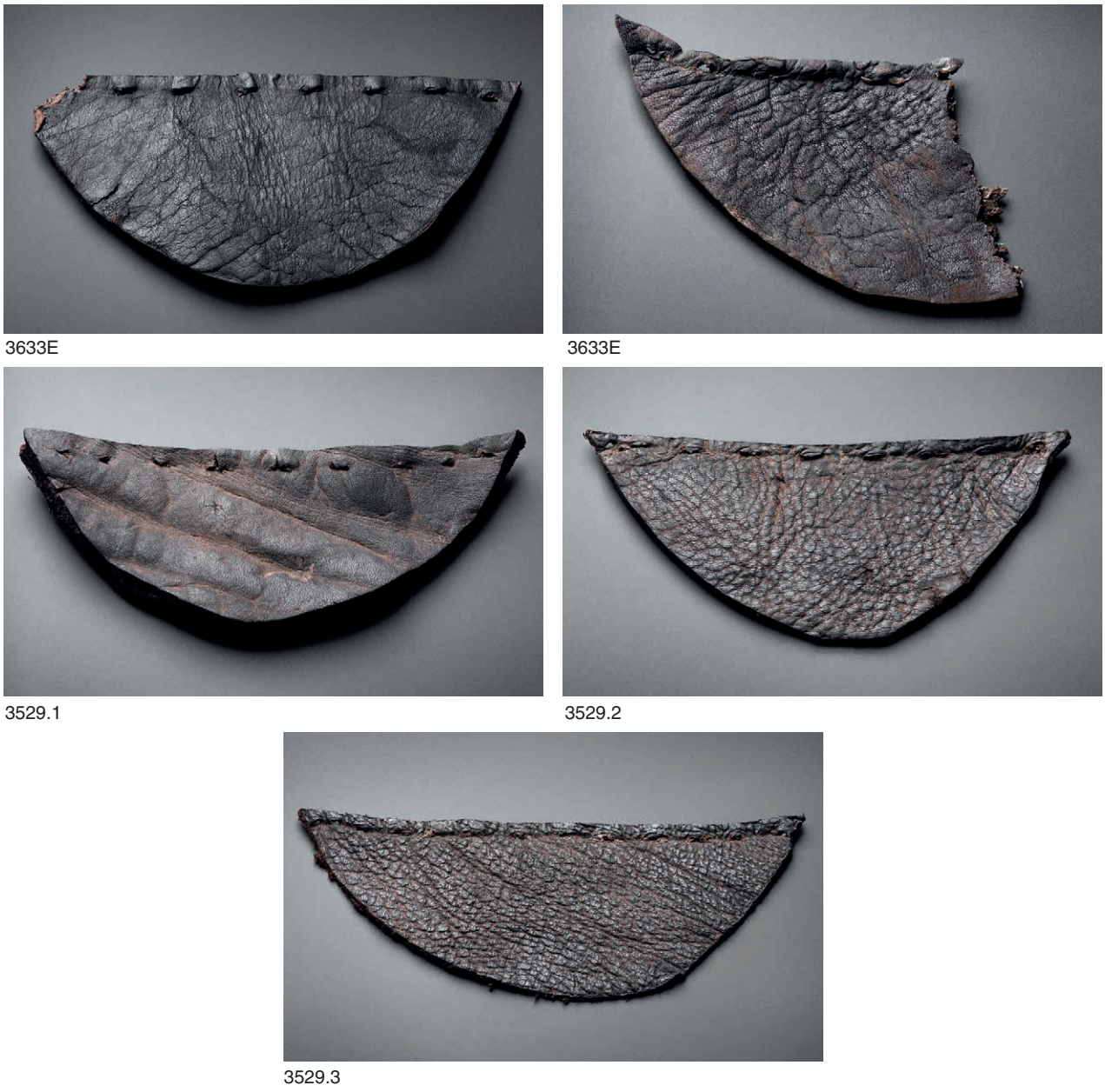


Figure 9.6 Bandolier shoulder pads (3633E, 3529.1–3; © Historic England Archive, photographs James O. Davies)

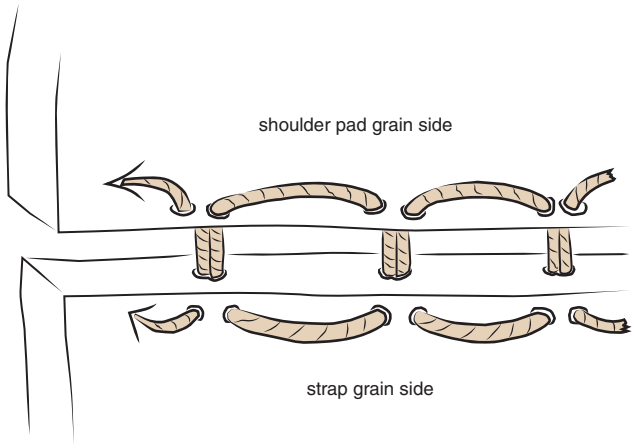


Figure 9.7 Edge/grain butted seam used on bandoliers (© Historic England, drawing Quita Mould and Esther Escudero)



3605



3719

Figure 9.8 Musket ball (shot) pouches (3605, 3719; © Historic England Archive, photographs James O. Davies)

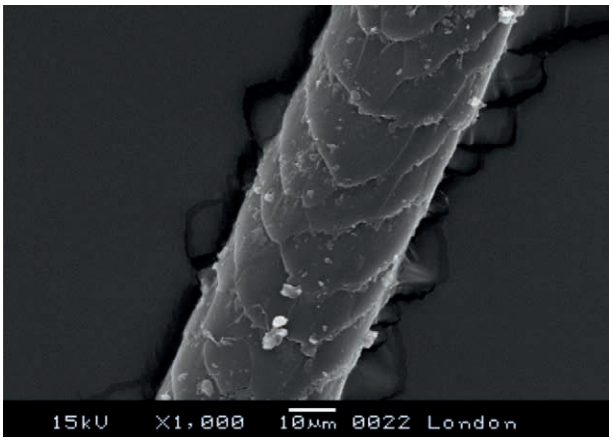


Figure 9.9 Scanning electron (SE) Micrograph/identification of hairs from leather pouch (3633C; © Esther Cameron)



Figure 9.10 Reconstruction drawing of recovered shot pouch (3719; © Historic England, drawing Marquita Volken)

closed seam. The better-preserved example (3719) has a lobed strap by which the pouch was suspended by paired strings from the bandolier (Fig. 9.10).

A drawstring passed through the two lower holes in the strap, the paired holes in the rear panel and through the slots in the top edge of the front panel. The suspension strap was too small to hang directly onto the belt, so it was suspended by a thong or cord threaded through the upper pair of holes. The style is that of a 'pouch purse' (Goubitz 2009, 41–2) and is comparable with girdle purses with single suspension loops in use in the Netherlands in the 15th and 16th centuries. Some surviving examples, contemporary illustrations and representations show pouches with a front flap but none were recovered from the *London* wreck and there is no evidence for them.

Other contemporary bandoliers

To date few examples of bandoliers have been recovered from shipwrecks around Britain. A short length of bandolier belt recovered from the Duart Castle wreck (1653) is notably wider (40mm) than the *London* examples with 'rolled and stitched edges' (Martin 2017, 172 and 174, SF103, illustration 236). Other examples of this wider style in the Royal Armouries collections (RA XIII.213, XIII.217) indicate that the rolled and stitched edges result from a strap lining.[8]

The *London* bandoliers are comparable to many surviving examples, with small differences reflecting the work of different craftsmen rather than the uniform production of a single supplier.[9] The semi-circular shoulder pads of the *London* bandoliers differ from many other surviving examples which are more angular in shape. In addition the *London* shot pouches are soft and flexible, like those often depicted in contemporary illustrations,[10] and are slightly larger in size and differ in construction. The surviving examples of shot pouches in the Royal Armouries collections comprise a six-sided inflexible rear panel of cattle hide to which a soft semi-circular, drawstring-closing front panel is attached. The Royal Armouries examples have a priming powder box suspended from paired string holes at the bottom of the shot pouch rear panel, while on the *London* these items were suspended directly from the bandoliers.

8. In the case of a particularly well-preserved bandolier (RA XIII.217) the edges of a separate lining are folded over the front of the belt, which is hair-on, and stitched in place, adding to its decorative appearance.
9. Comparison with the 17th-century examples in the Royal Armouries collections shows that the same seams used to join the belt terminals and the shoulder pads appear to be used throughout.
10. For example, Wallhausen's Kreigskunst zu Fuß (1615) and Hexham's Principles of the Art Military (1642) (Blackmore 1990, 74–5, figs 94–5).

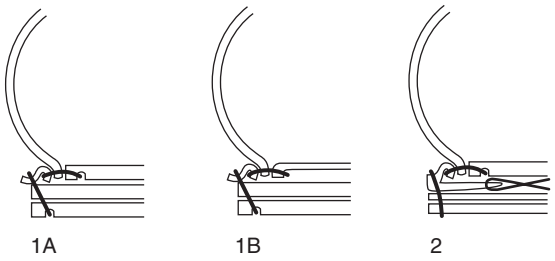


Figure 9.11 Diagram of welted shoe constructions (© Historic England, Quita Mould and Esther Escudero)

Discussion

Usually there were eight, occasionally nine, paired holes on the wearer's left side of the belt and three, or possibly four, on the right.[11] In addition, one or two pairs of string holes at the belt terminals were used to suspend the priming powder box and shot pouch. The number of paired string holes has been used to determine from which side of the belt each fragment came and that at least 12 bandoliers are represented. This accords relatively well with the number of powder boxes that have been recovered (Allen 2019, 6).[12]

Like the Duart Castle wreck, none of the recovered powder boxes displayed evidence of a leather covering.[13] Five of the seven powder boxes recovered from the *Vergulde Draeck* Dutch East Indiaman, sunk off the coast of Australia in 1656, had a leather covering (Green 1977, 234–5), which suggests that this feature, if present, can survive in the marine environment. The leather covering also survived on three powder boxes buried in the castle bastion ditch at Newcastle upon Tyne (Goodhand 1983, 206). This suggests that had the *London* examples been covered in leather the evidence would have survived.

Owing to their fragmentary state and the aggressive burial environment it is difficult to ascertain whether the chest contained a consignment of new or used bandoliers. While none appear very heavily worn, features such as the particularly poor condition of the leather at the shoulder area, the distortion of some of the string holes and the variation in the degree of 'graining' along a single length of belt suggests that the bandoliers had been used.

Footwear

Complete and near complete shoes and many individual shoe parts were recovered from the wreck. The number of shoes represented by the separate shoe parts is difficult to ascertain, as currents may have displaced components some considerable distance, but the 144 records appear to represent between 30 and 35 shoes,[14] with no evidence for boots or for women's shoes. The shoes fall clearly into two groups, latchet (strap)-tying shoes found across the site, which suggests they were probably being worn at the time of the incident, and buckle-fastening, flat-soled shoes that were found packed together either as supplies for the men or as cargo.

Construction

The shoes are typical of footwear of this period, with shoe bottoms comprising several layers (insole, midsoles, middle packing and outer (tread) soles) and uppers with small open sides, vamps with square toes and long tongues, and paired quarters, with latchets to fasten across the tongue over the instep. The shoe bottoms and uppers are made of bovine leathers, mainly cattle. Some of the uppers were lined internally, with thinner leathers such as calfskin and sheep/goatskin at the sides or at the toe (toe puffs). The sewing thread is preserved in many seams of both the shoe uppers and the shoe bottoms. Samples taken from shoes in one group (3118) were found to be made of coarsely-processed plant bast fibres, probably hemp (Chapter 16, Gleba).

The shoes are of welted construction with two basic types represented (Fig. 9.11), both of which were commonly used during the 17th century. Most of the shoes have the upper and bottom components attached to a relatively narrow welt with an 'S'-shaped section (type-1 construction);[15] a smaller number of fashionable heeled shoes have a wider 'folded' welt (Goubitz *et al.* 2001, 96, fig. 21c) and had been braced during construction leaving the impression of the bracing on the bottom components (type-2 construction). Occasionally fragments of the bracing thread survives (e.g. 3761 has bracing thread 2mm thick).

Shoes recovered from the *London* appear to straddle a period of transition from shaped shoes, for left or right feet, to the emergence of straight shoes that could be worn on either foot. The straight shoe had been adopted to accommodate the new fashion of the separate heel at the very beginning of the 17th century, although shaped shoes were still used for some heel-less and low-heeled shoes in the 1620s (Swann 1982, 7) and even into the 1640s (Swann 2001, 108). Although many of the shoes from the *London* were straight, some were shaped.[16] The recovery of shoes of both types from the *London* suggests that this continued for

11. As illustrated in Hexham's *Principles of the Art Military* (illustrated in Blackmore 1990, 75, fig. 95).
12. Wooden powder-boxes were found in direct association with leather bandolier remains on two occasions (3476 and 3633), one a short length of belt with five pairs of string holes present (3476), the other a group of pieces representing at least three bandoliers (3633).
13. It has been suggested that they may have been oiled or painted to make them damp proof (Martin 2017, 173).
14. The information available to this author at present suggests that the shoes were recovered chiefly from the gundeck (Steve Ellis pers. comm.). A large group of shoes were found packed together in grid square G10. Six further shoes were found elsewhere on the wreck, occurring individually in S2 trench 3 and grid squares G11, K10, K18, L19 and M19, with parts from other shoes being recovered from S2 trench 3 and J8, J10, K15, K18.
15. In type-1 construction the insole is sewn to the upper and welt with an edge/flesh seam (type-1A) or the insole is sewn to the welt with a closed grain/flesh seam causing the edges of the insole to be rolled under (type-1B). These two seam variants look very similar and can be distinguished only when the edge of the insole is well preserved and visible. In type-2 construction the insole is sewn to the upper and the folded welt with an edge/flesh seam; holes from the bracing thread run along the other wide, flat edge of the welt and the impression made by the bracing thread is visible both on the underside of the insole and on the upper face of the midsole or sole.
16. E.g. 3064/3065, 3118A.1, 3118A.2, 3118D.2.

Table 9.5 The London *stacked leather heels (measurements in mm)*

Location	SF	Top piece	Lifts	Pegs	Length	Width	Height	Other
J10	3047	1	3	7	58	64	20+	–
K15	3337	–	6	6	55	60	38	+1 jump
K18	3761	1	5	4	67	63	30	pitch
L19	3731	1	6	8	?	?	31	–
M19	3390	1	8	9	67	61	40	?pitch
Trench 3	3543	–	8+	9	67	64	32	–

another generation, implying that the period of transition from shaped to straight shoes was more protracted than previously thought.

The front-tying shoes found occurring separately on the wreck

Possibly as many as 11 front-tying shoes are represented by parts found separately across the wreck.[17] One shoe bottom (3103/3104, from grid square G11) comprising a decorated sole (3103) and a matching midsole (3104) is distinct but shares characteristics with those of shoe group 3118 (found together in grid square G10), so is likely to relate to that group (see below).

Front-tying heel-less shoes

Five well-preserved shoes fasten across the instep by tying through narrow straps, known as latchets, on the quarters and paired holes in the high vamp tongues.[18] A single example (3064/3065, found in grid square K10) differs from the others in that it was made without a heel (Figs 9.12 and 9.13) but, like those in group 3118, it has a series of separate lifts between the insole and the sole to raise and cushion the heel of the foot. These lifts had been made from scraps of shoe uppers that presumably had been lying around in the workshop. The shoe was of type-1A construction; the uppers were flesh side outward ('suede') with seams sewn so that they were visible for decorative effect (Fig. 9.13).

Front-tying heeled shoes

The other shoes had separate stacked leather D-shaped heels with straight breasts. Two other stacked leather heels (3047 and 3337 from grid squares in J10 and K15 respectively) were found separately, not directly associated with other shoe parts (see Table 9.5). The heels comprised several individual layers, known as lifts, and smaller pieces, known as jumps, all held together with large oval-sectioned wooden pegs. The lowest lift in contact with the ground is known as the top piece. Some of the lifts are so compressed that the number used is uncertain. The heels now range in height from 30 to 40mm but none were excessively high.

These well-preserved heeled shoes (small find numbers 3390, 3495/3542/3544–7, 3731, 3761) were all made in the same way with a folded welt, type-2 construction, and are of the same general style. Their uppers were made of bovine leathers, grain outward, and were tied over the instep with laces through the fastening latchets and the vamp tongue. Each varies slightly exhibiting different fashion features. One shoe (3390 from grid square M19) has an exaggerated wide square toe, known as a forked toe (Figs 9.14 and 9.15), while another (3731, found between the wooden spars on the orlop deck in grid square L19), has a particularly narrow and elegant profile (Figs 9.16 and 9.17). A third shoe (3761 from grid square K8) has a long toe turning upward at the tip, a decoratively shaped tongue, a visible back seam and the top edge enhanced by a tooled line for further decorative effect (Figs 9.18 and 9.19).

These three shoes (3390, 3731 and 3761) have an additional pair of holes in the vamp tongue that held a decorative feature and the surviving remains of their silk ribbon ties (Chapter 16, Gleba). Two silk ribbons (3390 and 3761, shown in Figs 9.14 and 9.18, but see Figs 16.2 and 16.2 for detail) are woven, one (3761) being 20mm wide, the other (3390) 30mm wide, though of differing weaves (Chapter 16, Gleba). The third (3731), 22mm wide, is plaited or braided using three strands and is round rather than flat in section. The silk ribbon ties in two of the shoes (3731 and 3761) were threaded through their lower pair of fastening holes, so were functional laces used to fasten the shoe to the foot. The silk ribbon in the third (3390) was threaded through the upper pair of holes and is the remains of an attachment for a decorative feature, a 'rose' of silk or lace that ornamented the front of the shoe.

All three silk ribbons are now brown in colour but originally may have been coloured differently. Analysis was undertaken to see whether the presence of any organic dyes could be identified (Vanden Burghe and Coudray 2019). A blue indigoid dye was detected in one of the two yarns sampled from the braided silk lace from one shoe (3731), indicating that it had been dyed with either oriental indigo (*Indigofera* or *Polygonum* species) or woad (*Isatis tinctoria L.*), which suggests it had been black in colour. No dye compounds were detected in the silk laces from the other two shoes (3390 and 3761).

Compounds from the degradation products of hydrolysable tannins were found in all three silk laces. These tannins, which could have come from a range of plant sources, may have been used to produce the brown

17. Better preserved examples occurring individually in S2 trench 3 and grid squares G11, K10, K18, L19 and M19, with parts from other shoes being recovered from S2 trench 3 and J8, J10, K15, K18. Excluding the shoes in group 3118, described separately below.
18. Small find numbers 3064/3065, 3390, 3495/3542/3544–7, 3731, 3761.



Figure 9.12 Shoe 3064/3065 (© Historic England Archive, photographs James O. Davies)

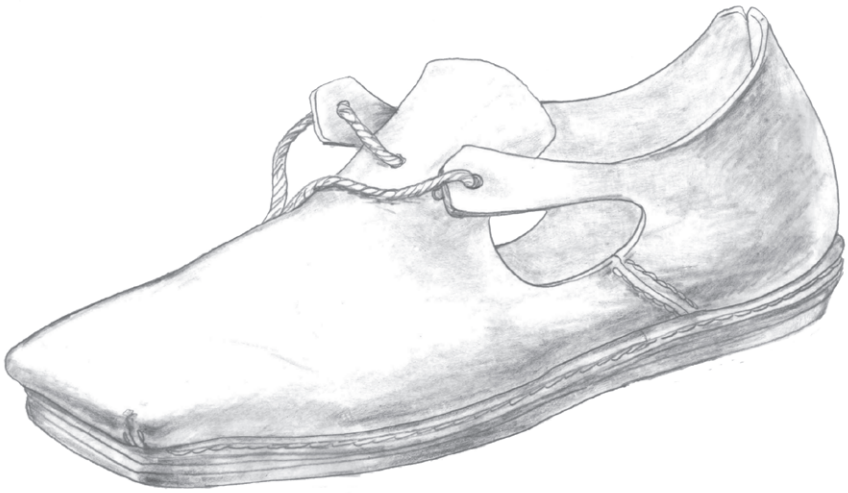


Figure 9.13 Reconstruction drawing of shoe (3064/3065; © Historic England, drawing Marquita Volken)



Figure 9.14 Shoe 3390 (© Historic England Archive, photographs James O. Davies)

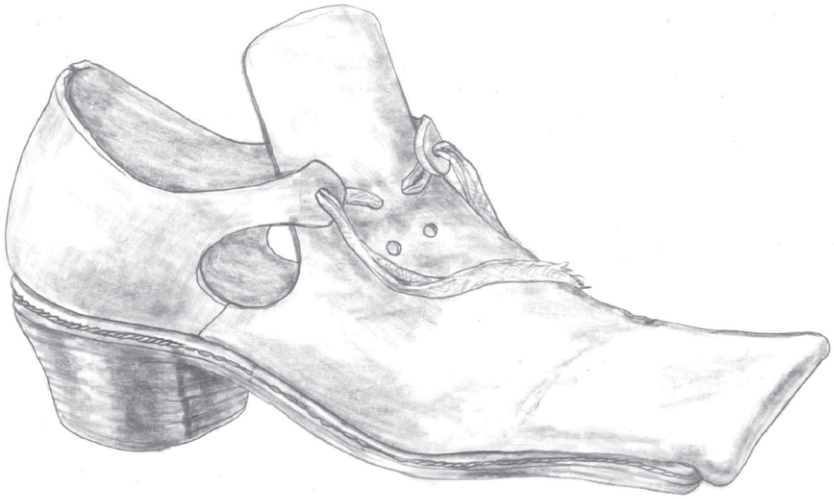


Figure 9.15 Reconstruction drawing of shoe 3390 (© Historic England, drawing Marquita Volken)

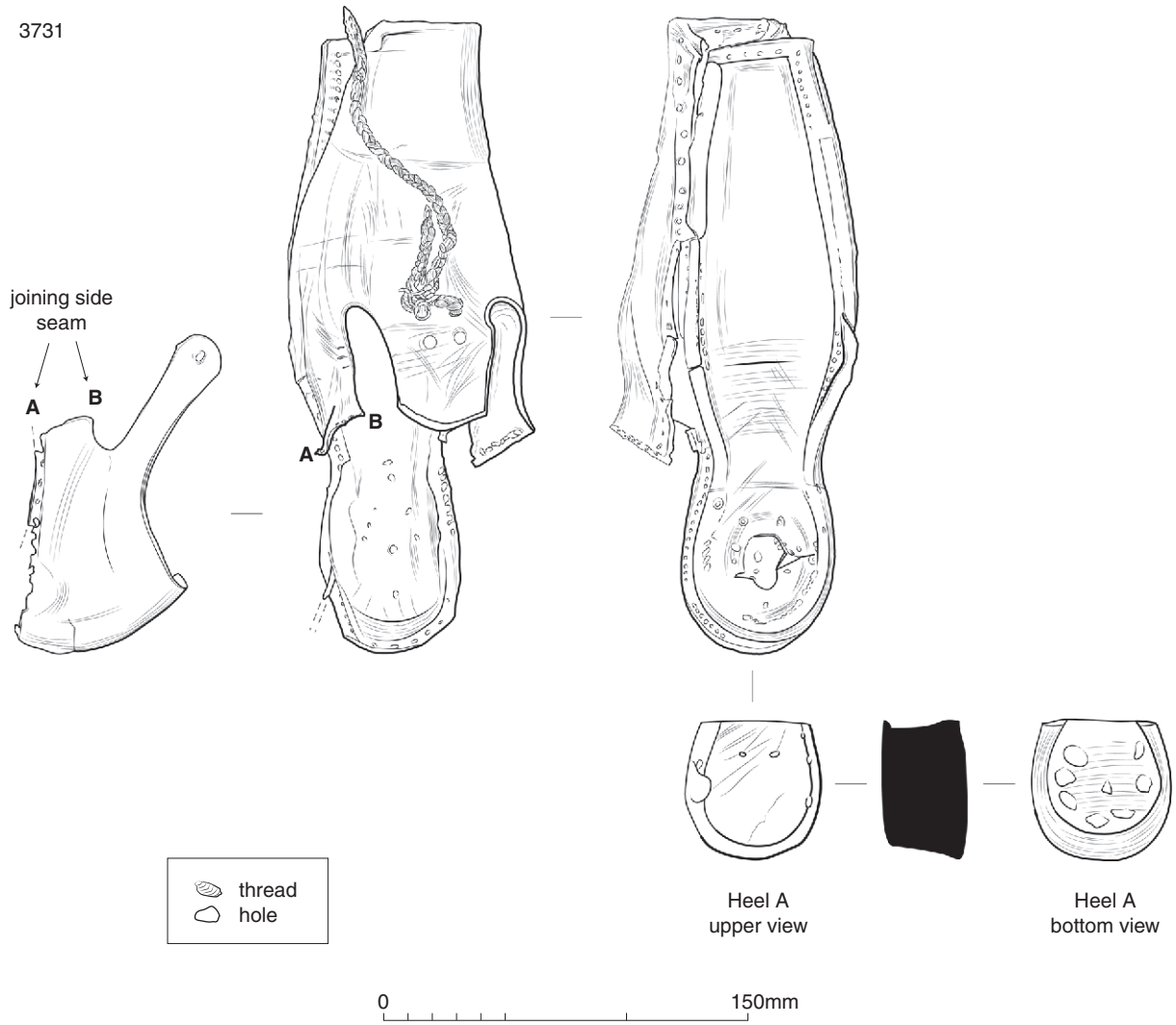


Figure 9.16 Shoe 3731 (© Historic England, drawing Judith Dobie and Helena Munoz-Mojado)



Figure 9.17 Reconstruction drawing of shoe 3731 (© Historic England, drawing Marquita Volken)



Figure 9.18 Shoe 3761 (© Historic England Archive, photographs James O. Davies)

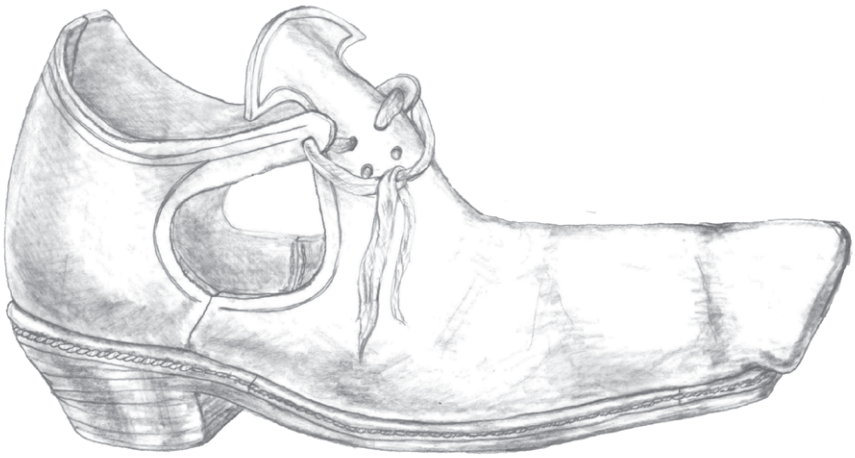


Figure 9.19 Reconstruction drawing of shoe 3761 (© Historic England, drawing Marquita Volken)

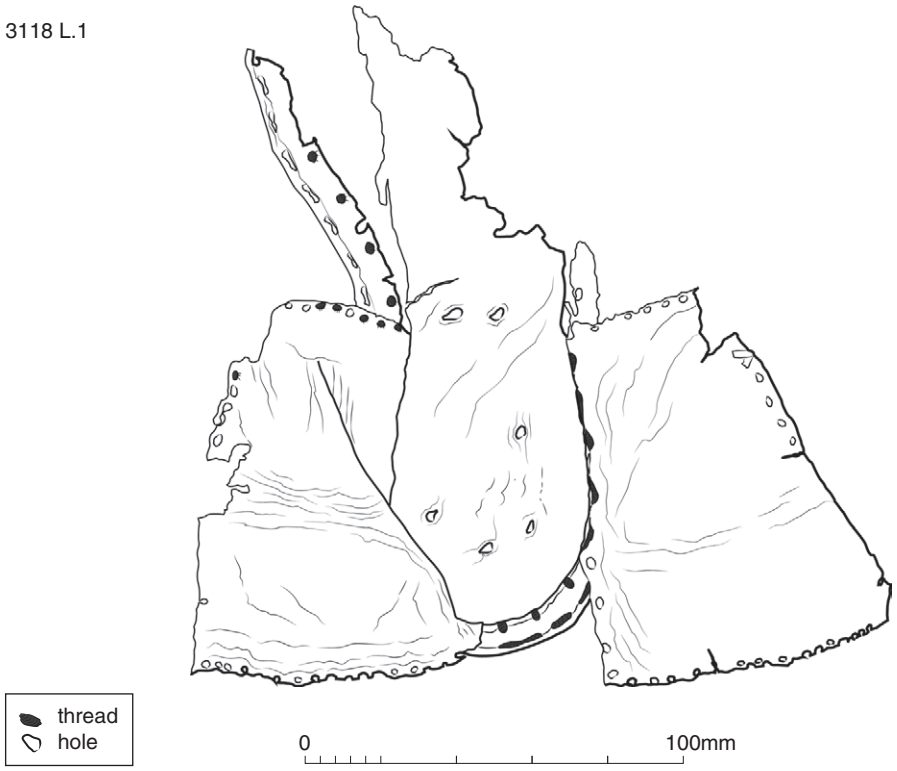


Figure 9.20a Shoe quarters, insole and welt with stitching medium in place (3118L.1; © Historic England, drawing Esther Escudero)

colouration present, but equally could have come from a secondary source such as the shoe leather, with which the laces had been in direct contact, or wood, including that of the ship's hull (Vanden Burghe and Coudray 2019, 4). The insole of one shoe (3761) still bears the impression made by a knitted stocking, or sock, visible on the upper surface (Fig. 16.7, Chapter 16, Gleba).

The group of shoes (3118)

A large number of shoe parts (3118) were recovered together from G10. While some of the shoe parts were connected, with much of the stitching medium in place (3118C.2, 3118L.1, 3118P.1, Fig. 9.20a and Fig. 9.20b), for the most part the shoes were fragmentary. Attempts to marry shoe components to the shoes from which they came proved largely fruitless owing to the uniform nature of the shoes and the extent of breakage and delamination that the individual parts had undergone.

The absence of wood associated with these shoe parts suggests that, unlike the bandoliers, the shoes had not been stored in a wooden chest or cask. It is possible that they had been contained in a textile bag or bags, as small scraps of sacking were found adhering to two shoe parts (3118H.1 and 3118O.19) identified by Dr Margarita Gleba (Chapter 16; Gleba 2019) as balanced tabby weave of a coarsely processed yarn made of plant bast fibre (hemp), which may well be the remains of a bag.

Style

All the shoes in this group (3118) were of the same general style. The square-toed shoes had flat soles, lacking a separate heel but raised with internal lifts at the seat. The uppers had vamps with peaked tongues and small open sides fastening across the instep with small latchets on the paired quarters (e.g. 3118A.1 (Fig. 9.21) and 3118C.2 (Fig. 9.22)). No lace holes were present in the vamp tongues or the latchets indicating that they had fastened with a small buckle, a feature that was just becoming fashionable (Swann 1982, 20).

No buckles have been recovered from the wreck to date. Small buckles were detachable so they could be transferred from one shoe to another, so they may not have been stored with the shoes. No holes for a studded or anchor buckle chape[19]were evident, nor were any small holes from a pronged (forked) chape noted (Swann 1981), though deterioration of the leather might have removed this evidence. The shoes appear to show some slight signs of wear, but all lack any signs of heavy wear in either the soles or the uppers, suggesting they were nearly new when stowed on board.

Quantification, condition and construction

The shoe bottoms comprise an insole, one or more midsoles and an outer (or tread) sole. The sides of the tread area often have additional strips of middle packing and some examples have scraps of leather placed over the tread area

19. An anchor buckle chape is a shoe buckle that has an integral shank with a T-shaped terminal to attach the buckle to the buckle strap through a hole (rather than sewing it on). A studded buckle chape has a stud at the end rather than the T-shaped terminal.

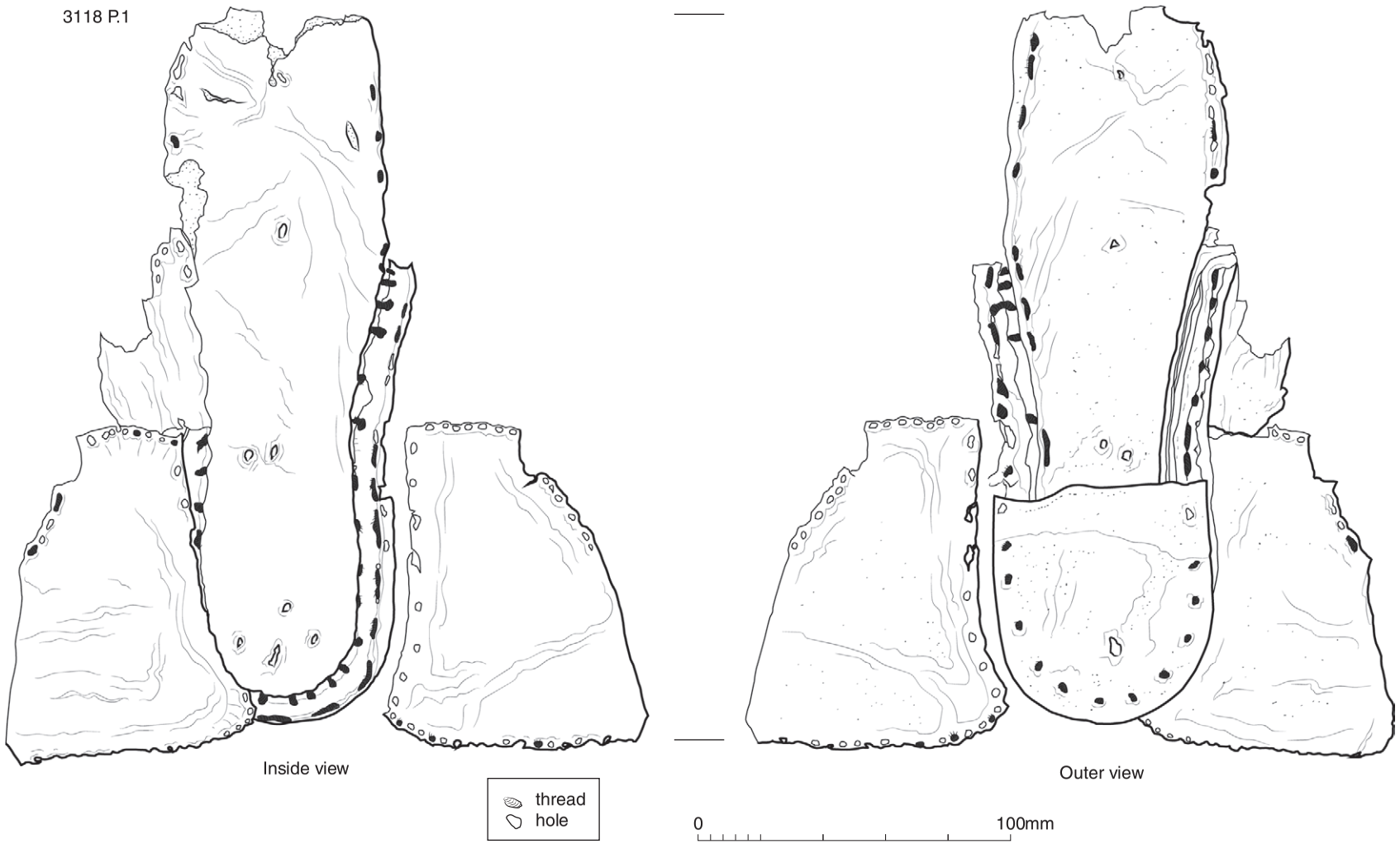


Figure 9.20b Shoe quarters, insole and welt with stitching medium in place (3118P.1; © Historic England, drawing Esther Escudero)

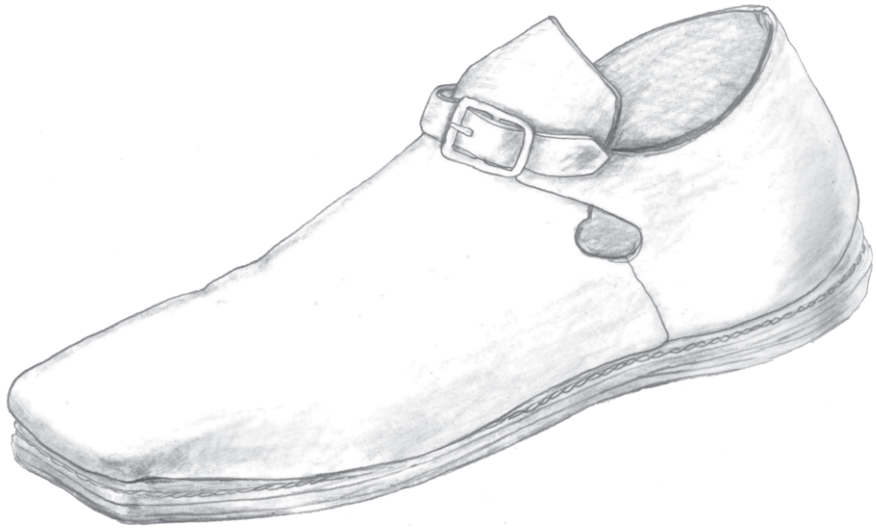


Figure 9.21 Reconstruction drawing of shoe 3118A.1 (© Historic England, drawing Marquita Volken)



Figure 9.22 Shoe (3118C.2) (© Historic England Archive, photograph James O. Davies)

as filling. D-shaped pieces (lifts) were inserted between the insole, midsole and sole to raise and cushion the foot beneath the heel and occasionally an additional piece (toe lift) was placed at the toe. The shoe bottom and the upper were stitched to a welt running around the edge of the shoe, one row of stitching to join the upper and insole and another joining the midsole and sole, construction types-1A and 1B. The row of stitching in the sole was set well in from the sole edge and sunk within a groove known as a stitching channel.

Most of the shoe parts have delaminated so that the flesh side of the leather is now missing and the original thickness is unknown. Despite this the grain surface is in very good condition. As many shoe parts, particularly the uppers, have only the grain surface of the leather surviving, the seams are broken and few stitch holes survive so components from the same shoe cannot be matched easily. Several of the shoe soles have broken along the seam, resulting in a separate strip that has broken away from the edge of the sole and has become detached (e.g. 3118O.30D). These have been termed 'strips torn from sole edge' in the basic record. While the sole leather had been weakened by the depth of the stitching channel into which the stitching had been sunk, it is possible that something coating the thread used to stitch the sole seam may also have promoted rotting at this point.[20] Consideration of the key shoe parts present (soles, insoles, vamps and quarters) suggests that at least 22 shoes are represented, but other smaller parts indicate the total is probably 24 shoes, 12 pairs, are present in group 3118.

While the shoes are all of the same general style, with only slight constructional variations, one feature was very different. Many of the uppers had the flesh side outward,[21] while others had the grain side outward, giving a smooth, shiny appearance. The majority of the shoe uppers from the shoe group (3118) were flesh side outward; three examples, found with components of the uppers and bottoms still stitched together[22] show that the thin grain surface, all that now survives of the upper leather, was on the interior of the shoe (Fig. 9.23).

Others, such as two vamps (3118E.4 and 3118F.3), have moulded lasting margins[23] clearly showing that these were grain outward. Loss of the flesh side of the leather has resulted in much of the seam stitching being lost and it is now difficult to determine which face was outermost.[24] The flesh side is also outward on the only front-tying shoe with no heel (3064/3065). Footwear with the flesh side outward was popular throughout the 17th century and, as here, both flesh and grain out leathers were used for the shoes and boots recovered from the *Vasa* (Swann 2001, 102).

Some of the shoes in the group (3118) fastened with narrow latchets that were integral to the quarters, others had slightly wider separate latchets seamed to the front of the quarters (see Figs 9.23 and 9.24).[25] The two quarters from three shoes that could be matched show an integral latchet on one quarter and a separate latchet on the other,[26] while two others had a separate latchet on each quarter.[27] A separate latchet was thought to have been the result of repair to replace an integral latchet that had failed, having been substantially weakened by the buckle attachment (Swann 1981, 2), although this was not the case with the shoes from the *London*, which appear to have been hardly used.

The shoes show other small differences in their construction. While all are of the same welted construction (see Fig. 9.11), some insoles (e.g. 3118K.7, 3118M.1) were sewn to the upper and welt with an edge/flesh seam (construction type-1A) but most had the edges of the insole rolled over to form a closed grain/flesh seam (construction type-1B).

Similarly, differences in the choice of seam used to join the upper components can also be observed, although the loss of the flesh side of the leather has resulted in the loss of stitching evidence in several cases. A small number of upper components were joined with butted seams but most were joined with closed grain/flesh seams, these latter are likely to be those that had their uppers flesh side outward. At least one vamp (3118P.4), however, had both stitch types used on the same length of side seam indicating that practicality dictated the choice of stitch used when necessary.

Eight examples of quarters have integral latchets,[28] 20 quarters have a small seam to attach a separate latchet, one quarter has a latchet present (Fig. 9.23) and seven latchets were found separately (3118O.20–26; Fig. 9.24). Again, some latchet seams were sewn with a whipped grain/flesh stitch, others had a butted edge/grain seam (e.g. 3118O.22). These small constructional differences indicate that the shoes were the work of several craftsmen and may suggest that they had been supplied by more than one workshop. Further, it suggests that the group of shoes were not a single batch of production, but rather a collection from several sources being stored together.

The decorated shoe soles

Perhaps the most notable feature present amongst the group of shoes (3118; Figs 9.25–9.27) was the occurrence of external shoe sole decoration. Five shoe soles from the group have linear decoration[29] and a strip broken from a sole edge (3118O.30D) may have come from another example

20. During conservation tar was noted around stitch holes on the shoe bottoms and this might be responsible (Angela Middleton pers. comm.). Initially the lack of a seam on these soles created some difficulty in distinguishing them from broken insoles but the recovery of examples with areas of the outer strip remaining in place (e.g. 3118H.1) clarified this aspect.
21. 'Suede' as we understand the term today.
22. Small find numbers 3118C.2, 3118L.1 and 3118P.1.
23. The way the lasting margin was bent (moulded) showed which surface had been on the outside and which on the inside of the shoe.
24. For this reason, whether the quarter was for the right or left side of the shoe has been only tentatively suggested in the basic record where appropriate.
25. As these latchets are wider and lack fastening holes they should best be termed straps, but the term latchet continues to be used here for clarity.
26. Small find numbers 3118C.1,3118C.2, 3118J.10/3118J.11.
27. Small find numbers 3118L.1 and 3118P.1.
28. E.g. small find numbers 3118L.1, 3118P.1, 3118O.9–10.
29. Small find numbers 3118H.1, 3118I.1, 3118I.2, 3118K.1/3118N.1, 3118K.2.

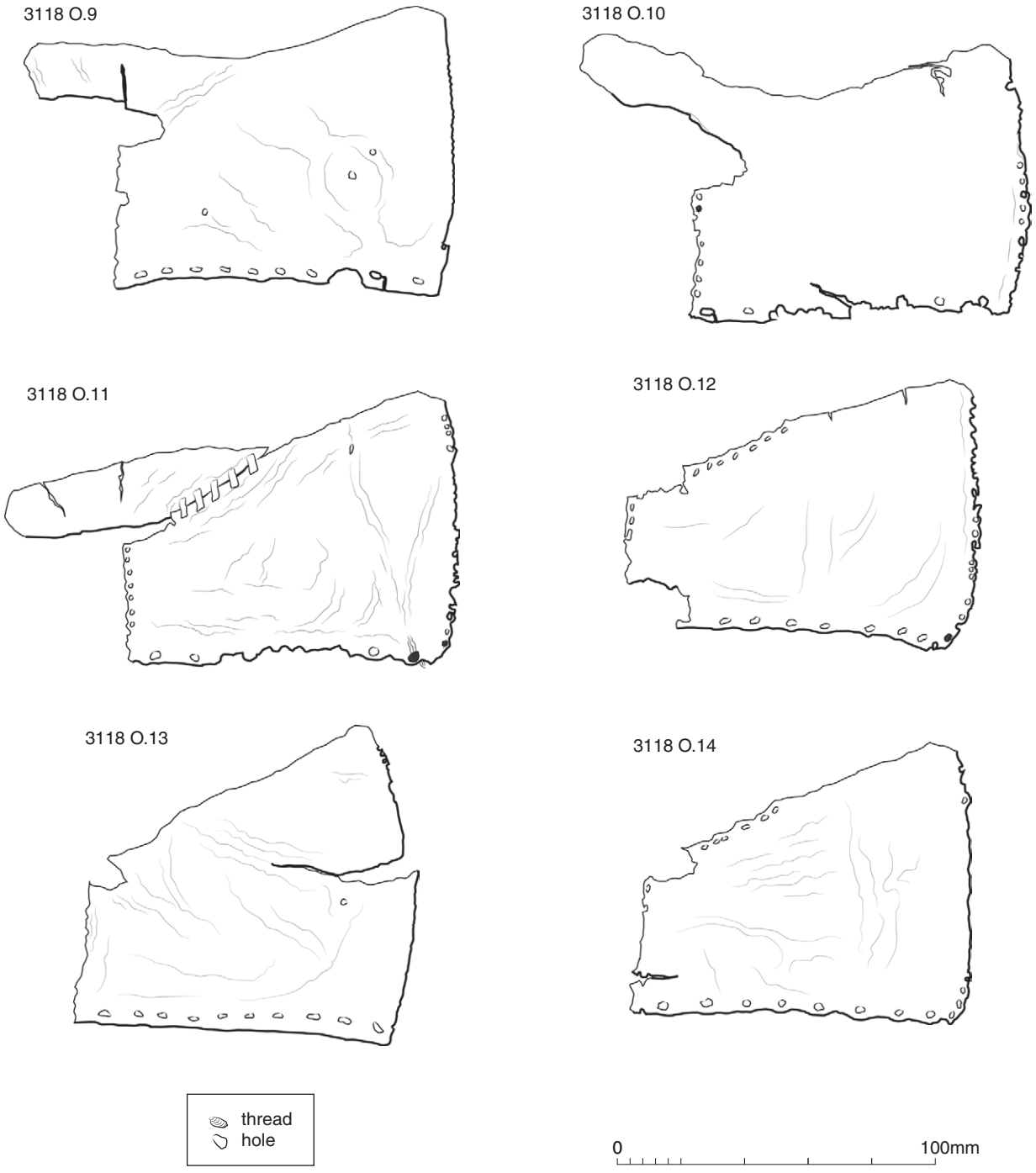


Figure 9.23 Shoe quarters, two with integral attached latchets (3118O.9–10; © Historic England, drawing Esther Escudero)

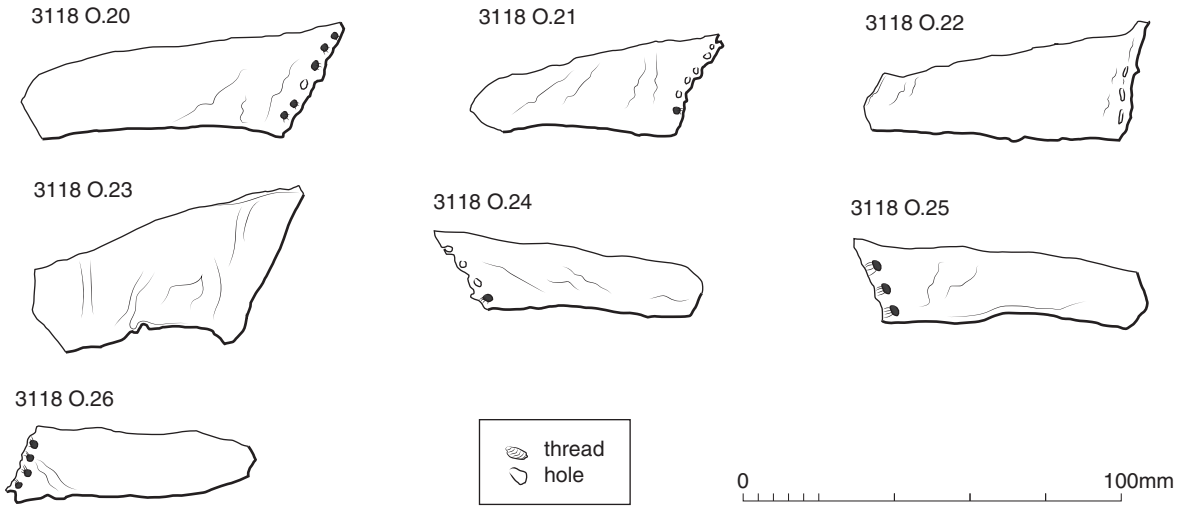


Figure 9.24 Separate latchets (3118O.20–26; © Historic England, drawing Esther Escudero)



Figure 9.25 Decorated soles (3118I, 3118K.2, 3118K.1 and 3118N.1; © Historic England Archive, photographs James O. Davies)

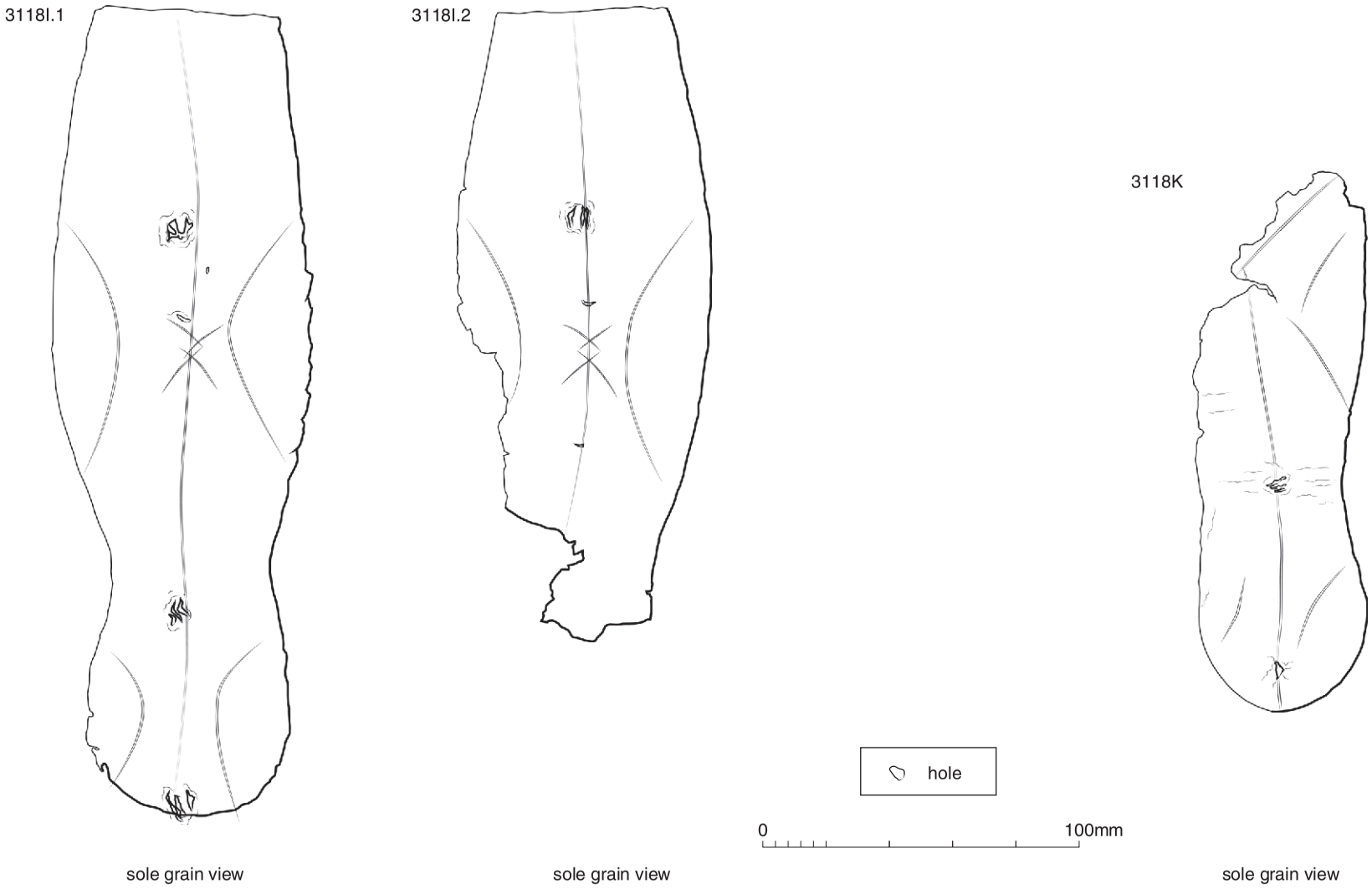


Figure 9.26 Decorated soles (3118I.1, 3118I.2 and 3118K.2; © Historic England, drawing Esther Escudero)

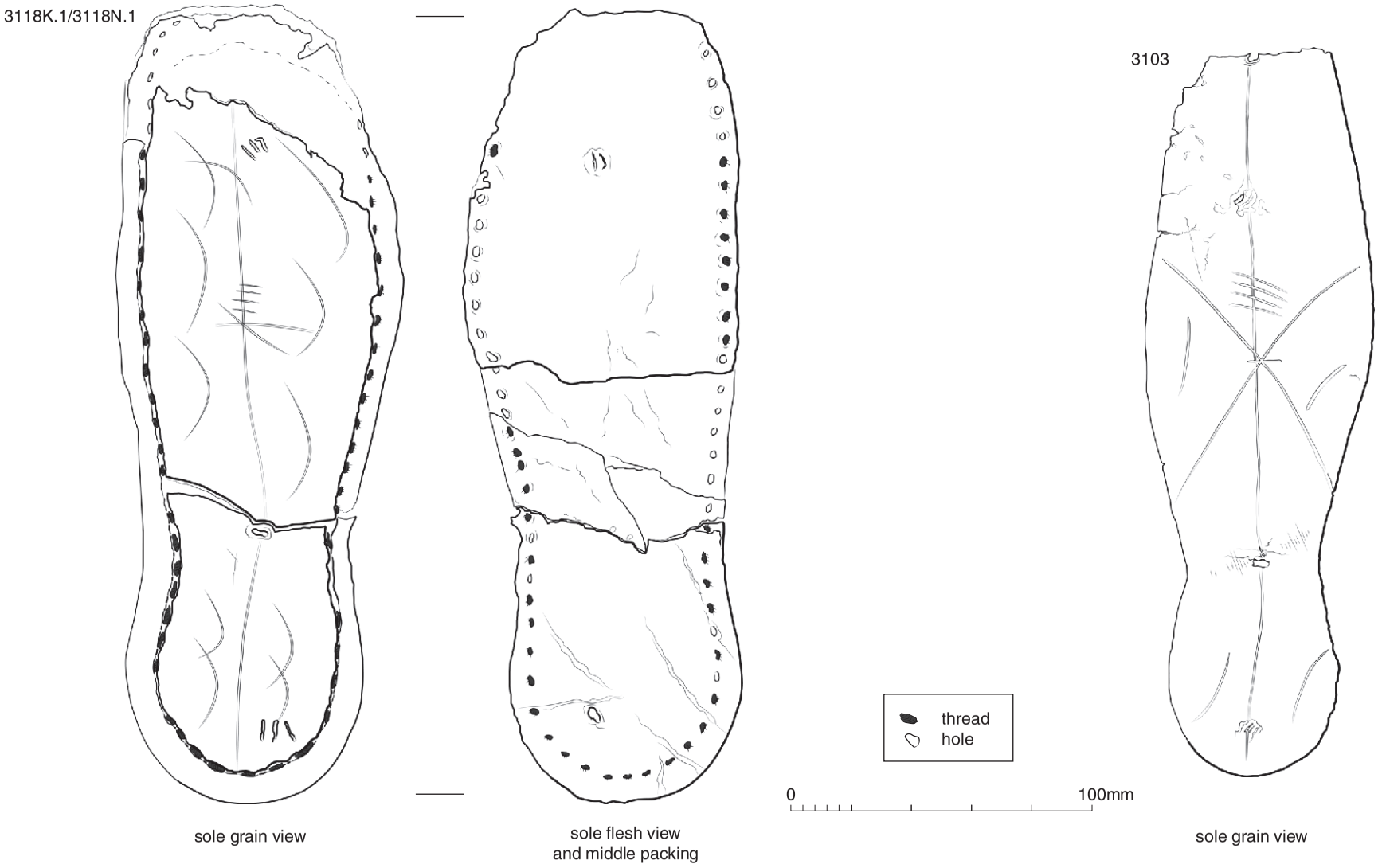


Figure 9.27 Decorated soles (311K.1/3118N.1 and 3103; © Historic England, drawing Esther Escudero)

if it does not belong to 3118K.2. In addition a decorated shoe sole (3103; Fig. 9.27, right) was recovered along with a midsole (3104) close by (from G11) and appears to have been one of the 3118 group, displaced by currents or later activity.

The patterns, comprising a central vertical line with combinations of a cross and oblique small slashes at the centre of the tread with arcs to either side at the tread and seat, suggest at least three possible pairs of shoes (Fig. 9.27):

- 3118K.1/3118N.1 matching 3118H.1;
- 3118I.1 matching 3118I.2; and
- 3118K.2 matches 3103.[30]

The designs had been impressed with a blunt tool, with occasional small oblique lines being incised. Another shoe sole (3118I.3) has a single incised vertical line running down the centre of the tread but lacks any other motifs. This decoration on the exterior surface of the shoe sole is an unusual feature indicative of expensive, possibly bespoke, footwear for a person of higher rank;[31] a contradiction to the idea that the 3118 group of shoes might represent a bulk issue of kit for the men on board. The decoration would soon have been obliterated by wear and was generally unseen by others except when the wearer was riding or kneeling in prayer.

A small number of shoes with highly decorated soles, for both men and women, dating to the second quarter of the 17th century survive in shoe collections in Sweden (Swann 2001, 120–1, figs 133–4), including a shoe reputed to have been worn by Georg Fleetwood at his wedding in 1640 (Swann 2001, 110–11). Seventeenth-century shoes with decorated soles are rare in Britain. Shoes with soles with less elaborately incised lines were present in burials, dating to *c*. 1620, in the family vault of the Archer family in St Mary's Collegiate Church at Kilkenny City, Ireland. These shoes, with incised linear decoration amounting to little more than 'laying out' lines with a central vertical line and two pairs of parallel lines across the waist, do not appear to have been worn and may have been made for the burials (J. Nicholls pers. comm.).

The highly decorated Swedish examples and those worn by members of the Archer family were high status footwear. A child's shoe (15E0033:111:16), however, found in Kevin Street, Dublin, with a sole tooled similarly to the Archer family footwear and of similar date, had been well worn (J. Nicholls pers. comm.) indicating that the wearing of shoes with such decoration was not restricted to ceremonial occasions. The Swedish examples exhibit a wide variety of patterns, which has been interpreted as a reflection of the pride in workmanship by the shoemaker at a time when the craft was respected and most profitable (Swann 2001, 121). The *London* examples, being less elaborately tooled than the Swedish shoes but more decorative than the 'laying out' lines seen on the Kilkenny burial shoes, fall somewhere between the two, but appear to be expensive products.

Shoe sizes

Eleven complete insoles have been recovered so the equivalent modern shoe size has been calculated from measurements of the complete conserved insoles. Six complete insoles were recovered from group 3118 that varied in equivalent modern shoe sizes from adult 4 (37) to 5 (38). Shoes recovered from elsewhere in the wreck ranged in size from adult 3 (36) to 6 (39).[32] In the late 19th and early 20th centuries adult sizes 2 (34) to 7 (41) were the most popular sizes worn by men (Grew and de Neergaard 1988, 103). As no female styles or shapes of shoe were found we may safely assume that all the footwear recovered from the *London* had been worn by men.

Discussion on condition and ownership

There is no evidence of heavy wear, with no holes in the soles or uppers, no repairs of soles and no excessive wear on the heels. There is evidence of one possible repair on the rear of a shoe bottom (3393 from grid square M19; Fig. 9.28); it had a black shiny substance present at the seat between the lower surface of the midsole and a heel lift and a yellow sticky residue by the stacked heel. Fourier transform infra-red (FTIR) analysis of this substance, also found around the stitch holes on the shoes confirmed that the residues were tar (Fig. 9.29). [33]

Apparently this had been used as an adhesive, probably in this case to make a quick repair. A black pitch/tar-like deposit is also present on the heel top-piece of another shoe (3761 from grid square K18). Two heel lift examples are also black in colour, one (3390 from grid square M19) is the heel top-piece, the other the single surviving heel lift of a shoe bottom (3141 from grid square J8).

This distinct difference in colouration from the rest of the heel may suggest contact with tar, although neither is now sticky to the touch. A pitch/tar-like substance has been noted occasionally on the shoe bottoms and heels of footwear of 17th-century date, chiefly recovered from shipwrecks and harbourside locations. Tar/pitch was used to waterproof footwear worn by seamen and others working or living in extreme conditions (Archaeological Leather Group 2018, 6–9).

30. Slight differences in design between 3118K.1/3118N1 and 3118H.1 and the continuation of the decoration onto sole edge strip 3118O.30D, however, may suggest that five pairs are represented.
31. The most senior rank on board at the time were the warrant officers.
32. Selected shoe parts were measured before and after undergoing conservation treatment by freeze-drying (see Chapter 5, Middleton) and an average shrinkage rate of 3% was noted following treatment. Measurements adjusted to allow for this shrinkage gave the shoes from group 3118 sizes adult 3 (35) to 5 (38) before treatment but did not change the size range of the entire assemblage.
33. Perkin Elmer Spectrum 100, fitted with an attenuated total reflectance (ATR) accessory. Spectra were recorded over the range 650–4000cm^{-1}, with a resolution of 4.00cm^{-1}, and were averaged over 32 accumulations. Broadly speaking, the spectra display the same peaks at the same wavelength, although they differ in intensity from one sample to the other (Fig. 9.29).



Figure 9.28 Sticky yellow residue by the stacked heel of a leather shoe fragment (3393; © Historic England, photograph Angela Middleton)

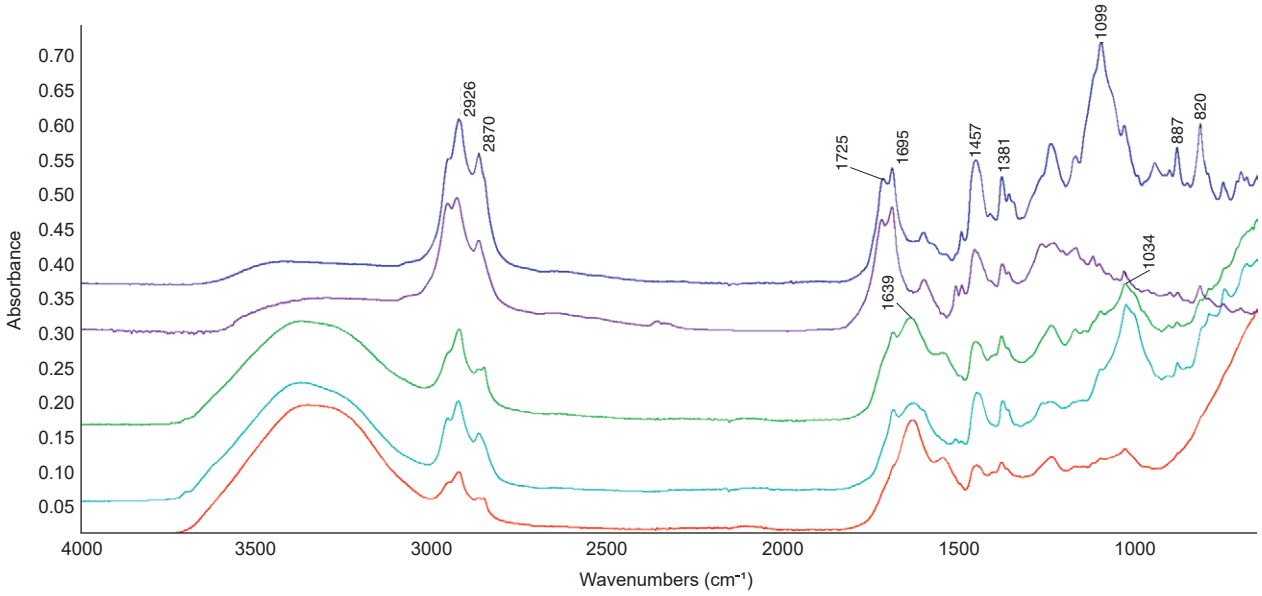


Figure 9.29 FTIR spectra of tar remains collected from leather artefacts, including a shoe (3393; light blue) and a bucket (3046; blue/3381; green and red), with a reference spectra of pitch (purple) (© Historic England, Angela Middleton)

Table 9.6 The leather book covers (measurements in mm)

Object no.	Location	Leather	Height	Width	Spine width	Decoration
3391	M19	cattle	175	125	20	Fillets, rouletting
3718	Trench 3	bovine	180	140	30	Fillets, gold leaf, red pigment
3763.1	K18	calf	172+	118+	?	Fillets, red pigment
3792	J16	calf	?170	?168	?	Fillets

Not only are all the shoes from the wreck in unusually good condition, those found stored together (group 3118) were notable in appearing to have been hardly, if ever, worn. The shoe soles showed little, if any, signs of wear, while the uppers were also in good condition, though some vamps did show slight wear along the sides just above the lasting margin. It could be argued that movement created by the sea currents might account for the limited amount of wear visible on the shoe leather but, on consideration, it is suggested that the shoes had been worn but not extensively.

The soles of the shoe group (3118) have a series of deep and distinct holes or grip marks occurring singularly or in small groups at the centre of the toe, the tread, the waist and the seat. While all shoe bottoms have small nail/tack holes at these points made during the lasting process they were usually quickly obscured and eventually removed during normal wear. In contrast the holes or grip marks are more numerous and very conspicuous on this group (3118). It is presumed, however, that they too result from attaching the shoe bottom to the wooden last during manufacture. These lasting holes, together with the decorated soles and the lack of general wear, indicate that these shoes have not been subjected to normal wear on the street. Could it be that they had been worn only on board ship? This seems unlikely as the wreck predates the introduction of standardisation.

The shoes found separately on the wreck had been worn by persons on board when the ship went down; these fashionable heeled shoes may perhaps have been worn by warrant officers. The more exaggerated shapes, decorative features and silk laces exhibited on some (small find numbers 3390, 3731 and 3761) support this further. Though fashionable they were not at the 'very cutting edge', however, as they were tied with laces at a time when the most highly fashion conscious were adopting the buckle fastening. Samuel Pepys records first wearing buckles on his shoes in January 1660 (Latham 1996a, 9), though buckles were not in general use immediately. John Evelyn recorded in October 1666 that only then had the king worn shoe buckles for the first time (Swann 1982, 20). The sinking of the *London* falls squarely into this period of transition in men's shoe fastenings.

The shoes in group 3118 have flat soles, suggesting they were practical work shoes but their fashionable buckle fastening seems to contradict this. Contemporary genre paintings show men of the 'middling sort' wearing flat-soled latchet-tying shoes through much of the 17th century. These flat-soled buckle-fastening shoes raise several questions: why were they being stored together, what was their purpose and to whom did they belong?

While the possibility exists that the shoes in group 3118 might have belonged to one man, they do vary, though only slightly, in size but not in style, begging the question why would one person want so many similar-looking shoes? They might have been 'cargo' belonging to a sailor intending to sell them at the end of the journey; a known practice (J. Swann pers. comm.), which might have been a likely proposition had the *London* been destined for a long voyage rather than a short journey to engage in battle.

Perhaps they were being stored together for later distribution on board ship in the manner of the bandoliers. Lacking heels, is it possible that they were deck shoes worn for a particular purpose? Traditionally deck hands went barefoot in all but the coldest conditions. There are similarities between these shoes and the 'magazine shoes' worn by those manufacturing and working with explosives well into the 20th century (D. Pascoe pers. comm.). Magazine shoes are of a tie-fastening, flat-soled style selected to prevent sparks.[34] The style is comparable to the shoe group 3118, differing only in the tie rather than the buckle fastening. While it is possible that these shoes in group 3118 were worn by those handling the explosives on the ship, is it not more likely that they would also have been tie-fastening rather than buckle fastening, the very epitome of high fashion at that time? Would the shoes of powder monkeys or gunners have decorated soles like those of the gentry? Conversely, if these shoes were expensive footwear of the elite would they not have had fashionable heels? Might they possibly represent part of a 'uniform' or special kit issued to the men when on board? Or were they intended for sale by an entrepreneurial sailor when the vessel returned to port? At present the purpose of these shoes found together in group 3118 is unknown.

Book covers

The description and discussion of the leather book covers provided is necessarily limited but should serve as a starting point for others wishing to research further into these items. The terms employed are those given in the *Language of Bindings Thesaurus*.[35] Four leather book covers (Table 9.6) are all that survived of the books they originally covered, which were of similar size with comparable bindings. All were made of brown bovine leathers, two of calfskin (3763.1 and 3792: Fig. 9.30) and two of fine-grained cow

34. Known colloquially as 'Waltham Abbeys', see, for example, those on exhibition at the Explosion Museum of Naval Firepower, Gosport, Hampshire.
35. Language of Bindings Thesaurus https://www.ligatus.org.uk/lob/ (accessed 23 September 2025).



Figure 9.30 Leather book cover (3792; © Historic England Archive, photograph James O. Davies)

leather (3391 and 3718; Cameron 2019; Fig. 9.31 and 9.32). The bindings were plain, the only decoration being a rectangular border frame of two-line fillets (impressed lines), front and back.

One book (3391) also has a line of rolled (rouletted decoration) marking the upper (head) and lower (tail) edge of the book (Fig. 9.32). The spines do not have pronounced ridges, which may suggest that the books had recessed cords; where areas of the spine survive two-line fillets are present marking the position of cords beneath.

The remains of gilding or gold pigment, visible within the fillets running along two edges of another cover (3718; Fig. 9.33), indicate that the fillets of this binding had been ornamented originally with gold leaf. No gold pigment is visible under low magnification on the other three covers, which appear to have been 'blind-tooled' (i.e. without any gold leaf).

In addition specks of a red pigment are present on the inside of one book cover (3718; Fig. 9.34) preserved in the crease of the seam that wrapped around the board of the book cover; remains of the paste board were also recorded (Fig. 9.35). Larger areas of a red pigment are also visible on the interior, flesh side, of a second cover (3763.1; Fig. 9.36).

The gilding and red substance were analysed by Sarah Paynter and Florian Ströbele using X-ray fluorescence (XRF) spectrometry[36] but as the object was still damp no vacuum was applied, so light elements could not be detected. As a control an undecorated area of the flesh side of the book cover was analysed and elevated levels of iron were detected, probably from the burial environment. When an area of suspected gilding was analysed gold was detected, confirming this identification.

The analysis of the red pigment detected strongly elevated levels of mercury and lead, so the red pigment is vermilion, a mercury sulphide (HgS), the synthetic version of the mineral cinnabar. Vermilion has a long history of use by both artists and manuscript illustrators. It was very expensive so was often cut with cheaper materials (Cennini 1933) such as red lead[37] and this probably accounts for the roughly equal proportions of lead and mercury detected in the red pigment. It is likely to have derived from ink present on manuscript waste that had been used to make the book boards when binding the book. Remains of vermilion, transferred in this manner from red ink lettering to the interior of book covers, was also a feature of the large collection of book covers recovered from the 17th-century

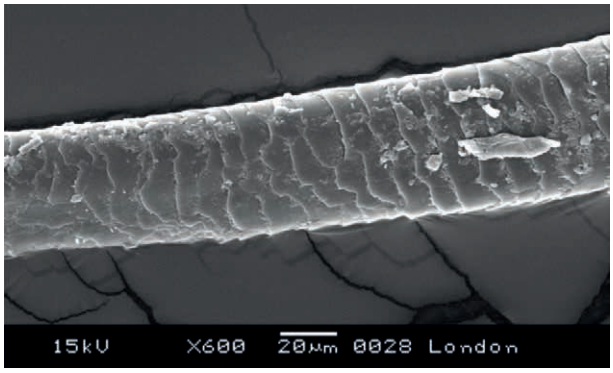


Figure 9.31 SEMicrograph of hairs from leather book cover (3391; © Esther Cameron)

36. Using the M4 Tornado XRF analyser at Historic England's material science laboratory based at Fort Cumberland, Portsmouth. The machine has a polycapillary lens so a small area can be analysed (spot size of 25µm). Analyses were undertaken at 50kV, and 200µA for 200 seconds live time.
37. Minium lead oxide (a naturally occurring form of lead tetroxide) Pb_3O_4.



Figure 9.32 Near-complete leather book cover (3391; © Historic England Archive, photograph James O. Davies)



3718 Detail

Figure 9.33 Grain side of a book cover (3718) post-conservation. Note gold leaf detail on right hand edge (close up; © Historic England Archive, photographs James O. Davies)



Figure 9.34 Red vermilion pigment inside top turn-in of book cover (3718; © Historic England, photograph Angela Middleton)



Figure 9.35 Flesh side of book cover (3718) post-conservation. Note remains of paste board (light brown colour) (© Historic England Archive, photograph James O. Davies)



Figure 9.36 Leather book cover fragment (3763; © Historic England Archive, photograph James O. Davies)

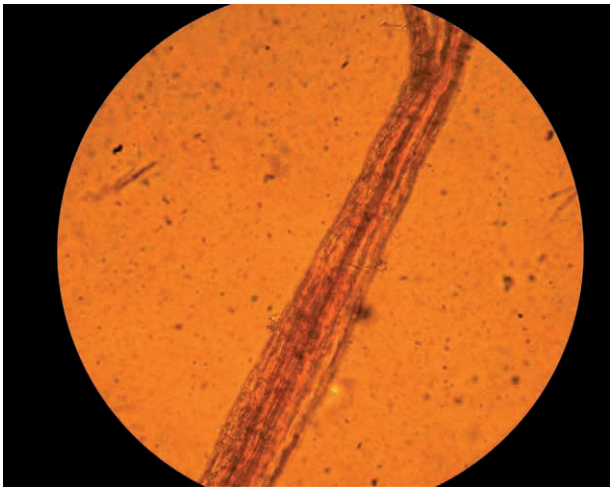


Figure 9.37 Fibre from paste board of book cover examined under transmitted light using a Leitz 'SM-LUX-POL' microscope at a magnification of ×400 (3718; © Historic England, Angela Middleton)

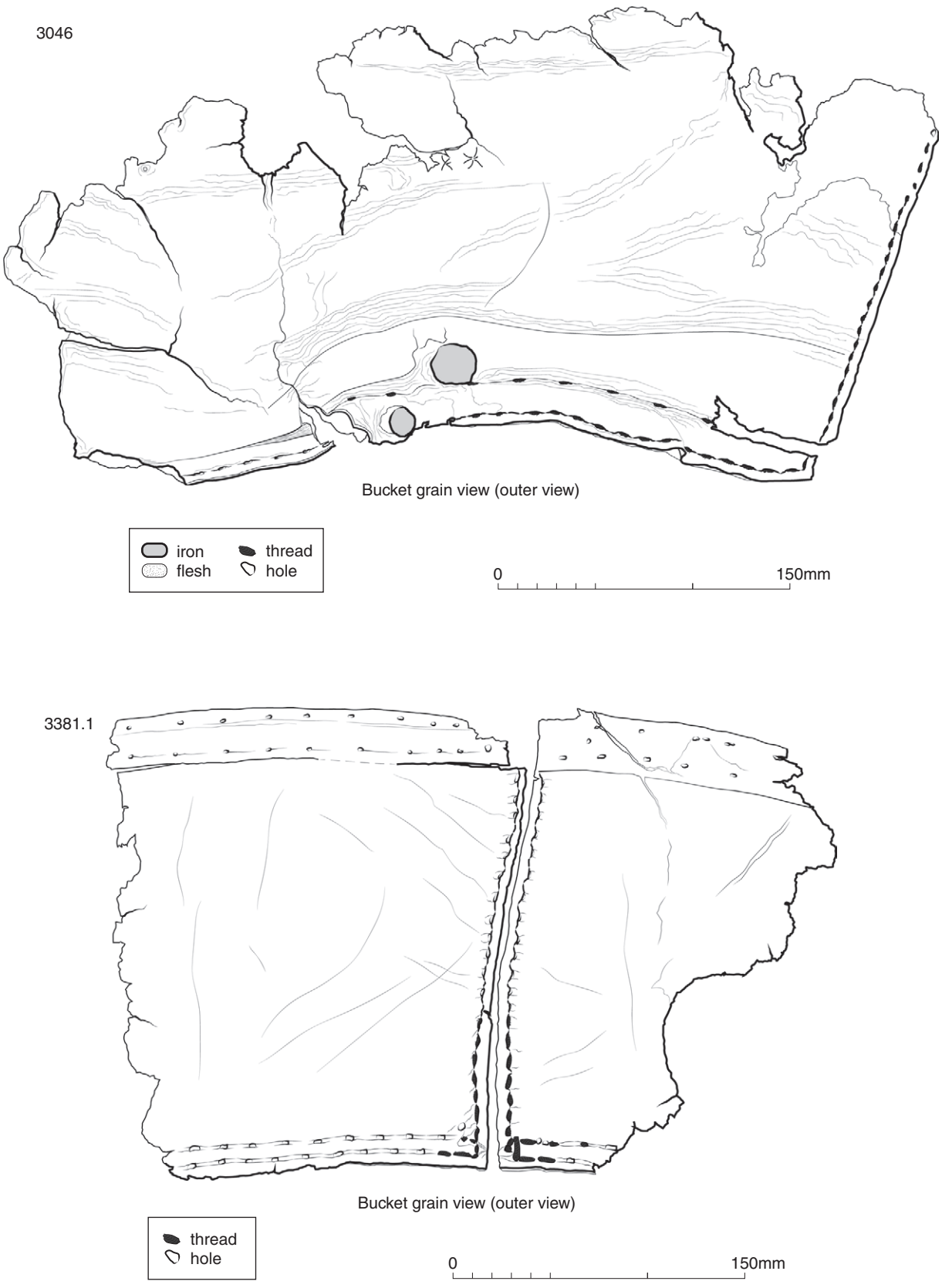


Figure 9.38 Bucket parts (3046 and 3381.1; © Historic England, drawing Esther Escudero)

Table 9.7 Leather bucket panels (measurements in mm)

Object no.	Height	Panel length	Seam type*	Max thickness	Grid square
3046	216+	460+	Closed g/f	3.97	I10
3381.1	232	365+	Butted e/g	7.25	J11
3381.2	262	433+	Closed g/f	3.77	J11

*seam type refers to the vertical seam joining the body panel

wreck BZN17 off the Dutch island of Texel (J. Dickinson pers. comm.).

Two samples, one from the crease of the seam inside of book cover (3718) and the other from the possible paste board, were sent to Paul Garside and Zoë Miller for fibre identification.[38] The fibres from under the crease of the seam appear to be flax (Fig. 9.37) as they are grouped in bundles (ultimates), typical of bast fibres. They have characteristic 'V'- and 'X'-shaped nodes, or dislocations, along the length of the fibre, and appear to have narrow, continuous lumens (rather than the broader lumen typical, for example, of hemp).

The fibres from the board sample were much more difficult to identify accurately. While those that could be examined readily were clearly of plant origin, they had been heavily processed and subject to significant degradation, which has damaged or obscured any characteristic morphological features which might have enabled identification. It was therefore not possible to determine the nature of the fibres more accurately. A more precise characterisation of the fibres (and potentially of other components present) might have been possible with a more invasive analysis but this would potentially have damaged or caused permanent changes to the specimens.

A single small tack-like hole close to the fore edge of two covers (3718 and 3792) possibly marks the position of a book tie. Although book ties at this time were made of leather, linen or, less commonly, silk, these small holes suggest a linen or silk tie, as a leather tie would have required a larger hole.[39]

Three of the book covers were found in relatively close proximity, in grid squares M19, K18 and J16, while the fourth (3718) was recovered from trench 3 to the west.[40] One book cover (3792) was found close to human remains in square J16. Another (3763.1) was found in association with a shoe (3761), fragments from a second shoe (3763.2), copper-alloy dividers (3760) and a clay pipe (3762) in square K18. The third cover (3391) was found in proximity to a 'fork-toed' shoe (3390) and the sole of a second shoe (3393), near three pieces of clay pipe (3720–2) and a rim of salt-glazed pottery (3723) in square M19.

Discussion

These book covers appear to be typical of book bindings of the early 17th century, when very plain bindings of calfskin, decorated only with vertical and horizontal fillets 'in blind' to create simple rectangular panels, were popular (Palmer 2011). The two better preserved book covers (3391 and 3718) are framed by fillets, with an additional vertical fillet parallel to the spine, a feature consistent with the date of the wreck (mid-17th century). This feature has not survived on the other two covers but none of the covers bear small corner decorations that were often present at this time.

The leather book covers from the *London* are better quality than the most common cheap book cover types, paper wrappers or limp vellum bindings and, although bovine leather was at the lower end of leather book bindings, it was not the lowest; similar plainly decorated sheepskin covers were known to be easily torn and were subject to insect attack (Pearson 2005, 18–9, 190, n.3 quoted by Palmer 2011). The book cover with gold decorated fillets (3718) indicates a more expensive binding but all the covers represent books of some, if not the best, quality.

The size of only two books could be estimated from the surviving covers (3391 and 3718) but all four seem consistent in size (Table 9.6) and may be considered small format books. They all fall into type 2 of the three book cover types recovered from the *Mary Rose*. The three examples of *Mary Rose* type 2 books found were of three different heights and spine thicknesses (Richards and Gardiner 2005, 128 table 3.4). The *London* examples were each made from a single piece of leather with the edges turned over on the inside, lacking any form of cover stiffener or tie fastening (*ibid.*, 128). The spine width suggests book thicknesses of 20mm (0.8"; 3391) and 30mm (1.2"; 3718), the *Mary Rose* examples being 25mm, 33mm and 38mm. Another example was found on the Duart Castle wreck (Martin 2017, 222–3).

Although the book size and the extent of the decoration on two covers (3763 and 3792) could not be ascertained, wider tools were used to form the decoration as the

38. Small samples which had become detached from the bulk specimens (possibly the board) were temporarily mounted on microscope slides under coverslips, using water from the sample vials as the mounting medium. The samples were examined in transmitted light using a Leitz 'SM-LUX-POL' microscope at a magnification of ×400. Unfortunately, owing to equipment limitations, it was not possible to record micrographs with this set-up, so reference images were subsequently captured using an Anmo 'Dyna-Lite Edge' digital microscope, taken at x60 magnification, with a Nikon camera attached to the microscope.
39. A horizontal >-shaped tear running inward from the edge of another (3391) might indicate a fastening having been torn off, although it appears in the wrong place.
40. It is not known at present whether cover 3718 was found in the same general location as the bandoliers. The licensee recalls that all the book covers were found on the gundeck, one being located near to the ship's cable (S. Ellis pers. comm.).

individual lines of the two-line fillets are more widely spaced. This suggests that these books were bound at different establishments. The size of these books points to personal journals or log books (J. Dickinson pers. comm.) intended for utilitarian rather than recreational use.

Leather buckets

The rectangular body panels from the walls of three leather buckets, one larger (3046 from grid square I10) and two smaller examples (3381.1 and 3381.2 from grid square J11; Fig. 9.38), have been recovered (Table 9.7). The circular base, handle and other components are missing. All are made of cattle hide, two (3046 and 3381.2) approximately 4mm thick, the other (3381.1) over 7mm thick, all of which have delaminated in places. Like the shoes, the buckets were sewn with hemp thread (Chapter 16, Gleba).

The rectangular body panels were joined with a single vertical seam; the two panels of thinner leather joined with a closed grain/flesh seam, while the panel of thicker leather (3381.1) joined with a butted edge/grain seam; both seam types are visible on the outside of the bucket. A double row of saddle-stitching from a large closed seam runs along the lower edge to join to a circular base.

The upper edge forming the rim of the bucket is present on two body panels (3381.1 and 3381.2), having a double row of stitching to attach a separate leather rim band that would have held a hoop of wood, metal or rope supporting the bucket rim. Each has horizontal cuts below the top edge scoring the grain surface and only partially cutting the flesh surface beneath. This may be the result of the rim band having been removed deliberately. A small vertical cut is also present running obliquely down the vertical seam of one (3381.1). These cuts may indicate that these two buckets had been modified.

Areas of tar/pitch adhere to the interior (flesh side) of all three buckets. A very thick crumbly yellow deposit was also present inside one bucket (3381.1). A possibly similar substance, described as cream/buff/orange in colour, stained the interior of a leather bucket found in 17th-century backfill of a well at Moor House in the City of London (Mould 2006, 124–6 and fig. 103). This bucket shares other characteristics with the *London* example, having a butted edge/grain seam and showing similar cuts below the rim band stitching, although in this case fragments of the rim band and the wooden hoop also survived. FTIR analysis was undertaken on a similar residue from a third bucket (3046),[41] which confirmed the residues to be tar (see Fig. 9.29).[42]

Unlike the two smaller buckets (3381.1 and 3381.2), the original height of the third (3046) is unknown as only the lower part survives. The notably wider spacing, however, of the double stitched seam along the lower edge to join the panel to its base suggests that it was larger than the other two. One bucket (3381.2) measures approximately 262mm (10") tall, which is comparable to those from the *Mary Rose* (Mould and Cameron 2005, 366, table 8.6) and that from the Moor House well (Mould 2006, 126). The other bucket (3381.1) is slightly smaller in size being 232mm (9") tall.

What remains of the three *London* examples appear to differ little from other 16th and 17th-century buckets (Mould and Cameron 2005; Mould 2006), lacking only a supporting strip covering the vertical seam or other points around the bucket panel.[43] The locations of the buckets found on the *Mary Rose* suggested that they may have been associated with gun furniture rather than with domestic activities being undertaken on board (Mould and Cameron 2005, 363).

41. Perkin Elmer Spectrum 100, fitted with an ATR accessory. Spectra were recorded over the range 650-4000cm^{-1}, with a resolution of 4.00cm^{-1}, and were averaged over 32 accumulations.
42. Broadly speaking the spectra display the same peaks at the same wavelength, although they differ in intensity from one sample to the other (Fig. 9.29).
43. While any associations of the buckets with other items are unknown to the author at present, musket and pistol shot were also found in grid square J11.

Chapter 10
Clay Tobacco Pipes and Stoppers

D.A. Higgins

Fifty-four clay tobacco pipe fragments (comprising 30 bowls and 24 stems but no mouthpieces) and two pipe stoppers were recovered, all but one of which were in a clean and dry state when examined; the wooden pipe stopper (3342) was still in conservation. The exact find spot for almost all the finds has been recorded to within a 1m grid square on the site. The pipes are particularly important because of the close dating and social context afforded by the wreck. As such they can be used to check and refine regional bowl form typologies as well as providing valuable insights into smoking habits at this period. All but one of the fragments is consistent with a mid-17th-century date and so almost all the finds can be attributed to the *London* with a very high degree of probability. A 19th-century bowl will not be considered further as it is either a casual loss or may have come from the later wreck that abuts the *London* (Fig. 10.1). This bowl (3071) dates from *c.* 1820–60 and has leaf decoration on its front seam and the relief-moulded maker's initials 'WB' on the sides of its heel (Fig. 10.1). The bowl is quite poorly moulded and finished, the rim having become deformed into an oval plan. This is an average quality product of a style that was typical of manufacturers in London and the south-east at this period. Given that it could simply have been discarded from a passing vessel it is not possible to suggest a specific source or manufacturer. The very low level of contamination on the wreck site is perhaps surprising given its location in the Thames Estuary but adds to the significance of the assemblage as a single tightly dated group.

Description

Fifty-three clay pipe fragments (29 bowls and 24 stems, Table 10.1) can be attributed to the *London*. The pipe fragments have been examined individually and details of each piece entered onto an MS Excel worksheet, the layout of which is based on the clay tobacco pipe recording system and methodologies that have been developed at the University of Liverpool (Higgins and Davey 2004; Higgins 2017a). A letter has been appended as necessary (A, B, etc.) to distinguish the individual pieces where there is more than one item in a bag. Where stem fragments were found to join, they have been stuck using acetone soluble HMG glue, with short sections of cocktail stick inserted into the stem bore to reinforce the join. In order to test the existing dating systems each pipe bowls was allocated a date using the two most commonly used typologies for the London region. Where an exact match could not be made the nearest alternatives were logged with the dating adjusted accordingly, as it would be for an assemblage where the date was not already known. Finally, the individual mould types used to produce the pipes have been identified (so far as is possible). This has been done using bowl profile where the forms are clearly distinct and mould flaw analysis where they are very similar. The latter involves using a strong low-angle cross light and a 10x lens to try to identify small surface defects in the mould that have left a discernible mark on the pipes produced from it. These act like a fingerprint, allowing the individual mould types to be identified. Where mould flaws are clearly visible they have been included on the drawings (Items 1, 11, 15, 16 and 17). Details of all the pipes recovered are given in find number order in Table 10.1. The pipes are

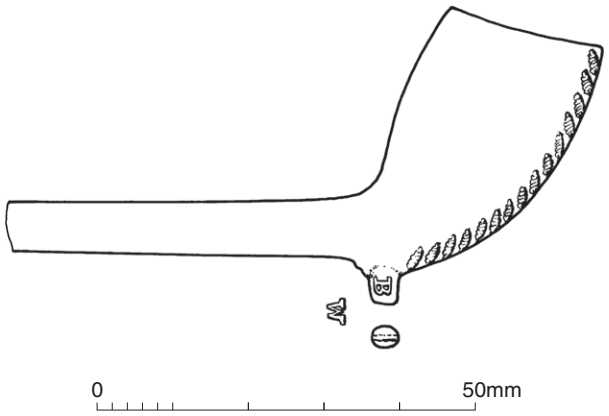


Figure 10.1 A later bowl (3071) of c. *1820–60 that is intrusive to the wreck group (© Historic England, drawing D.A. Higgins)*

Table 10.1 Details of the clay tobacco pipes

No.	Grid square	Bowl	Stem	Smoked	Bot	M4	B/64	AO	AO date	OS	OS date	Fig.	Comments
3040	H9	–	–	–	–	–	–	–	–	–	–	10.8	Copper alloy ring-stopper
3042	H9	1	–	Yes	Yes	Yes	8	12/18	1660–1680	G6	1660–1680	–	From the same mould as Fig. 10.3.17. Damaged bowl with only about one quarter of the rim surviving, most of which is milled
3048	J10	1	–	Yes	Yes	3	7	12/18	1660–1680	G6	1660–1680	10.3.15	–
3071	H10	1	–	Yes	No	0	4	29	1820–1860	G13	1780–1820	10.1	19th-century bowl
3108	I14	–	1	–	–	–	8	–	–	–	–	–	–
3117	J10	1	–	Probably	Yes	2	8	12/18	1660–1680	G6	1660–1680	10.4.19	–
3150	J8	1	–	Yes	Yes	2	8	12/18	1660–1680	G6	1660–1680	10.3.17	3042 is from the same mould
3151	J8	1	–	–	–	–	7	–	–	–	–	–	Part of a heel only
3152	J8	1	–	Yes	Yes	4	8	12/18	1660–1680	G6	1660–1680	–	From the same mould as Fig. 10.3.16
3161	J10	1	–	Yes	–	–	8	12	1640–1670	G6	1660–1680	–	Bowl fragment, drawn for 2016 report (Fig. 10.2.6) but omitted in 2019 as a more complete example had been recovered (3677A)
3329	I9	1	–	Yes	Yes	2	8	12/18	1660–1680	G6	1660–1680	–	Probably from the same mould as Fig. 10.3.16
3342	–	–	–	–	–	–	–	–	–	–	–	10.7	Wooden pipe stopper, now in two parts
3343	M17	1	–	Yes	Yes	Yes	8	11/12	1650–1660	G5	1640–1660	10.2.8	This bowl has about half of the rim surviving, all of which is milled
3344	M17	1	–	Yes	Yes	0	8	13	1660–1680	G6	1660–1680	10.4.21	–
3345	M17	1	–	Yes	–	–	9	12/13	1660–1680	G6	1660–1680	10.2.10 and 10.5	The whole rim of this pipe has been chipped away and ground smooth and the stem has been broken at 60mm, and then reused, with a rounded break and clear tooth wear from extensive use. The whole pipe has a smooth matt surface from either having been smoothed down or extensively handled and has clearly been heavily smoked
3346	–	1	–	Yes	Yes	0	8	9/15	1650–1670	G17	1640–1670	10.2.1	Joins stem 3371
3347	M17	1	–	Yes	Yes	0	8	12/18	1660–1680	G6	1660–1680	10.4.18	–
3348	M17	1	–	Yes	Yes	4	8	14	1660–1680	G17	1640–1670	10.2.4	Joins stem 3372
3349	M17	–	1	–	–	–	8	–	–	–	–	–	–
3371	M17	–	1	–	–	–	8	–	–	–	–	10.2.1	Joins bowl 3346 and has a slight ridge around the stem near the narrower end, suggesting a repair during manufacture
3372	–	–	1	–	–	–	8	–	–	–	–	10.2.4	Joins bowl 3348
3388	J10	1	–	Yes	Yes	G1	8	18v	1660–1680	G7v	1660–1680	10.3.14	Plain groove (not milled) around one quarter of the rim
3440	–	–	1	–	–	–	8	–	–	–	–	–	17th-century style stem
3497	–	–	1	–	–	–	7	–	–	–	–	–	17th-century style stem
3663	Tr3 (J10)	–	1	–	–	–	7	–	–	–	–	–	17th-century style stem
3692	Tr3 (J10)	1	–	Yes	Yes	Yes	8	11/12	1640–1670	G5/G6	1650–1670	–	Damaged bowl, quite small and with a heart-shaped heel
3708	Tr3 (J10)	–	1	–	–	–	7	–	–	–	–	10.3.11	17th-century style stem, badly iron stained – and joins with bowl 3677A
3709	Tr3 (J10)	–	1	–	–	–	8	–	–	–	–	–	17th-century style stem
3720	M19	1	–	Possibly	Yes	3	8	12	1640–1670	G6	1660–1680	10.2.9	Small chip from rim. Clean looking bowl but possibly with light discolouration from having been smoked
3721	M19	1	–	–	–	–	8	15	1660–1680	G17	1640–1670	–	Spur fragment only – all bowl missing

3722	M19	–	1	–	–	–	9	–	–	–	–	–	17th-century style stem
3754	K14	1	–	Probably	Yes	2	7	15	1660–1680	G17	1640–1670	10.2.5	Bowl very iron stained but probably with signs of having been smoked
3755	K14	1	–	–	–	–	8	13	1660–1680	G6	1660–1680	10.4.20	Large round heel fragment only – all bowl missing. Quite a long surviving stem (107mm) with a good burnish
3762	K18	1	–	Yes	Yes	2	7	12/18	1660–1680	G6	1660–1680	10.3.13	Bowl has small chips from the rim but a long surviving stem of 193mm. The stem is reasonably straight but has twisted during manufacture so that the seams are at about 45 degrees to the vertical axis where it has broken
3766	L16	–	1	–	–	–	8	–	–	–	–	–	17th-century style stem
3767	L16	–	1	–	–	–	7	–	–	–	–	–	17th-century style stem
3768	L16	1	–	Yes	Yes	Yes	7	15	1660–1680	G17	1640–1670	10.2.3	Only one quarter of the rim survives, with milling, but a marked stem where the botter has dug in deeply
3769	L16	1	–	Yes	Yes	4	8	15	1660–1680	G17	1640–1670	10.2.6	Neat, well-finished bowl form with a flattened base to the spur
3770	L16	1	–	Yes	Yes	1	7	15	1660–1680	G17	1640–1670	10.2.2	Neat, well-finished bowl form with a flattened base to the spur
3771	L16	1	–	Yes	Yes	Yes	7	18	1660–1680	G7	1660–1680	10.3.12	Only half the rim survives, all of which is milled
3772	L16	–	1	–	–	–	7	–	–	–	–	–	17th-century style stem
3773	L16	–	1	–	–	–	7	–	–	–	–	–	17th-century style stem. Joins bowl 3090B
3774	L16	–	1	–	–	–	8	–	–	–	–	–	17th-century style stem
3775	L16	–	1	–	–	–	8	–	–	–	–	–	17th-century style stem
3776	L16	–	1	–	–	–	7	–	–	–	–	–	17th-century style stem
3777	L16	1	–	–	–	–	8	15	1660–1680	G17/18	1640–1680	–	Spur fragment with almost all the bowl missing
3779	L16	–	1	–	–	–	7	–	–	–	–	–	17th-century style stem
3780	L16	–	1	–	–	–	7	–	–	–	–	–	17th-century style stem
3887	L16	–	1	–	–	–	8	–	–	–	–	–	17th-century style stem
3090 A	G14	1	–	Probably	Yes	–	7	15	1660–1680	G17	1640–1670	10.2.7	3090 comprises 2 bowls and 1 stem (A–C added). This bowl (A) has about 2/3 of the rim surviving, none of which is milled
3090 B	G14	1	–	Yes	Yes	2	7	12/18	1660–1680	G6	1660–1680	10.3.16	3090 comprises 2 bowls and 1 stem (A–C added). This bowl (B) has four small mould flaws above the right-hand side of the heel and is from the same mould as 3152. It is also probably from the same mould as 3329. Bowl 3090B also joins with a stem fragment (3773)
3090 C	G14	–	1	–	–	–	7	–	–	–	–	–	3090 comprises 2 bowls and 1 stem (A–C added). This is the stem fragment (C)
3134 A	J10	–	1	–	–	–	7	–	–	–	–	–	One of two plain stem 17th-century fragments with this number (now A and B)
3134 B	J10	–	1	–	–	–	8	–	–	–	–	–	One of two plain stem 17th-century fragments with this number (now A and B)
3677 A	Near Tr3 (J10)	1	–	Probably	Yes	2	7	12v	1640–1670	G6	1660–1680	10.3.11	One of two fragments with this number (now A and B). Both very heavily iron stained. This bowl joins with another iron stained stem, 3708 and is from the same mould as damaged bowl 3161
3677 B	Near Tr3 (J10)	–	1	–	–	–	8	–	–	–	–	–	One of two fragments with this number (now A and B). Both very heavily iron stained. This piece is a 17th-century style stem
Total	–	**30**	**24**	–	–	–	–	–	–	–	–	–	–

Notes
Whether a bowl or stem fragment; whether showing signs of having been smoked or not; whether bottered (Bot); the amount or rim milling (in quarters) to the nearest quarter (M4); the stem bore, in 64ths of an inch (B/64); The Atkinson and Oswald (1969) type number (AO) and date range; the Oswald (1975, General Typology) type number (OS) and date range; the figure number and any comments.
A dash (–) indicates missing or unmeasurable data and a diagonal (/) that milling is present but that the rim is incomplete and so it cannot be given a value.

Table 10.2 The clay tobacco pipes by bowl style and mould type

Pipe style	Figure nos	No. of examples	No. identified to mould type	No. of moulds represented
Spur bowls	10.2.1–7	9	7	7
Heart-shaped heels	10.2.8–10 and 10.3.11	6	6	4
Round heels	10.3.12–17 and 10.4.18–21	14	13	9
Total		**29**	**26**	**20**

generally in good condition with most surviving as quite large fragments with sharp edges, which suggests little post-depositional abrasion. Four stems join with bowl fragments, which suggests little mixing of artefacts on the seabed so complete pipes might be recovered if all fragments were collected.

All 29 bowls are typical of the mid-17th-century forms that would be expected from London and the south-east, so it is highly probable that most came from the Chatham area where the ship had been refitted recently and had taken on its crew. Almost all the pipes were produced in different moulds, suggesting that, rather than being provisioned from a single supplier, they came from a wide variety of sources. Furthermore, almost all show clear signs of having been smoked, indicating that they were likely to have been personal possessions of crew members rather than stores carried on the ship. Three of the bowls were too fragmentary to identify the mould type but the remaining 26 examples represent at least 21 different mould types; a 'mould type' being a unique individual mould used to make the pipe that has been identified from diagnostic features such as bowl profile or small mould flaws in the surface of the pipe (Figs 10.2–10.4). These can be divided into three broad styles of pipe comprising spur bowls, heel bowls with heart-shaped bases, and heel bowls with round or oval bases (Table 10.2).

Seven[1] of the nine spur pipes with bowls present have slightly different-sized bowls and profiles, indicating that they were all produced in different moulds (Fig. 10.2.1–7). Six of the bowls recovered have heart-shaped heels and four different mould types[2] are represented (Figs 10.2.8–10 and 10.3.11). The heels vary considerably in size and plan, from quite a small and compact form (3345; Fig. 10.2.10) to a very large and heavily built type (3677a; Fig. 10.3.11). Like the spur forms, these bowls fall within a common range overall but vary individually in their exact size and build.

The remaining 14 bowls all have round or oval heels representing at least 10 different mould types.[3] One of these mould types can be easily distinguished by its very different bowl profile (3344; Fig. 10.4.21), but several of the others are very similar and can often only be distinguished by a detailed examination of the bowl form and/or mould flaws. The round heel form was clearly the most popular form in use on the ship, with several different moulds being used to meet the demand, and presumably representing various manufacturers.

Almost all of the fragments from the wreck group are from everyday low to average quality pipes for the period and none of them bears a maker's mark. Only one of the fragments (bowl missing) has a burnished surface (3775; Fig. 10.4.20), a finish that was often applied to better quality pipes. Rim milling, which can also be a measure of quality, could be measured on 17 rims (see Table 10.3): no milling (3), quarter milled (2), half milled (7), three-quarter milled (2) and fully milled (3). On average the pipes were only half milled, which, as an indication of the quality, suggests they were of 'everyday' types. The stem bores were predominantly 8/64" (3.1mm; 18 examples), with just one larger example of 9/64" (3.6mm) and 10 smaller examples of 7/64" (2.8mm), giving an average of 7.69/64" for the 17th-century pipe bowls.

One of the pipes (3345; Figs 10.2.10 and 10.5) is one of the most heavily smoked 17th-century pipes ever seen by the author. The stem has been broken short (60mm) but then smoothed off for reuse and smoked subsequently to such an extent that clear tooth-wear marks are visible on the stem. Similarly the rim has been chipped all round from 'tapping out' so that the whole thing has been reduced in height and then ground smooth to produce a new rim. To have become so worn this pipe must have been cherished by its owner and used over a considerable period.

*Table 10.3 Attributes for the 17th-century (*c. *1665) pipe bowls*

Bowl attributes	No. of examples
No rim milling	3
One-quarter milled	2
Half-milled	7
Three-quarters milled	2
Fully milled	3
7/64" stem bore	10
8/64" stem bore	18
9/64" stem bore	1

Bowl form typologies

This closely dated group of pipes provides a rare opportunity to check the range of forms and accuracy of the dating provided by established typologies. The two most commonly used typologies for pipes from London and the south-east are Atkinson and Oswald's London typology (1969,

1. 3346/3371, 3770, 3768, 3348/3372, 3754, 3769 and 3090a.
2. 3343, 3720, 3345, 3677a/3708.
3. 3771, 3762, 3388, 3048, 3090b, 3150, 3348, 3117, 3775 and 3344.

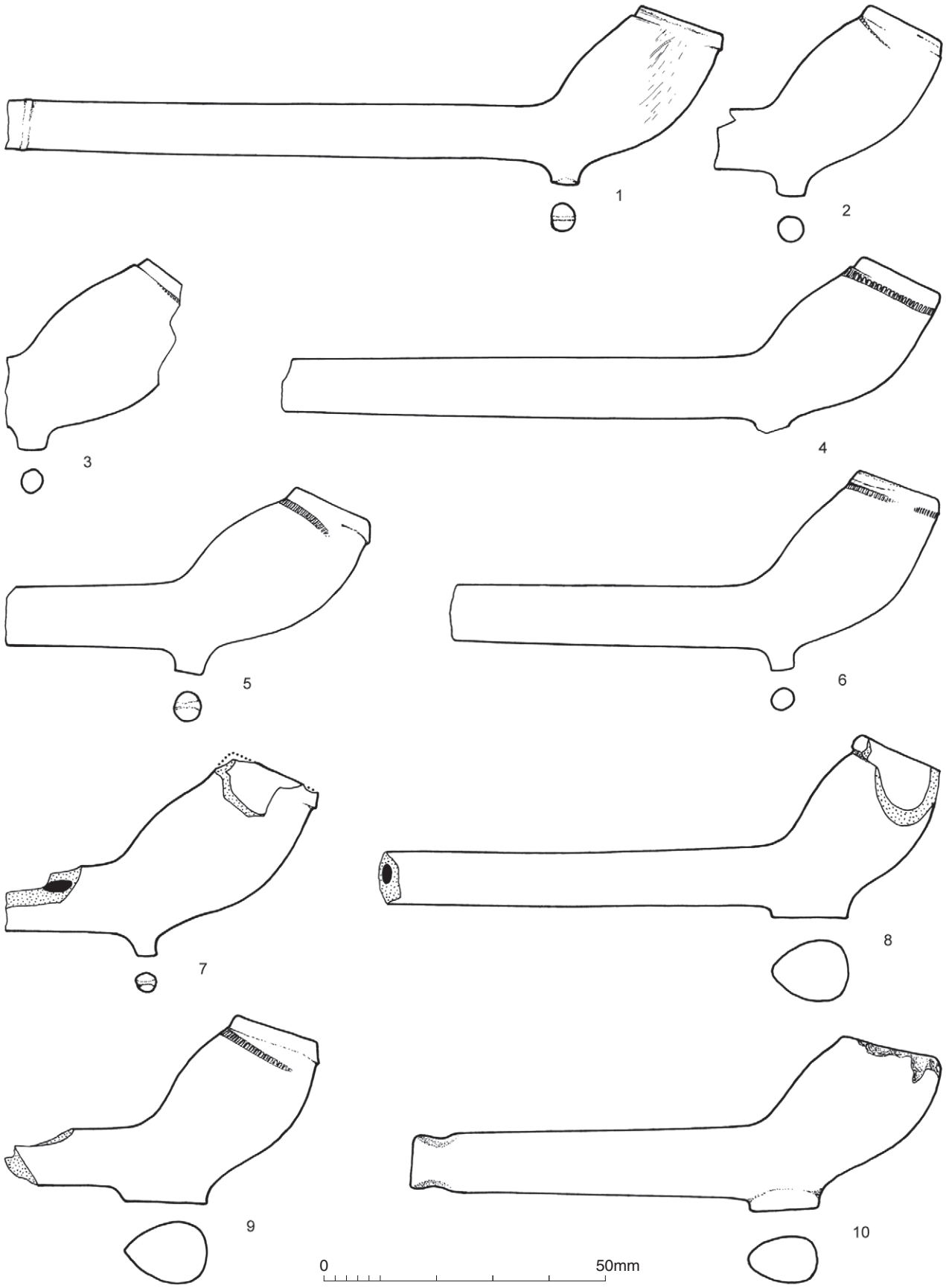


Figure 10.2 Clay tobacco pipes (© Historic England, drawing D.A. Higgins)

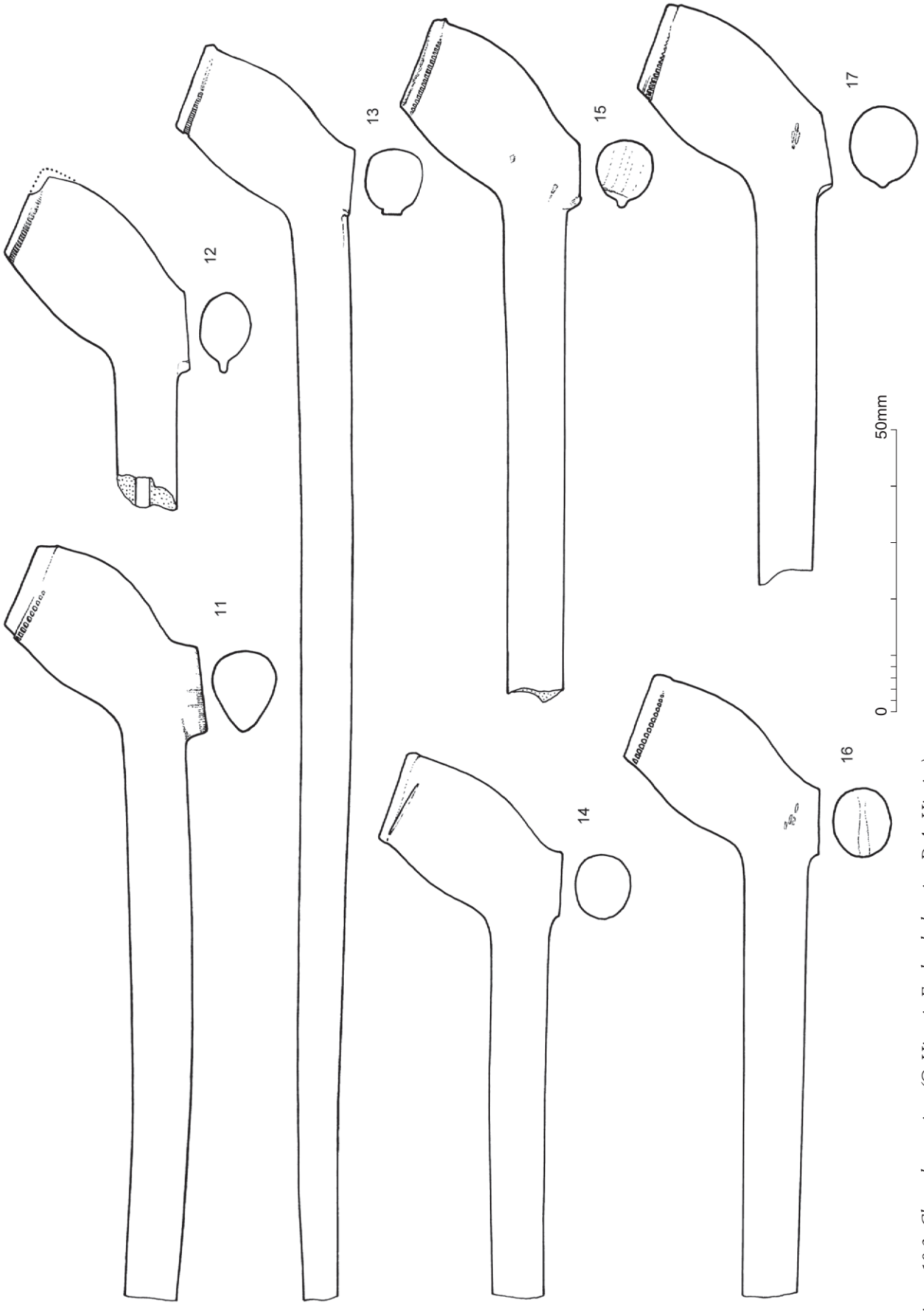


Figure 10.3 Clay tobacco pipes (© Historic England, drawing D.A. Higgins)

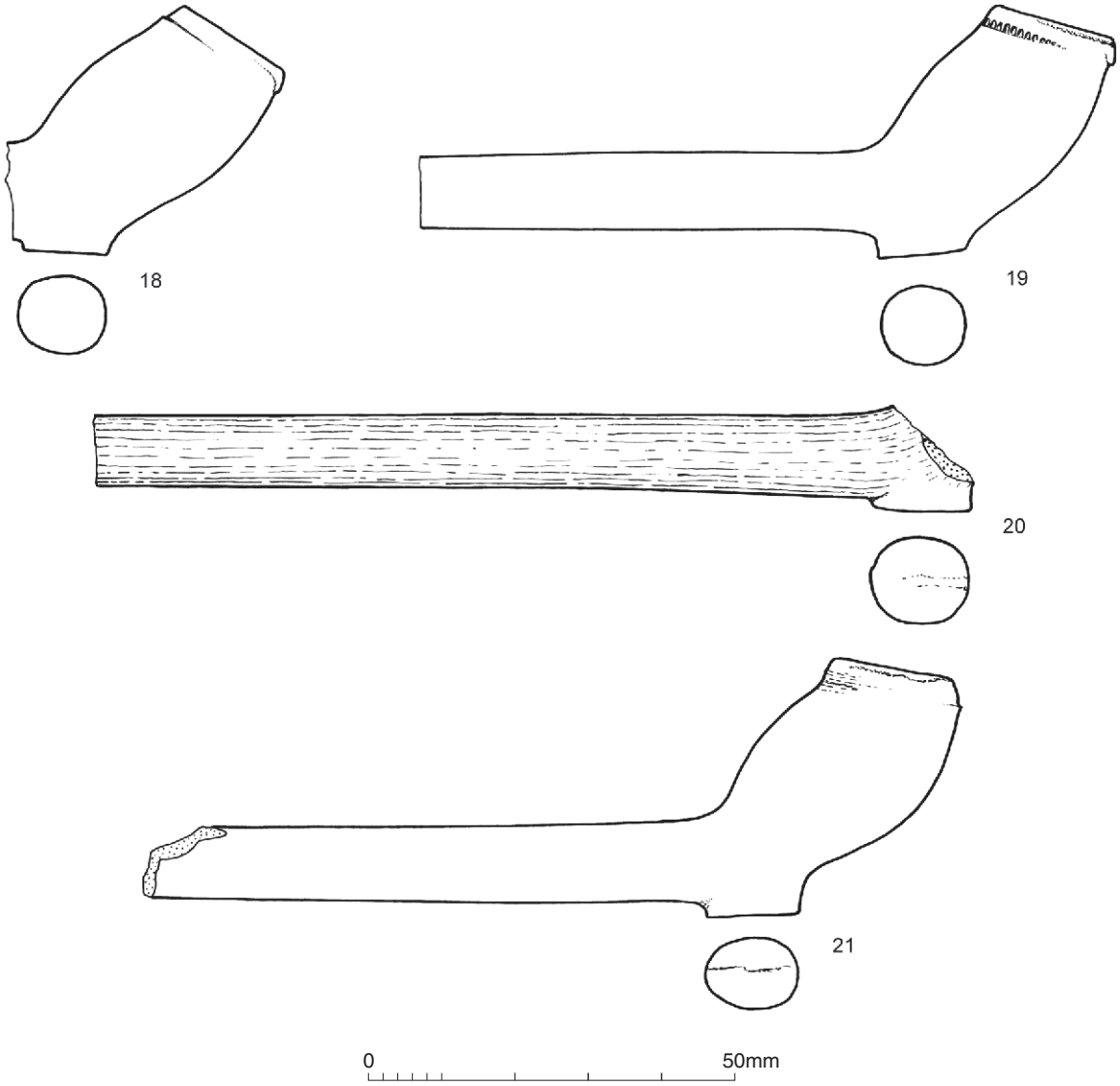


Figure 10.4 Clay tobacco pipes (© Historic England, drawing D.A. Higgins)



Figure 10.5 A broken but reused and heavily smoked pipe (3345; © Historic England, photograph Steven Baker)

177–80) and the 'simplified general typology' published by Oswald (1975, 37–41). Both systems offer around 30 different forms ranging from *c.* 1580 to 1910 and the dates derived from each of these typologies have been added to Table 10.1. The generally accepted convention, followed below, is that type numbers from the 1969 typology are given the prefix AO and those from the 1975 typology OS. While the actual date (1665) for each of the individual bowls from the *London* fell within the date range offered by almost all the forms in both typologies, the overall range for the wreck group as represented by all the dates for the different bowls was quite wide (*c.* 1640–1680 for both systems). There were also some specific strengths and weaknesses that were identified for each system.

In broad terms the 1969 typology was found to be more satisfactory to use. This is partly because the forms in the 1969 typology are much more accurately drawn than those in the 1975 typology, so that they are more realistic and easier to match with actual specimens in the hand, and partly because the forms are not only London based but also offer more sensitivity in matching the various types. In total seven of the 1969 forms were relevant to the *London* group and six of the 1975 forms. Having said that, the more limited range of forms in the 1975 typology made it simpler to pick one specific type to cite as a parallel whereas many of the bowls fell partway between two of the 1969 forms, giving rise to 'AO12/18', etc. The most notable problem in finding an exact match using the 1969 typology was with regard to the barrel-shaped forms with a round heel, the dominant style used for much of the 17th century. In the 1969 typology the early forms of *c.* 1610–40 are represented by AO4 or AO5; the mid-century forms of *c.* 1640–60 by AO10 but the only somewhat similar style offered for the period *c.* 1660–80 is AO13, which has a rather different bowl form with a more constricted 'waist' rather than a barrel-shaped form. This 'waisted' form was certainly found on the wreck (cf. Fig. 10.4.21), but it was the barrel-shaped forms (Figs 10.2.8–10.4.19) that were the most common type and yet these are not represented in the typology. A barrel-shaped form with a round heel form of *c.* 1660–80 could usefully be added to the 1969 series.

Another weakness with both typologies is that neither includes a plan of the heel or spur, which would help, particularly when a heart-shaped heel is one of the defining characteristics of a particular type. The 1969 typology illustrates two types with heart-shaped heels (AO11 and AO12) but the bowl forms are of completely different sizes, even though they are both dated to the same period (*c.* 1640–70). It is suggested that these two forms need to be given their own date ranges and that the overall range needs extending a little later since the *London* examples (Figs 10.2.8–10.3.11) show that the form was still in regular use until at least 1665 and the larger bowl size is otherwise identical to forms dated *c.* 1660–80. It is proposed that the smaller form (AO11) should be dated *c.* 1640–60, which is more in keeping with other forms with a similar bowl size, while AO12 should be dated *c.* 1660–80. The 1975 typology is less precise for this form, especially since it lumps examples with heart-shaped heels together with those with round heels (OS6), so that it is impossible to differentiate the two types if this system is used.

A general weakness with the 1969 typology is with regard to the use of the same period breaks for many of the forms without any overlap. The earliest forms (AO1–3), for example, are all dated *c.* 1580–1610, while the next set are all dated *c.* 1610–1640 (AO4–8). This presupposes that all the pipemakers changed their range of products in exactly 1610 without any overlap of styles. Such a scenario is clearly implausible, especially since the *London* finds show a range of different sized spur forms (cf. Figs 10.2.1 and 10.2.7) and heel forms (cf. Figs 10.3.13 and 10.4.21) that were clearly in contemporary use. This problem was partly addressed by the 1975 typology, whereby forms 1–3 are still given as *c.* 1580–1610 but the next set starts at *c.* 1600–40 (OS4), thus giving an overlap as new styles are introduced. The dating in the 1969 typology could certainly be refined by identifying where these overlaps of style occur and making slight adjustments to the dates accordingly.

The final but related problem with the 1969 typology arises because there are gaps in the sequence for some of the styles. The spur types, for example, progress steadily from *c.* 1610 up to a form of *c.* 1660–80 (AO15) but then there is a gap until *c.* 1690 before the next spur form is described (AO19; *c.* 1690–1710). There is a similar gap in the spur forms between *c.* 1720 and *c.* 1740, and likewise with heel types between *c.* 1820 and *c.* 1840. This issue was largely rectified by the 1975 typology, which bridges these gaps, but with forms that are less precise. So there is certainly room for improving the 1969 sequence by reviewing the archaeological evidence and making sure that all periods where these two basic forms occur are covered by an appropriate type specimen.

In summary, both typologies 'worked' in that the dating for all but one of the pipe bowls included the actual wreck date of 1665 but further refinement should be possible to provide more accurate date ranges for the individual forms represented. The 1969 typology was found to be more sensitive to the different shapes represented and was more satisfactory to use, since the forms are more accurately depicted. It was noted, however, that some additional forms could usefully be added to this series (and others are known, for example, a tall version of AO18, which was a standard form in the London area *c.* 1670–90). Likewise some of the date ranges need to be adjusted to allow for overlapping styles being in contemporary use and to make sure that there are not chronological gaps in the evolution of particular styles. Given the time that has elapsed since these typologies were introduced, and the new dating evidence that had since become available, a new London area typology is now clearly warranted.

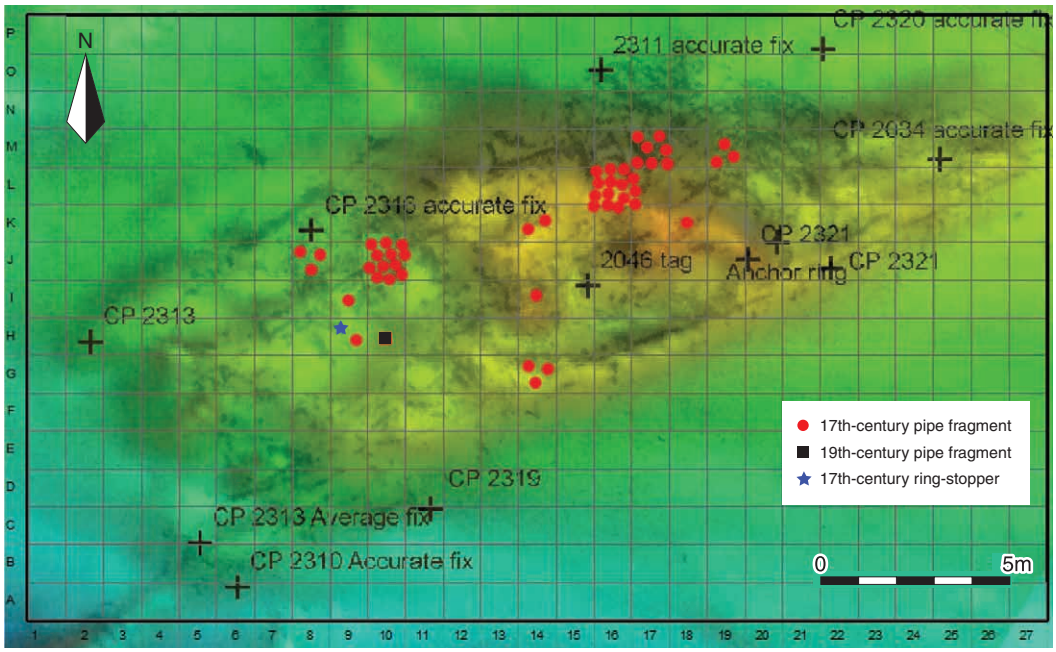


Figure 10.6 Distribution of smoking-related objects across the site (© Historic England)

Distribution of the smoking-related objects

As the majority of the smoking-related objects (51 items) were recovered by the licensee team under the terms of the surface-recovery licence, the exact find spots of all but five have been recorded using the 1m square grid (see Table 10.1; Fig. 10.6). Finds were logged only to the nearest grid square and so the exact placement of the individual find spots is only schematic. Smoking-related finds were scattered across the site, indicating that they were common objects in many parts of the ship, but with marked concentrations. Predictably, almost one third of the objects came from trial trenches T1 (G14 and H14), T2 (I14), and T3 (J10), but there were also marked concentrations in squares L16 and M17, which produced particularly dense clusters of material. One cross-join was found between pipe fragments in squares 5m apart (G14 and L16), which shows that there has been some movement of material across the site.

The excavation of the gun carriage (J10) also produced one of the highest concentrations of pipe fragments, at least six of which had either definitely or probably been smoked, and the ring-stopper was found nearby (H9). It is unclear exactly how much post-depositional movement there has been but it seems that the gunnery equipment found with the gun carriage remained in close proximity to where it had been stationed at the time of the accident.

Social context

The introduction to Europe of smoking in the 16th century had a profound effect on the social habits, material culture and economy of the post-medieval period. Initially tobacco was difficult to obtain and/or very expensive, so smoking appears to have been associated particularly with two social groups: the very wealthy (who could afford it) or the sailors (who had access to it). Although 16th-century pipes are very rare from terrestrial sites, they seem to be found regularly on wrecks of the period, including the Alderney wreck (1592) where both clay and pewter pipes were found (Higgins 1997, 134) and the *San Pedro* off Bermuda (1595), where a pewter pipe was recovered (David 1993, 17).

The particular association between sailors and their pipes seems to have lasted well into the 17th century and to have been very widespread geographically. An Icelander recalled how the first time he saw anyone smoking was on his first voyage from Iceland to England in 1615 (Cederlund 1980, 256) and some of the earliest pipes from Sweden come from the *Vasa* (1628) (*ibid.*, 256). An account of 'Mr Ward's trip to America, in 1669' says of the New England population that 'their mouths stink as bad as the bole of a sailor's pipe, which he hath funked in, without burning, a whole voyage to the Indies' (*The Chester Chronicle*, Issue 12, 17 July 1775). The term 'funked' is the equivalent of the modern 'smoked', while 'burning' refers to the practice of placing a foul pipe in a fire to burn it clean again, the implication being that sailors were prone to using the same pipe for long periods so that it reeked of burnt tobacco.

This reference is very telling, especially in relation to the recovered broken but reused and heavily smoked pipe (3345; see Fig. 10.5). The documentary and artefactual evidence suggests that 17th-century sailors repeatedly used the same pipe, which was offensive to other sectors of contemporary society. The reuse of a pipe with a shortened stem is very unusual amongst terrestrial assemblages of the



Figure 10.7 Wooden pipe stopper (3342; © Historic England, photograph Angela Middleton)

period from England but may well have suited the cramped conditions below decks, as well as being a pragmatic response to the problems of keeping a long-stemmed pipe intact or getting fresh supplies while at sea. Even as late as the 19th century correspondence from a sailor on a naval ship shows that he spent a lot of time on board smoking, despite tobacco costing two and a half times as much on the ship than onshore (Higgins 2017b).

Smoking was a particularly hazardous activity on wooden sailing ships, especially on warships with large stores of gunpowder. In 1628 the Swedish Navy drafted a statute prohibiting smoking anywhere on naval ships, except in the galley (Cederlund 1980, 256). Similar restrictions applied to British ships, with an Admiralty regulation of 1663 stating 'smoking on board ships in the dockyard to be absolutely forbidden and not permitted in ships afloat except over a tub of water' (Woollard 2006, 49).

This regulation was restated in 1673 when the scale of the problem was realised, as pursers were allowing two pounds of tobacco per man per month (Woollard 2006, 49). This substantial amount of tobacco indicates the prevalence of smoking on board ships. The 1673 regulation also indicates that smoking was most likely to have taken place on the forecastle:

> *Commanders of ships taking care that the same [tobacco] be taken at due times over tubs of water in the forecastle or elsewhere in vessels where there are no forecastles, so as may prevent the danger that may arise therefrom, and not otherwise.*
> (Woollard 2006, 49)

The evidence from the *London* clearly shows that smoking was widespread among the crew with pipe fragments, almost all of which had clearly been used, comprising a significant proportion of all non-organic or non-weaponry artefacts recovered. Whether pipes were alight at the time of the explosion cannot be ascertained but they were found in close association with a cannon and other gunnery equipment on what appears to have been one of the gundecks. How well the Admiralty regulations were enforced is unclear but with more than 300 men on board, most of whom probably smoked, it would appear not very strictly, especially as no officers were present at the time. Something clearly set off the gunpowder, leading to the loss of this ship and the evidence for widespread smoking on board certainly provides one of the most obvious sources of ignition that could have led to this disaster.

The pipe stoppers

Two pipe stoppers (3342 and 3040), another of the smoker's essentials, have also been recovered. In English, from the early 17th century onwards, these items were known as 'stoppers' but some recent authors, especially from America and the Portable Antiquities Scheme (PAS), refer to them as 'tampers'. They were used to compress the tobacco to the correct density for effective smoking. These two are particularly important archaeologically, not only because so few have been recovered from sound archaeological contexts but also because these are two of the earliest securely dated examples and one was made from wood that does not survive normally in other environments. The wooden stopper (3342; Fig. 10.7) was noted as having been found with clay pipes, while the brass ring-stopper was recovered from an area with a concentration of pipes (grid square H9; Fig. 10.8). The precise origin and form of the earliest stoppers is uncertain and the subject has not been well researched.[4] The examples from the *London* are therefore of crucial importance, since they provide closely dated examples against which stoppers found elsewhere can now be assessed.

Background

It is assumed that some form of stopper was used soon after the introduction of smoking to Britain at the end of the 16th century. By the early 1620s Dutch tobacco boxes had an integral stopper (Leslie 2012), a feature sometimes found also in England on 17th-century smoker's tongs (Lewis 1978). Separate high-value stoppers were certainly

4. Several 19th to mid-20th-century notes focus on a collector's or art historical perspective, with little regard for establishing the typology, chronology or distribution patterns of the various types. More recent studies have been hampered by the small number of extant examples in museum collections (Forsyth 1992, 35), while very few examples made before 1750 are dated securely (Leslie 2012, 7). As a result many stoppers can only be dated by general analogy and examples on the PAS database (https://finds.org.uk) have been given wide (and often differing) date ranges in the absence of closely dated parallels (see below).



Figure 10.8 Brass ring-stopper. The detail of the seal matrix is shown at twice life size (3040; © Historic England Archive, photograph James O. Davies, © Historic England, drawing D.A. Higgins)

being used in England by 1632 when a sub-standard piece was 'broken' by the Goldsmiths Company (Leslie 2012, 31). Most examples, however, would have been made of much cheaper materials,[5] and many were probably homemade, like those made from wood taken from the famous Glastonbury Thorn in 1649,[6] or even improvised.[7]

What is certain is that by the 1640s a 'tobacco stopper' had become such a commonplace object that the term was included in a 'Vocabularie of common-words English and Latine' (Hoole 1649, 167). Surviving examples (Leslie 2012) show that they were made in a bewildering variety of different materials and forms, although the very fact that the illustrated examples have survived to form the basis for his recent study suggests a bias towards 'special' rather than 'everyday' examples. The archaeological record is biased towards those made of durable materials, while there is an inherent bias in those recovered by metal detectorists. Fairholt (1859, 235–6), however, notes that 'many cheap tobacco-stoppers were cut in hard wood, some few in mahogany; but by far the greatest number were cast in brass'.

Cast copper-alloy stoppers are thought to have appeared by the early 17th century. Fairholt (1859, 233) cites a stopper decorated with a soldier in the half armour of James I or Charles I as the earliest he had come across. A similar example from Meols on the Wirral was considered 'old' when found in the mid-19th century, while others with a soldier design have been recovered from early American sites, such as Jamestown (founded 1607) and Flowerdew Hundred (founded 1619; Higgins 2007, 269). Leslie (2012, 6–11) illustrates an example decorated with a Tudor rose and

5. A 'woodden [sic] Tobacco-stopper with a face upon it' is alluded to in 1648 (Anon 1648, 5).
6. 'I did take a dead Sprigge from it, wherewith I made two or three Tobacco stoppers, which I brought to London' (Taylor 1649, 6).
7. For example, by using a piece of broken pipe stem – 'as any Gentlemen can make Tobacco-Stoppers at a Coffee-House, by breaking of whole Pipes' (Hodges 1694, 11).

describes others with a series of Royalist or Parliamentarian motifs, which must originate in the political turmoil of the 1640s and 1650s. The satirical religious stoppers described by Forsyth (1992) are likely to originate in the same period and show that a wide variety of different copper-alloy designs were already being produced by the mid 17th century. These early examples provide parallels for the form of the stem of the stopper itself, even if the decorative motif at the top differs.

Ring-stoppers can, therefore, be seen as just one of a wide range of forms that were being produced by the Civil War period. One is described as 'a ring-stopper, to be worn upon the finger as an ordinary ring, the stopper concealed in the hand; it can thus be easily turned round for use when required, and does not run the risk of being lost or mislaid by the smoker' (Fairholt 1859, 234). This type of stopper remained popular for some time, with two examples being depicted in William Hogarth's *c.* 1730 painting *A Midnight Modern Conversation*. One of the figures wears a stopper on his little finger, while another has one on his index finger. Ring-stoppers may have remained popular well into the 18th century (Fresco-Corbu 1961, 1345).[8]

Description

The ring-stopper from the *London* (see Fig. 10.8) was made as a single-piece brass casting, with traces of the mould seams visible along the sides of the object. It weighs 7.6g and has an overall length of 44mm. The ring section has an internal opening that is almost perfectly circular, measuring 18.3mm by 18.4mm. The bezel has a flat surface 14.8mm across and 13.2mm deep that has been engraved with a bird motif within a serrated octagonal border. The edge of the bezel has been shaped slightly to mirror the octagonal shape of the seal matrix and one shoulder has facets reflecting this shape while the other does not. The hoop has quite thin sides and a maximum external diameter of 21.5mm. The stopper itself is cast as one with the ring and projects 23mm from the hoop, opposite the bezel. It has a ribbed collar top and bottom but the main part of the stopper is of a smooth but slightly flaring form. The end of the stopper is smooth and round, with a diameter of 7mm.

The wooden stopper has not been seen by the author as it was still in conservation (see Fig. 10.7). The 'working end' of the stopper comprises a plain slightly flaring section just under 23.4mm in length and now broken from the head, which is carved in the shape of a small casket or urn that is 30.5mm wide and rectangular in plan. Overall it would have been about 55mm in length when complete, with the stopper end being 10.6mm across. The end of the stopper is discoloured a mottled greyish/black, which probably represents charring from use.

Discussion

There are so few pipe stoppers from controlled archaeological excavations that it has proved impossible to find any other similar excavated examples of a ring-stopper from Britain with which to compare the *London* example (see Fig. 10.8). There are several parallels in antiquarian or collector's literature, but these are unprovenanced pieces and by far the best source for comparison is the PAS database.[9] Various different types are represented, most notably later forms where the stopper section would have unscrewed to reveal a pricker or corkscrew within.

Some forms had bezels formed as a separate disc sitting above and projecting out from the shoulder or where the stopper terminated in a wide flaring end. Other forms recorded elsewhere include examples where the ring is surmounted by a three-dimensionally modelled head or animal (D. C. C. 1909), where the ring is formed as a plain hoop without a bezel (Everest n.d. 316) or where the hoop itself was ornately decorated (MacKay 1970). All alternative forms have been rejected as representing different 'types', even though some include otherwise identical details.

This is especially true of some of the examples with a distinctive flared end to the stopper, which are probably contemporary with the *London* example, the only material difference being that they have a stopper end of nearly twice the diameter of the shaft. This is important to note, since some writers have suggested that the size of the stopper was related to the date of the pipe, because bowl size (and rim diameter) grew steadily during the course of the 17th century.

This argument, however, seems to miss two points; first, that all pipe bowls taper internally, so no one diameter would fit any given bowl at all depths and, second, that the purpose of the stopper was simply to compress the tobacco, so it did not necessarily need to fit right across the bowl interior. The very small end of the London stopper (7mm) is much smaller than the rim opening of the pipe bowls found with it (12.3–13.8mm), and different from the 10.6mm end of the wooden stopper from the same assemblage. In short, it is unlikely that the end diameter of a stopper can be used as a reliable indicator of its date.

A total of 24 examples were found to be closely comparable with the *London* find (Table 10.4). From this it is possible to identify a specific style of ring-stopper that the *London* example represents and to define its characteristics.[10]

The *London* example belongs to a group of copper-alloy ring-stoppers that have been cast in one piece. They are characterised by a narrow smooth-sided stopper shank that flares slightly towards its end, which has a small base of around 7mm in diameter. There is also a ribbed collar

8. These later forms, however, often had a fairly cylindrical stopper section that unscrewed to reveal either a pipe pricker for cleaning tobacco from the base of the pipe bowl or a small corkscrew, which presumably also doubled as a pipe reamer.
9. This was searched in August 2016 for the term 'ring tamper' (since the database does not use the term 'stopper'), which resulted in 82 entries.
10. One particular problem encountered in using the PAS database was that not all of the stoppers had been photographed or relevant views taken. This was particularly true of Norfolk, where none of the stoppers had been photographed. This made it very difficult to compare them in detail with the other finds and impossible to assess features such as the style of the matrix design – particularly frustrating when one of them was a bird, which may have been similar to the *London* example.

Table 10.4 Ring-stoppers from the Portable Antiquities Scheme (PAS) database that are comparable to the London *example (extracted 14 August 2016)*

County	Parish	Object	Date	Height (mm)	Weight (g)	Motif	Matrix Design and/or Comments
Berkshire	Shawcum Dennington	8ERK-3D2281	1650–1800	43.25	8.4	EB	Very corroded but motif appears to be ES(not retrograde) with scroll/stylised fleur-de-lys above and below within an oval border – possibly beaded
Cambridgeshire	Water Newton	PA5-68CA73	1600–1699	43	–	(not recorded)	'A 17th-century AD pipe tamper with a seal matrix attached to the distal end. This has been constructed from a signet ring with an inlaid intaglio'. No image or description of the matrix
Cheshire	Lower Withington	LVPL-380087	1600–1700	(127)	(4.0)	monogram	Ring only survives plain circular junction with stopper. Monogram too corroded to decipher
Essex	Thorpe-le-Soken	8H-62F267	1600–1800	(26.3)	(S.24)	RH	Initials RH flanking a plant motif within a border – very corroded and with the stopper broken off
Flintshire	Brynford	LVPL-21D28D	1600–1700	(126.52)	(4.6)		Only the stopper section survives – very corroded
Hampshire	Abbotts Ann	HAMP2195	1650–17S0	42.5	–	castle	Castle with central gateway and three towers, flying flags, within a serrated oval border
Kent	Dartford	KENT-6687C8	1600–1800	45.67	–	Rampant lion	Rampant lion within an oval border (?serrated). A stopper of the same form and with a similar rampant lion motif with in a possibly serrated border (but the lion facing right) was found at the Cordea's Hope site in St Mary's City, Maryland
Kent	Trottisclilfe	KENT4306	*c.* 1680	44	–	EH	'EH with floral motif and acorns' – no image taken and no detailed description of this example other than 'Copper alloy ring "seat matrix" pipe tamper'
Lincolnshire	Owersby	SWYOR S2F821	1650–1700	43	7.16	acorn	Acorn with attached leaves within an octagonal border
Norfolk	Hoe	NMS-FS354S	1650–1750	41.5	–	anchor	'A worn and corroded post-medieval copper alloy combination pipe tamper and signet ring. D-sectioned hoop with a flat ovoid bezel/matrix: within a border an anchor. The tamper is oval-sectioned and has a moulded collar above the oval- sectioned shank with expands slightly towards a terminal disc with radial groove. Bezel measures 6.5mm x 6mm. Internal diameter of ring19mm. Length 41.5mm. Second half 17th–first half 18th century.' No image taken
Norfolk	Marham	NMS-1AFFD6	1600–1700	48	–	SI	The seal matrix 'depicts a heart pierced by an arrow between the letters S (retrograde) and I (with a mid-stem cross bar).' No image taken
Norfolk	Trowsewith Newton	NMS-8A2203	1650–1800	40	–	bird	'The shank of the tamper is hexagonal in cross-section between a double collar at the top and single one at the base above the convex terminal. The hoop of the ring is D-sectioned and its bezel octagonal. The matrix depicts a standing bird with a sprig in its beak.' No image

Table 10.4 Continued

County	Parish	Object	Date	Height (mm)	Weight (g)	Motif	Matrix Design and/or Comments
Norfolk	Wicklewood	NMS·D2E8A7	1650–1750	43.5	–	HC	Entry states, 'post-medieval copper alloy pipe tamper incorporating a signet ring with an oval bezel, HC with sprigs above and below. Length 43.5mm. Bezel 16mm x 13.5mm. Pad at base 7.5mm x 7mm. External and internal diameters of ring 21mm and 18.5mm. *c*. 1650 – *c*. 1750.' No image taken
Somerset	Limington	SOM-1556F1	1650–1850	44.44	8.36	FE	Initials FE flanking a plant motif within a dotted oval border
Somerset	Nether Slowey	SOM-6DB705	1650–1750	(31.9)	(2.78)	–	Stopper section only survives – very corroded
Staffordshire	Fradswell	WMID-2FBBS1	1650–1850	(47.1)	(5.9)	–	Bezel missing and sides bent up, distorting height. Very corroded
Surrey	Ewell	SUR-243678	1550–1650	(26.03)	(5.64)	EG	Initials EG (not retrograde) with eight arm star above and below within a plain oval border
Surrey	Worplesdon	SUR-SAOAOC	1600–1700	(25.91)	(4.99)	RI	Initials RI flanking a plant motif within an oval dotted border
West Sussex	Patching	SUSS-373EAS	1600–1700	45.2	10.04	RT	RT with foliage spray above and below within a serrated oval border
Wiltshire	Wootton Bassett	WllT-88DAC7	1650–1725	46	9.15	WH	Mark recorded by PAS as 'The bezel has 'HW' or 'MH' surrounded by an oval following the edge of the face', but the photo suggests the mark should be read as WH (assuming the letters are retrograde). The letters and surrounding oval border are formed of numerous small punched dots
Worcestershire	Shrawley	WAW-416CAS	1600–1700	42.44	7.3	harp	Harp within an octagonal serrated border – the harp possibly crowned (obscured by dirt). An almost identical design (crowned harp flanked by two dots on each side within a serrated octagonal border) was illustrated by D. Stuckey and J. Evan-Hart in *Treasure Hunting*, September 1999, 45
Yorkshire	Conistone with Kilnsey	SWYOR-4BBAD6	1600–1700	41.4	5.79	pierced heart, crowned	Heart pierced by crossed arrows, crowned, within an oval line border. Stopper is similar to The *London* example, except it only has one groove to the top and bottom rather than two
Yorkshire	Hatfield	SWYOR-DOA4Fl	1600–1700	42.22	9.22	seven stars	Matrix comprises seven stars within an oval serrated border. Very similar form to The *London* example
Yorkshire	High Hoyland	SWYOR-783C60	1600–1800	42.5	5.23	bird on branch	Matrix image very corroded but described as 'The matrix design appears to be an image of a bird stood on a branch, possibly wings raised behind it.' Image possibly shows a bird with a long neck such as a swan, with 'ground' beneath it, rather than a branch

top and bottom of this section, usually with two or three ribs. The stopper shank is almost always circular in section, although one example is hexagonal. The hoop itself is finely cast and the shoulder merges into a broad, generally oval, bezel, which is usually engraved.

The designs are invariably set within a border that is usually beaded or serrated, most frequently oval but sometimes octagonal. Just under half the engraved designs are symbols and these cover a typical range of subjects for the period, including heraldic, religious and nationalistic motifs. These symbols seem likely to be 'stock items' that would have been available for customers to choose from, particularly since very similar examples occur. For example, the rampant lion motif from Dartford in Kent is very similar (although reversed) to an example excavated at the Cordea's Hope site in St Mary's City, Maryland, and the crowned harp from Shrawley, Worcestershire, is very similar to an unprovenanced example (Stuckey and Evan-Hart 1999, 45).

The remaining stoppers all have initials on them, all of which are set within an oval border made up of either a beaded or serrated line. The initials are usually accompanied by other decorative motifs, most often foliage-like motifs between the letters but in one instance stars above and below the letters. The style of the lettering and accompanying motifs is very similar to that found on pipemakers' stamps of mid- to late 17th-century date, particularly from Yorkshire (cf. White 2004) and this provides a probable date range for these stoppers. These examples were presumably customised for the purchaser and represent the owners' initials. They are usually professionally executed although in one case (Wootton Bassett, Wiltshire) they have been crudely picked out with a series of punched dots, suggesting a 'home made' version. Most of the initials are reversed, so that the ring can be used as a seal, but in a few instances the initials are the correct way around.[11]

The very close similarity of these pieces in form, detail and finish suggests that they were probably made at just a few production centres (possibly just one) and that they are likely to have a limited chronological range.[12] Their distribution, however, is very wide with examples scattered across the country from North Yorkshire to Somerset and from Lincolnshire to the Welsh borders. There are also colonial examples, such as the stopper from Maryland referred to above. This suggests that these small and easily portable objects were widely disseminated as part of a shared contemporary British culture so that regional forms did not develop in the same way as with the more fragile pipes themselves.

The *London* example now provides a fixed date of 1665 when this particular type of stopper was in use. The stopper section itself is very similar (almost cylindrical and with a ribbed collar at each end) to one surmounted by a Tudor Rose, which Leslie (2012, 7) considers to be one of the earliest surviving examples, and it is certainly similar to others that are thought to date from the early 17th century. The dating of these early stoppers is, however, very speculative and smoking only became common across the country from the 1620s onwards when the price of tobacco fell dramatically. Given the evidence for various forms of copper-alloy stopper being current during the Civil War period it seems reasonable to suggest that ring-stoppers of this specific form had probably appeared by about 1640.

At the other end of the chronological range, the style of the initials flanking a plant-like motif is not found on pipe marks after *c.* 1720, with the majority of the examples dating from before *c.* 1700. Based on this admittedly somewhat thin evidence, plus the firm date provided by the *London* example, it is suggested that this particular class of ring-stopper can now be dated provisionally to *c.* 1640–1720 overall, with the second half of the 17th century (1650–1700) being the period during which most examples are likely to have been made.

The wooden stopper (see Fig. 10.7) is even more difficult to parallel, since wood rarely survives in the archaeological record and the majority of early wooden stoppers that do survive have only been preserved because they are fine works of art in their own right. Although the *London* example is nicely carved, it is an 'everyday' example and the sort of item that could just as well have been produced by a sailor in his idle time as by a craftsman for the local market stall. It is a rare survival but one that illustrates the assertion that 'many cheap tobacco-stoppers were cut in hard wood' (Fairholt 1859, 235–6).

The two stoppers from the *London* are clearly important, both for the close dating that they provide and for the insight they provide into the accessories that would have been carried by the mid-17th-century smoker. Clay pipes survive well in the ground and are found in huge numbers because they were so cheaply produced and readily disposable. In contrast each smoker might have possessed only one or two stoppers, so they would have been cherished objects. They are more likely to have been lost than intentionally discarded and their subsequent survival depends on the burial environment. The wreck has acted as a 'time capsule' preserving objects and their associations in a manner that is almost impossible to find on terrestrial sites. These wood and metal stoppers were personal items that would have been carried by almost every smoker at the time and now provide a rare glimpse into the culture and possessions of the everyday 17th-century smoker.

11. These examples recorded on the PAS database range from 40 to 48mm in height (but typically 42–44mm) and weigh between 5.23g and 10.04g.
12. The dates given for this particular style of ring-stopper in the PAS descriptions range from 1550 to 1850, which seems far too broad for such an apparently discrete group of objects – although many of the dates are just broad period attributions in the absence of any better dating evidence.

Chapter 11
Small Finds

Jörn Schusters

A total of 376 individually registered items was examined, although the number of objects they represent is marginally lower as some items, recorded separately, belong to the same object, e.g. the syringe fragments (3394–6) or (conversely) the lump of coins. Objects were examined visually and, where required, with hand lenses (x4, x8 magnification). Basic type identifications such as 'coin' or 'shot' were recorded. X-radiographies were available for a selection of finds during analysis. Object identification, measurement and detailed descriptions were entered into an MS Excel spreadsheet (available in the archive). The small finds considered here are arranged in an amended version of the groups of functional categories devised for the classification system for the analysis of the finds from the *Mary Rose* (Gardiner with Allen 2005, 5–6). A breakdown by material and functional category of all finds is shown in Table 11.1 and the discussion will follow this sequence. Not every item belonging to a given category, however, will be considered in this chapter as certain types of objects, for instance the cannon and most nautical and navigational items, were examined by other specialists. For this assessment, the objects were grouped according to use (see for example, Chapter 7, Pascoe *et al.*):

- commerce and metrology include a gunmetal disc weight (and coins);
- domestic items include a screw-cap spout, a jug handle, a neck fragment and seven spoons;
- medical items include a probe and a urethral syringe;
- nautical items include two deadeyes and a fairlead or bracket;
- navigation items include four brass navigational dividers and a lead sounding weight;
- personal items include a sundial compass and brass lid, two brass pins, a pewter button, an ivory comb and a pewter chamber pot;
- equipment (including tools) includes a bone handle for a knife or tool, a hammer, a copper-alloy ring or washer, a probable lead ingot, 12 pieces of lead patch as well as one roll of lead sheet;
- weaponry includes 326 items only 6 of which are not lead shot, including a probable pistol handle butt plate, two pairs of brass wing calipers, a brass priming iron and a large iron ring; and
- objects of uncertain use include a copper-alloy strip, a lead bar and a 70mm-long concretion.

Commerce/metrology

The only object in this category, apart from the coins (see Chapter 14, Marsden and Rankin), is a gunmetal disc weight (3072; Fig. 11.1) from grid square J11. The weight is made of a copper alloy called 'caldarium', a leaded antimony bronze (Ströbele and Schuster 2019, 21). The weight has a raised rim with six concentric lines arranged in three double lines around a central pivot spot. A central casting sprue scar, several concentric flat ridges and pronounced filing marks are visible on the back but there is no verification or other marks. Some filing marks may relate to an adjustment of the weight, as was suggested for the lead balance pan weights from the Duart Castle wreck (1653), whose weights bear official stamped markings that guarantee their mass (Martin 2017, 224, fig. 302).

The *London* disc weighs 193.7g, which is 3.8% more than the standard weight of half a Troy pound (186.6g) or six Troy ounces (Egan 2010, 302, table 14). The number of concentric lines on the obverse of the weight may be of significance, as suggested by Crawforth-Hitchens (2005, 331–2, figs 8.32–8.33) in her discussion of the disc weights from the *Mary Rose*, although in that case the number of rings does not tally as closely to the probably intended weights as would be the case with the *London* weight. Another very good morphological comparison is a trade weight from the *Winchester* (built 1693; wrecked 24 September 1695) stamped with the number '14' near the central pivot spot.[1] While no measurement of that weight is presented, it could equate to a Bruges pound of 435.5g (14 Troy ounces of 31.1g; cf. Egan 2010, 303, table 14).

1. http://britishwarship.com/component.numo?module=shopping_cart&component=images&pid=24 (accessed 4 June 2019).

Table 11.1 Number of object records per material and functional category (following Gardiner with Allen 2005, 8, table 1.1 with amendments)

Functional category	Copper alloy	CuA & glass	Pewter & CuA	Pewter	Lead	Iron	Wood/ Iron	Ivory	Wood with concretion	Total
Commerce	1	–	–	–	–	–	–	–	–	**1**
Domestic	2	–	–	8	–	–	–	–	–	**10**
Medical	1	–	1	2	–	–	–	–	–	**4**
Nautical	1	–	–	–	–	–	2	–	–	**3**
Navigation	4	–	–	–	1	–	–	–	–	**5**
Personal	3	1	–	2	–	–	–	1	–	**7**
Tools/equipment	1	–	–	–	14	–	1	1(?)	–	**17**
Weaponry	3	–	–	–	321	1	–	–	1	**326**
Uncertain	1	–	–	–	1	1	–	–	–	**3**
Grand total	**17**	**1**	**1**	**12**	**337**	**2**	**3**	**2**	**1**	**376**



Figure 11.1 Gunmetal disc weight (3072; © Historic England Archive, photograph James O. Davies, © Historic England, drawing Aleksandra Osinska)

As the *London* disc weight appears to be closer to the Troy standard, it is possible that it is a trade or coin weight used by the purser rather than a powder weight, as the avoirdupois standard was used for the measurement of bullet calibre and powder (Foard 2008, 100; 2009, 6). What cannot be discounted, of course, is the possibility that a measure of powder weighed with this weight achieved a specific desired range in a particular gun.

Domestic objects

Spoons

Both the copper-alloy spoons (3056 and 3122; Fig. 11.2) are made of brass which, by the 17th century, had become the predominant copper alloy used for small or portable objects (Dungworth 2002, 9, fig. 6; Ströbele and Schuster 2019, 15). The two spoons had originally been tinned but only tiny spots of this are now visible on their largely corroded surfaces (Ströbele and Schuster 2019, 16–7, 19, 25). Both have oval bowls and flat hexagonal stems with a straight end and no knop ('slipped in the stalks' stem), suggesting that they belonged to a form that had been dominant since the beginning of the 16th century but was about to go out of fashion by the time of the *London*'s demise (Hilton Price 1908, 8). The use of brass for the two spoons is also less surprising, since the prohibition of the use of brass ('latten'), enforced by the Pewterer's Court at various stages during the 16th century, appears to have been relaxed during the first quarter of the 17th century (*ibid.*, 11–13). The more oval rather than fig-shaped form of the brass spoons' bowls is similarly commensurate with them being rather late in the development (Jackson 1892, 135–6). One spoon (3056) has a circular touchmark inside the bowl just below the junction of the stem, depicting within a beaded circle three spoons on a belt or a band with the letter 'G' at one end and 'I' or, more likely, 'P' at the other (Fig. 11.2). The other brass spoon (3122) had probably been stamped with the same mark but it is not as well preserved and only the letter 'G' and one of the spoons is still discernible (Fig. 11.2). The 'spoonsmark' was widely favoured by latten spoon makers, and there are no pewter spoons with 'spoonsmarks' before the middle of the 17th century (Hilton Price 1908, 18). While there are no three-spoon marks recorded with the letter combination 'G I', there are numerous records for 'G P' on various types of latten spoons ranging from the later 16th to the mid-17th century *(ibid.*, 37, 42, 45, 50, 59). The fact that the two brass spoons have similar compositions and were both tinned suggests they were made by the same manufacturer (Ströbele and Schuster 2019, 25).

The five pewter spoons all have more or less hexagonal stems of varying thickness and 'slipped in the stalks' ends, although the typical slanted end is not very pronounced in any of the examples. There is more variation in the shape of the bowls (for an overview of shapes see Egan 2010, 246, fig. 191). One spoon (3600), made of fine pewter (Ströbele and Schuster 2019, table 1), is the only one with a fig-shaped bowl, the dominant form from the 15th to the mid-17th century (Pearce 2016, 194), and the only one of the five pewter spoons which has a touchmark (Fig. 11.3). This is only visible on the X-radiograph and illegible due to corrosion pustules; however, it is just possible that it might have been a three-spoon mark based on the corrosion pattern of dimples and smooth areas where one would expect the bowls and stems. Even if the touchmark had been readable it is unlikely that it could have been linked to a known London pewterer as all the touch plates perished during the Great Fire of London (Cotterell 1929, 37), 18 months after the explosion of the *London*. An owner's mark, consisting of the letters 'B' and 'A', was stamped above the mark (bowl at top), suggesting that the spoon's owner was not married, at least at the time when the initials were applied. Had the owner been married, the initials would have been arranged in a triangle, with the letter 'A' for the surname at the top, the initial for his first name would still be on the left, while the initial of his wife's first name would have been on the right (*ibid.*, 53–4).

Two spoons have more or less round bowls, which is certain for one (3032; lead alloy pewter; Fig. 11.3), whose bowl is slightly bent, and likely for the other (3153; fine pewter) where most of the bowl is missing. Twelve similar spoons, apparently a form common on Dutch wreck sites, were found in the wreck of the flute *Lastdrager* lost off Yell, Shetland, in March 1653 (Sténuit 1974, 222, fig. 4.2), but they are also known from terrestrial sites, for instance from a mid-17th-century tavern context in Southwark (Pearce 2016, 194, 198, fig. 14, 39). The damaged bowl of a fine pewter spoon (3430) is only slightly less round but better described as oval (Fig. 11.3).

One spoon (3099) has a long-oval bowl and flat hexagonal-sectioned stem widening slightly to the straight end with slightly bevelled corners (Fig. 11.2). The bowl and stem are indicative of the so-called Puritan spoons that were fashionable in the mid-17th century (Hilton Price 1908, 41, fig. 25).

The absence of wooden spoons can be explained in a number of ways; there might not have been any on the ship or they could have floated away when the ship sank, as suggested to explain the small number of wooden spoons from the *Mary Rose* (Weinstein 2005, 449). Alternatively they might not have survived or might have been on part of the ship that has not yet been excavated. The excavations, however, produced large numbers of other wooden implements adjacent to the area where some of the pewter (3032 and 3099) and brass (3122) spoons were found.

The typological differences indicate that the seven spoons were not from a set of spoons issued to the crew, as has been suggested for some of the pewter spoons from the *Lastdrager* (Sténuit 1974, 221–2). It is more likely that the spoons were personal items and that the situation described by Pitt-Rivers for the 16th century persisted for the lower echelons of society:



Figure 11.2 Brass and pewter spoons (3056, 3099 and 3122; © Historic England Archive, photograph James O. Davies, © Historic England, drawing Aleksandra Osinska)



3032



3430



3600

Figure 11.3 Pewter spoons (3032, 3430 and 3600; © Historic England Archive, photographs James O. Davies)



Figure 11.4 Threaded screw-cap spout (3043; © Historic England, photograph Angela Middleton)

> *Throughout the sixteenth century everyone carried his own knife about with him, and it was very often hung at the girdle, the handle being perforated for suspension … Knives and spoons were the only implements for eating purposes in England, and rules were given for good manners in taking a piece of meat from the platters, and putting it into the mouth with the fingers.* (Pitt-Rivers 1890, 16)

The absence of evidence for knives on the wreck is perhaps a little more surprising (C. Martin pers. comm.).

Vessel fragments

Screw-cap spout

A screw-cap spout (3043)[2] with a wide double flange and an external thread of three turns is likely to have been part of a so-called 'case bottle' (Fig. 11.4). Several such screw-caps were recovered from the *Lastdrager* where they were found in close association with puddles of quicksilver (mercury) (Sténuit 1974, 240–1, fig. 21). Many examples from the *Lastdrager* still had fragments of green glass attached to them, presumably from the bottles they once capped. Although the corrosion products of some of the *Lastdrager* bottles also contained minute droplets of mercury, Sténuit remains uncertain as to their contents, suggesting that it was more likely some spirit rather than wine. Such tops are reported from many wrecks of the period, in particular Dutch East India Company (VOC) ships (for a list see Martin 2017, 197, ill. 265, 126), and examples from the *Elizabeth and Mary*, wrecked in Baie-Trinité off the Quebec coast in 1690, demonstrate their continued use towards the end of the century (Ringer 2008, 33, fig. 55). There is, however, ample evidence from the Netherlands illustrating that these square case bottles with pewter caps were used for getting wine from the vat in the cellar to the decanter at the table. They (or their corked equivalents) were also used for liquors like *aqua vitae* or brandy; the wide use of gin among the Dutch middle class did not occur before the third quarter of the 17th century, although possibly earlier for medicinal use on VOC ships (McNulty 1971, 103–5, figs 11–13, 15; 107). Similar narrow pewter caps were also found on another type of bottle which had pinched sides and ranges in date from the beginning to the third quarter of the 17th century (*ibid.*, 108–9, figs 28–29).

Jug fragments

The remaining two fragments comprise a jug handle (3039) with a three-lugged hinge (Fig. 11.5) and a neck fragment (3110) of a jug or flagon with a straight vertical rim and hinge for a missing lid and upper end of a profiled handle. While the jug handle is made of fine pewter, the neck fragment is a lay alloy (Ströbele and Schuster 2019, 17).

Owing to their fragmentary preservation it is difficult to be certain of their typological assignation, but both seem comparable to such details on serving flagons found in the starboard scour pit on the seabed next to the *Mary Rose* (Weinstein 2005, 436, fig. 11.15; 450, fig. 11.31; Weinstein 2011, 173, fig. 111) or, the handles specifically, to Stuart period flagons and tankards (Cotterell 1929, pls 35a and 69–70a–b).

Although morphologically similar, the neck diameters of the *Mary Rose* flagons appear to be twice the size of the *London* example (3110) and a better comparison might be the smallest of the three 'tappit hens' (a half-mutchkin measure) recovered from the wreck discovered off Duart Point (Davies *et al.* 2017; 2012, 281, illus. 2 left; 192–4, illus. 259–61, no. 121). While the 'tappit hen' is a form of measure peculiar to Scotland it was influenced by late 16th-century measures from the Low Countries and France (Davies *et al.* 2017; 2012, 288–9) and for reasons of proximity and the ship's history this region might provide a more likely origin for the fragment from the *London*.

Medical implements

Probe

A simple 104mm-long probe (3332) has a small widening spatula end whose flat end is bent slightly upwards (Fig. 11.6). At the other end of the double-convex stem it widens

2. Threaded screw-cap spout with wide double flange (H between flanges 4.4mm, depth 4.2–5.1mm), thread with three full turns (L 9.2mm). Internal L of spout: 11.3mm.

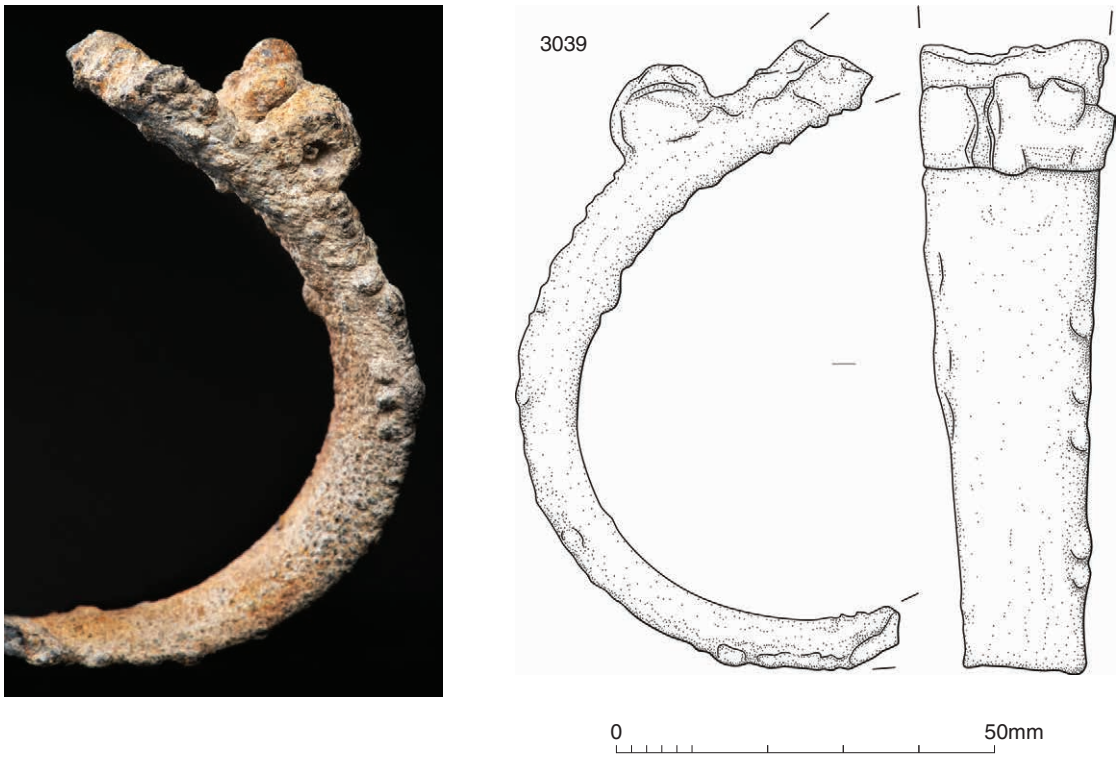


Figure 11.5 Jug handle (3039; © Historic England Archive, photograph James O. Davies, © Historic England, drawing Aleksandra Osinska)



Figure 11.6 Copper-alloy probe (3332; © Historic England Archive, photograph James O. Davies, © Historic England, drawing Aleksandra Osinska)

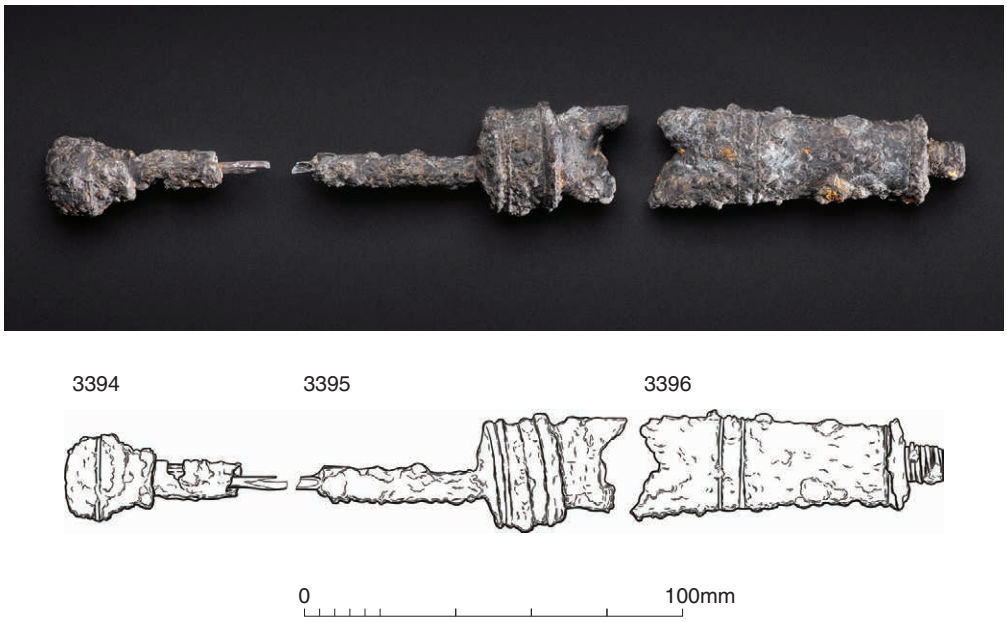


Figure 11.7 Urethral syringe (3394–6; © Historic England Archive, photograph James O. Davies, © Historic England, drawing Aleksandra Osinska)

to a flat, double-convex probe end, not dissimilar to some Roman instruments (e.g. Künzl 1983, 123, Abb. 97, 5). The object may be a shorter version of the 'styli' depicted under the letter 'M' among the Instruments of Vesalius (cf. Castle and Derham 2005, 209, fig. 4.29, from a woodcut in *De humani corporis fabrica libri septem* 1543), although a better explanation for its use might be presented by a 43mm-long scent bottle spoon from Meols (Egan 2007, 221–2, pl. 46, 3114), which is, however, bent out of copper-alloy sheet metal.

Urethral syringe

Three fragments (3394–6) that appear to make up most of an entire urethral syringe of pewter and brass construction (Fig. 11.7), most probably squashed and broken during the explosion, were recovered in close proximity. The parts include the top of the plunger (3394) with a spherical knob, the lower part of the plunger (3395), with a slightly domed end cap crimped onto the upper part of the barrel, and most of the barrel (3396) with the lower cap which has a nozzle with an external thread. No trace of the hollow needle was found on the nozzle, which might suggest that it was not fitted to the nozzle but had been stored separately or may have become detached during the wrecking process.

Morphologically the syringe corresponds exactly to the form recommended for the chests of East India Company sea-surgeons by Woodall in 1617 (fig. inserted before part B p. 1, nos 12 and 21) and still in use at the time that the *Stirling Castle* was wrecked in 1703 (Dungworth *et al.* 2020, fig. 9,7 ID 118). There appears to exist some typological development in syringe forms, as the mid-16th century examples from the *Mary Rose* all have flat discoid end plates rather than knobs, and their barrel caps could be attached with some form of bayonet latch (Castle and Derham 2005, 206, fig. 4.25). The same form was found in contemporary levels at Acton Court near Iron Acton, South Gloucestershire (Rodwell and Bell 2004, 370–2, fig. 9.36, 23–4), and a similar cap-locking mechanism might also be shown in the *Artzneybuch* of 1546 (Sachse 1546; see also the Welcome Collection n.d., and Castle and Derham 2005, 208, fig. 4.28).

A third form of syringe has a plunger with a looped end; this form is known from the end of the 15th century (Brunschwig 1497, 33) and was still used at the beginning of the 18th century, with a very similar example from the wreck of the *Queen Anne's Revenge*, Captain Blackbeard's flagship, which sank off North Carolina in 1718 (Queen Anne's Revenge Project n.d.). (For the controversy regarding the ship's identification see Rodgers *et al.* 2005.) That syringe was made in Paris in 1701 and contained a low concentration of mercury, which was an ingredient for most of the medications against syphilis, as mentioned by Woodall (1617, 21–2, 115) when describing the use of the 'small siringe [sic]' and the application of *Mercurius sublimatus* and other mercury containing unguents, including *Argentum vinum*, *Mercurius precipitatus* and *Cinabrium*/*Cinnabaris*, against *Morbus Gallicus* and other forms of syphilis. A small stoneware vial containing mercury was found on the *La Belle* wreck (1686) in Matagorda Bay, Texas, presumably for the treatment of venereal diseases that some of the crew members contracted during a stay at the Caribbean port of Petit Goâve, one of them being too ill to walk owing to syphilis just before it sank (Bruseth and Turner 2005, 98).

Despite a concerted effort, no traces of mercury were found in the syringe (Ströbele and Schuster 2019, 18, 21) but that need not necessarily imply that the lifestyle of the



Figure 11.8 Brass single-handed bow dividers (3760; © Historic England Archive, photograph James O. Davies)

London's crew made them less prone to venereal diseases. Alternatively, the ship's barber surgeon might have acquired a new syringe or the syringe might have been used customarily by administering one of the other treatments, not containing mercury, for the various forms of venereal diseases (Castle and Kirkup in Gardiner with Allen 2005, 180).

Nautical fittings

Deadeyes

Both deadeyes (3079 and 3315) are discussed above (see Chapter 6, Endsor and Chapter 8, Allen *et al*.).

Fairlead or bracket

The fairlead/bracket (3778) has a U-shaped open socket and one circular 7mm-wide hole near either straight end. The object is 292mm long, 50.3mm wide and its base is 31.2mm thick. Although discovered on the surface of site S2, it is probable that the object came from the later wreck that abuts the *London* (Evans 2017, 15, 17, 20–1), so it will not be considered further.

Navigation instruments

Dividers

The dividers include one pair of single-handed bow dividers (3760; Fig. 11.8) and three double-handed straight dividers (3041, 3392 and 3477; Fig. 11.9). Each arm of the single-handed bow dividers (3760) has a convex-arched top of two flat rectangular-sectioned strips, moving through each other when opening. These arched tops create a circle with a diameter of 38.5mm when closed. The circular hinge is secured with a flush rivet. While the upper parts of the straight, tapering arms are rectangular-sectioned, each with a concave notch in the middle of the inside, the lower parts of the arms have bevelled outer edges. One of the pointed tips is slightly bent inwards. Although the bow of the single-handed dividers might make it slightly easier to open the dividers with one hand, the distinction is somewhat arbitrary as both types can easily be manipulated with one hand when the pressure of the hinge rivet or screw is adjusted and maintained correctly (Stimson 2005, 274).

Four single-handed dividers, of the type found on the *London*, are known from the *Mary Rose*, including two pairs of dividers with zig-zag or cross decoration on the upper arms, which were found together with an ash case in the pilot's cabin; the description of the other pair, found on the upper deck near the stern, suggests that they had a moulding similar to the concave notches found on the upper arms of the *London* example (Stimson 2005, 273–4, fig. 7.8, pls 38–9). This form of single-handed bow dividers with strip bows moving through each other has been recovered from a number of other 16th to early 18th-century wrecks, including a presumed Spanish or French vessel wrecked off Bermuda probably between 1592 and 1609 (Treasure from sunken 16th-century ship, *The Times*, 14 January 1956, p. 12), the *Lastdrager* (lost 1653: Sténuit 1974, 233, fig. 14, 1–2), the Duart Castle wreck (*Swan*?) of the same year (Martin 2017, 171, illus. 234), the *Kennemerland*, wrecked three months before the *London* in December 1664 off Stoura Stack in the Out Skerries, Shetland (Muckelroy 1978, 121, fig. 3.30) and the pirate ship *Speaker*, lost off Mauritius in 1702 (Lizé 1984, 125, fig. 4). A further example was found in 1925 during excavations in the inner ward at Farleigh Hungerford Castle, Somerset, where its use might have been for terrestrial map or survey work, maybe during the unsuccessful Parliamentarian defence of the castle against the Royalists in 1643 (Farleigh Hungerford Castle EH acc. no. 85000148; FHC.68).



3392



3477

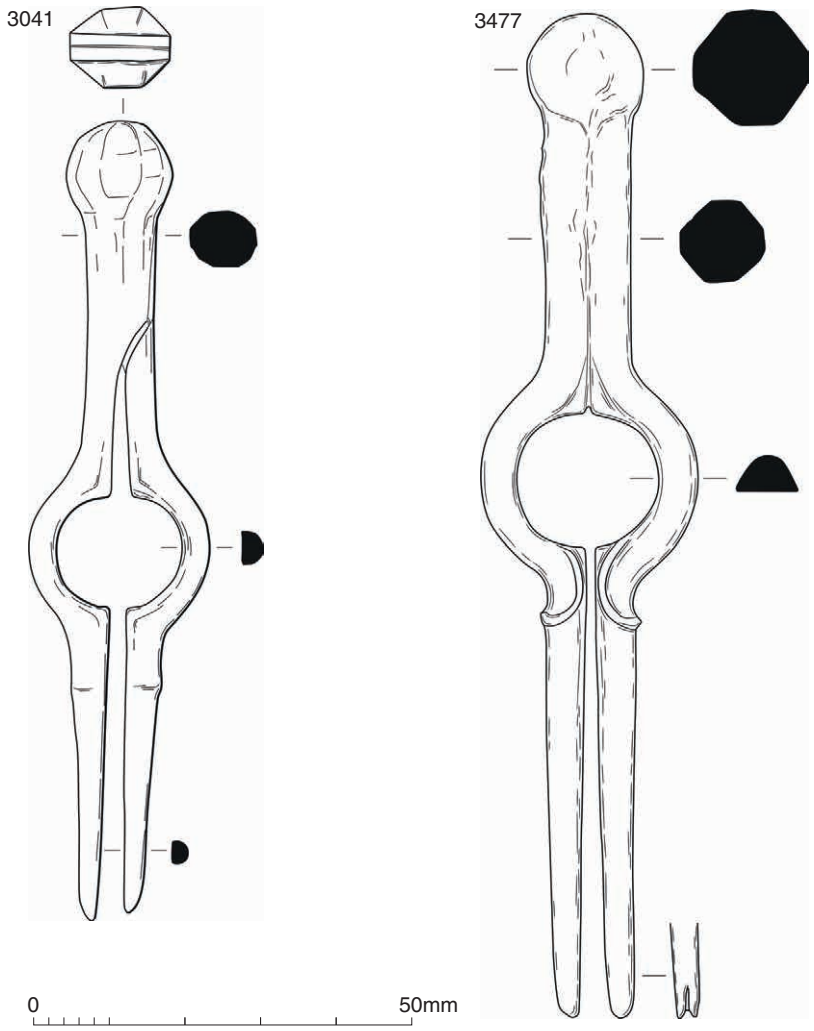


Figure 11.9 Brass double-handed straight dividers (3041, 3392 and 3477; © Historic England Archive, photographs James O. Davies, © Historic England, drawings Aleksandra Osinska

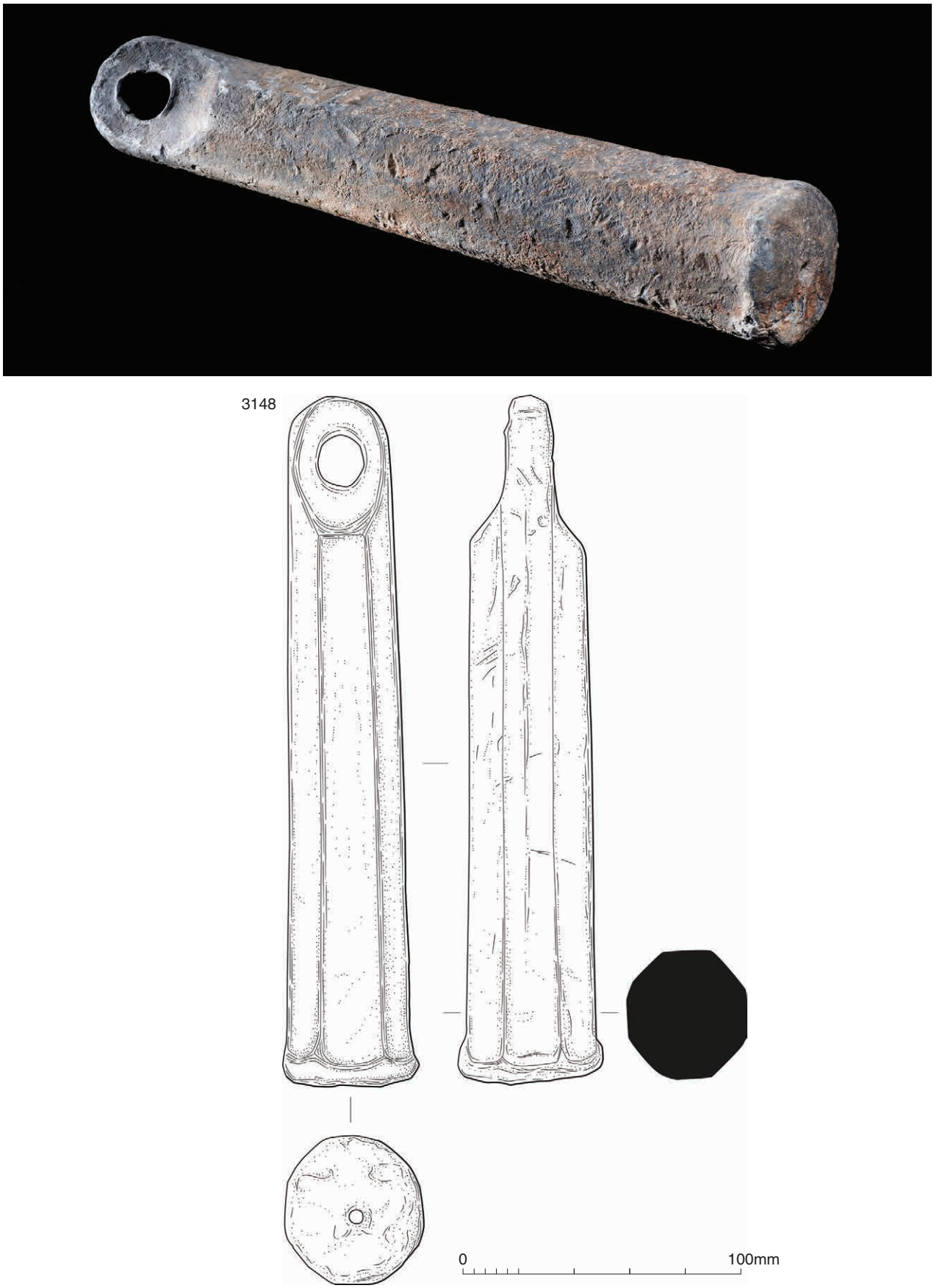


Figure 11.10 Sounding lead (3148; © Historic England Archive, photograph James O. Davies, © Historic England, drawing Aleksandra Osinska)

There is ample evidence for single-handed bow dividers from documentary sources, including illustrations on maps like Saxton's *Atlas of the Counties of England and Wales* of 1579 (British Library, Royal MS 18.DIII. no. 5), a plan of Dover Harbour between 1584 and 1592 (Minet 1922, pl. 71) or even playing cards depicting maps, all with images of bow dividers above the scale bars (Bowes 1590). The type is also depicted by Aubin in his *Dictionaire de marine* (Aubin 1702, 249, s.v. compas de carte).

Close morphological parallels of both types of dividers found on the *London* were recovered from the *La Belle* wreck (1686; Bruseth and Turner 2005, 108), from the *Elizabeth and Mary*, which sank in Baie-Trinité off the Quebec coast in 1690 (Ringer 2008, 30, fig. 45) and the *Dartmouth*, wrecked in the same year off Mull (Muckelroy 1978, 124, fig. 3.33; Takahashi *et al.* 2007, 292, fig. 24), as well as the *Stirling Castle* lost in 1703 (Dungworth *et al.* 2020, fig. 9, 9). Where analysed, these dividers, like those from the *London* (Ströbele and Schuster 2019, 15, 25), were made of brass (e.g. Tate in Takahashi *et al.* 2007, 289–91).

The three double-handed straight dividers (3041, 3392 and 3477) are all of the same type. They feature the same decorative elements, including straight semi-circular-sectioned arms (upper section possibly originally octagonal when closed) each with an arched middle section forming an open circle when the arms are closed. Below the arches sits a profiled scroll and the hinge at the top is spherical or ball-shaped and joined with a flush rivet. The tips of two (3041 and 3392) are rounded and blunt but those of the third (3477) are split to receive steel tips, probably not as long as those in the National Maritime Museum (NMM; NAV0517 and NAV0547) or those reconstructed for a third type of dividers like the consignment of 72 found on the *Lastdrager* (Sténuit 1974, 233–5, fig. 14, 9–11 and figs 15–16). Apart from the wrecks mentioned above, dividers with arched middle sections were also found in late 17th/early 18th-century contexts at Oyster Street in Portsmouth (Fox *et al.* 1986, 232, fig. 145, 5–6).

Sounding weight

The sounding weight (3148) has a tapered octagonal section and a chamfered top with a large perforation (diameter 14.6–16.0mm; Fig. 11.10). The base has a small hole (diameter 4.5–5.3mm, depth 21.2mm), which would have been filled ('armed') with tallow or grease to sample material from the seabed (Aubin 1702, 623, s.v. *Plomb de sonde*). At a length of 247mm and a weight of 3360g (7.41lb) the weight can be described as a 'hand lead' used to measure the depth of shoal waters (cf. Stimson 2005, 279; Martin 2017, 170). While the earliest depiction of a sounding lead, probably used in inshore waters, goes back to the 3rd millennium BC in Egypt (McGrail 2014, 48), the use of the sounding weight is well attested in the Mediterranean in antiquity from both literary sources and archaeological finds, already featuring both the perforated chamfered top for suspension as well as the hole in the base for sampling the sea-bed (Oleson 2008). A possible sounding weight recovered from the Copper Ship which sank in the Baltic off Gdańsk, Poland, in 1408, was of a very different form (Ossowski 2014a, 364, 367, fig. 15, 3).

The shape of the *London* sounding weight is similar to those from Tudor ships like the *Mary Rose* (Stimson 2005, 27, fig. 7.12) or the *Ann Francis*, lost in Swansea Bay in 1583 (Redknap and Besly 1997, 200–1). A very close comparison, in terms of its shape and dimensions, was recovered from the *La Belle* wreck (1686: West 2005, 132). The leads recovered from the *Lastdrager* and the Duart Castle wrecks, both lost in 1653, are of similar shape but a heavier class for deep sea waters, and their tallow holes are different as they are deeper and much more conical (Martin 2017, 170, illus. 233; Sténuit 1974, 232, fig. 13). A later example from *Queen Anne's Revenge* (1718)[3] is three times the weight of the *London* example (3148).

Personal items

Pocket sundial compass

The horizontal pocket sundial with compass disc (3165) has an hour or chapter-ring with a folding gnomon over a compass bowl, all made of brass (Fig. 11.11a–b). While most of the metal elements of the object can be described as brass, the high zinc content of the chapter ring suggests it might have been made with a 'modified calamine process', increasing the zinc content to 29.9% (Ströbele and Schuster 2019, 2, 16). The chapter ring is radially marked with the numbers '4' to '11' on the left and '1' to '8' on the right, all stamped across radial lines; the 12 o'clock position is covered by a loop holding the triangular indicator or gnomon; the position opposite the 12 o'clock mark is stamped with the initials 'GC' set within a sub-rectangular recess. The outer edge of the gnomon has been cut in the shape of two ogee curves forming a mathematical parenthesis '}'. The acute tip of the gnomon is held in a loop on an arc in the centre of the compass.

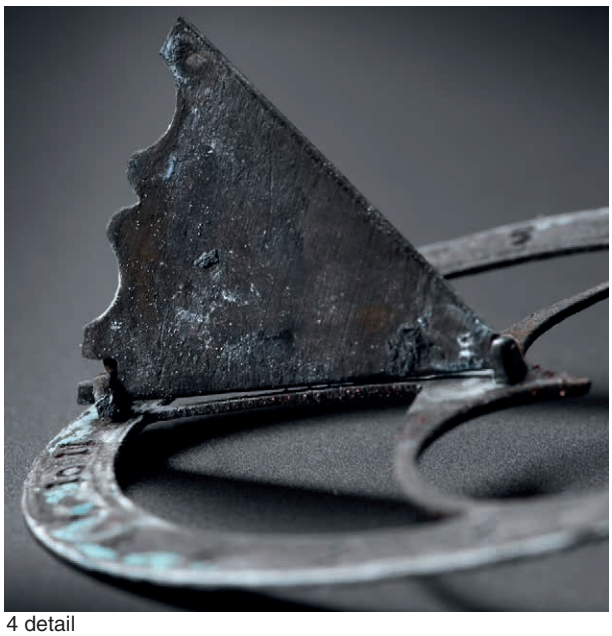
The bowl of the compass has three internal bands soldered below the opening. The first is a rest for the chapter ring (internal diameter 43.2–43.5; width 1mm; thickness 1.6–1.9mm) and the second (internal diameter 41.3mm; width 5.0–5.5mm) for the compass glass; a third, penannular, ring sits below this (internal diameter 43.7mm; width 1mm). At its equator the compass bowl has an external diameter of 47.8mm; below the equator 47.6mm and at its base 46.5–46.6mm. Although found separately, a lid (3328; Fig.11.12) is probably part of the sundial compass (3165). Apart from a double line above and a single line below its

3. QAR 004.001 c. https://www.qaronline.org/conservation/artifacts/tools-and-instruments/lead-weight (accessed 26 July 2019).



4

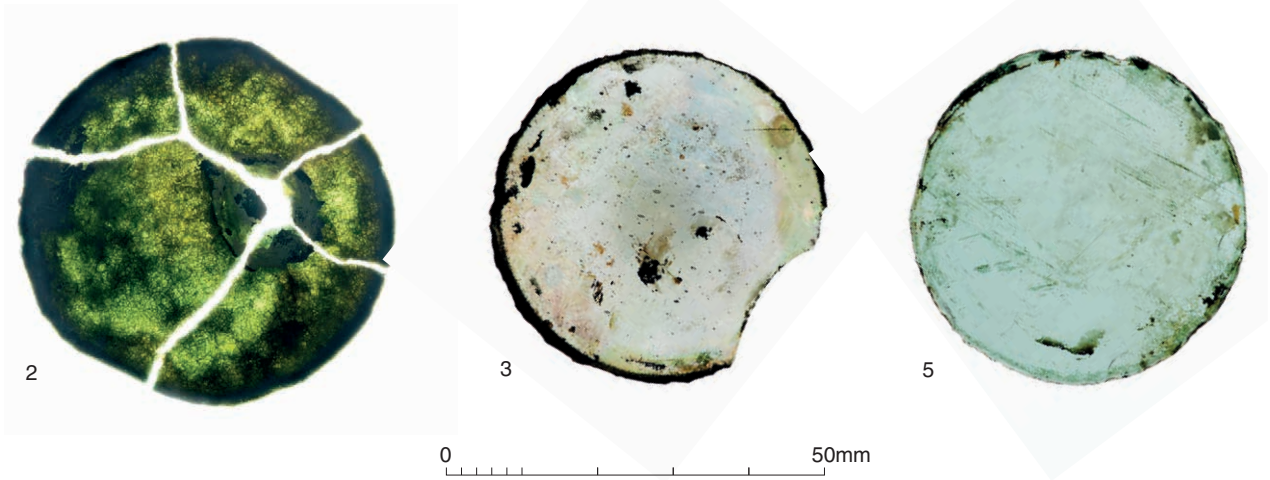
0 50mm



4 detail



4 detail



2 3 5

0 50mm

Figure 11.11a Pocket sundial with compass disc (3165, 3328; © Historic England Archive, photographs James O. Davies)

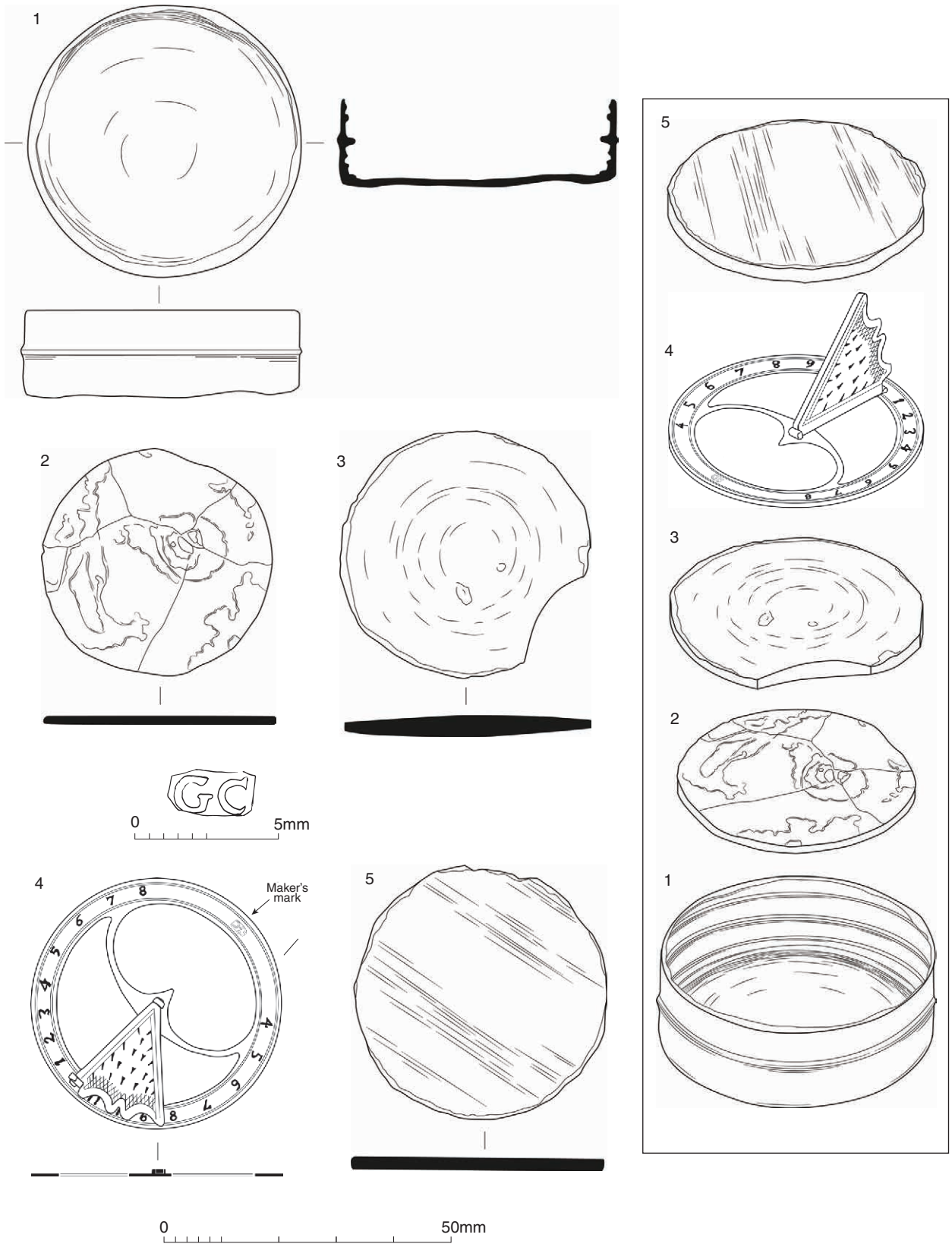


Figure 11.11b Pocket sundial with compass disc (3165, 3328; © Historic England, drawing Aleksandra Osinska)

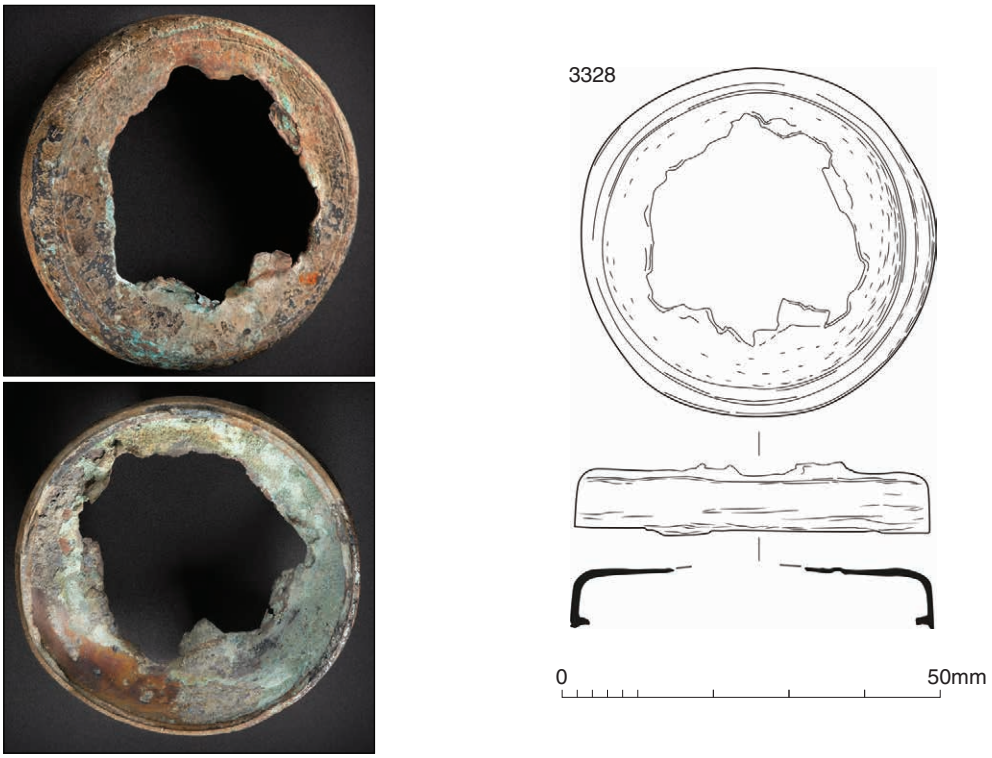


Figure 11.12 Sundial compass lid (3328, © Historic England Archive, photograph James O. Davies, © Historic England, drawing Aleksandra Osinska)

shoulder the lid is undecorated but most of the centre of the lid is now missing, leaving a hole of irregular outline.

Although no longer *in situ*, three glass discs are also related to this object. A transparent lenticular glass disc was probably set below the chapter ring as a cover for the compass whose markings might have been applied to the second glass disc (as opposed to a card as might be expected) which now appears black. The compass needle is missing and there is no trace of its pivot on this glass disc or on the base of the compass bowl. Alternatively, and more probably, there could have been a compass card with a magnetised needle fixed below the card, as found on the *Kennemerland*, or a probable German dial with ivory box in the collection of the NMM (Higton 2002, 108, no. 77); this construction is also described by Aubin (1702, 248, s.v. *compas de mer*):

> *C'est un instrument composé d'un carton mince, coupé circulairement; divisé en trente-deux parties égales, représentant l'horizon, avec les trente-deux vents. Au centre du compas est un cône concave de laiton, apellé [sic] chapelle, avec une aiguille en losange, de bon fer, ou d'acier; clouée au-dessous du carton, & touchée d'une pierre d'aimant; & tout ce composé est apellé [sic] Rose.*
>
> *It is an instrument composed of a thin piece of cardboard, cut circularly; divided into thirty-two equal parts, representing the horizon, with the thirty-two winds. In the centre of the compass is a concave cone of brass, called chapel (the pivot), with a lozenge-shaped needle, of good iron, or steel; nailed below the cardboard, and touched with a lodestone; and all this arrangement is called [a] Rose.*
> (transl. by author)

This arrangement would, however, leave the purpose of the now black glass disc unexplained.

A third disc of green glass might have been set into the lid to cover another scale of which there is now no trace. The operation of this type of portable equatorial sundial is described by Sténuit (1974, 231).

It has not been possible, unfortunately, to link the initials 'GC' with any known maker. The composition of the glass discs suggest that the glass was made in central Europe, probably Germany (see Chapter 13, Paynter). Similarly, the angle of the gnomon's oblique side (the style; 48.78° degrees or 48° 46' 48" degrees) is commensurate with the geographical latitude of southern Germany.[4] The angles of the hour lines, on the other hand, suggest a more northerly location.[5]

4. With cities like Regensburg, Ingolstadt, Augsburg or Pforzheim (with its significant goldsmithing tradition), Straßburg, but also Paris, located within a corridor of half a degree either side.
5. Since the variation of the results, however, ranges between 47° and 50°30' on the am-side (7am to 10am) and 52° and 55° on the pm-side (2pm to 5pm), the accuracy of the hour ring appears questionable (NB the accuracy is likely to be influenced by uncertainty as to which line to measure since the marks appear affected by corrosion) (Waugh 1973, 37–46, 218–21, table A10).



Figure 11.13 Brass pins (3166 and 3338; © Historic England Archive, photographs James O. Davies, © Historic England, drawings Aleksandra Osinska)

The presence of a sundial on board is not surprising. The closest comparison to this sundial compass comes from the wreck of the *Kennemerland* (1663; Muckelroy 1978, 109, fig. 3.24), which is better preserved and still has its compass card as well as an intermediate section set with a glass disc. In place of a maker's mark there is a six-pointed star on the hour ring opposite the gnomon similar to the, otherwise very comparable, hour ring of a 17th-century ivory barrel astronomical compendium in the NMM (Higton 2002, 323, no. 307) and two examples from the *Lastdrager* (1653; Sténuit 1974, 230, fig. 12). Other examples of this common 17th-century form of chapter ring and gnomon were found in Amsterdam,[6] with a maker's mark 'CC' set within a crown, and another marked 'PB' comes from the pirate ship *Speaker*, wrecked in 1702 off the east coast of Mauritius (Lizé 1984, 126, fig. 5). While they may not have been in every seaman's pocket, they were common enough, by the end of the 16th century, for Shakespeare to make frequent reference to dials (e.g. Jaques in *As You Like It* [II, 7] line 914; second merchant in *Comedy of Errors* [V, 1] line 1550; Shoesmith 1978, 101). Given their geographical constraints and lack of accuracy (cf. Morrison-Low in Takahashi *et al.* 2007, 296), dials of the type found on the *London* would probably have been of limited use for navigational purposes and more likely served as personal showpieces.

Dress fasteners

Pins

Two brass pins (3166 and 3338) both have wound wire heads, of two and three coils respectively, stamped in the shape of a small sphere (Fig. 11.13). One (3166) appears to be partially compressed but no traces of black vitreous material were noted, while the other (3338) looks like a well-formed sphere. The former belongs to Caple type B, while the latter is his type C (Caple 1985, 47–8, fig. 30; Caple 1991, 246, pl. 16). Although the production of wound wire headed pins in England can now be traced back as early as the 13th century (Biddle and Barclay 1990, 561–3), Caple type B has its floruit in the 16th century and type C becomes dominant after *c.* 1700, but this is a picture of gradual development rather than wholesale replacement of one type by another (Caple 1991, 246–7, table 1). Both length and diameter of the pins generally decrease over time, thus the dimensions of the two *London* examples (3166: 20.4 x 0.5mm and 3338: 22.1 x 0.7mm) are commensurate with their mid-17th-century deposition date (Caple 1991, 248–9, table 2).

Both shafts have round cross-sections with faint grooves from a wire-drawing vice. There is no trace of white metal coating on either of the heads. Where such white metal coating survives it has been shown to be an alloy of tin and lead (Caple 1985, 48). Given the complete lack of any tin in the analyses of the pin heads and shafts it is likely that the pins were never coated. It must be remembered, however, that preservation conditions in the marine environment can lead to dezincification and destannification (loss of tin from copper alloys; see Ströbele and Schuster 2019, 19). Whether the pins were of English or Continental production cannot be determined (see Caple 1991, 250) but the fluctuation in the production of brass wire, poor quality and problems with the enforcement of the brass wire monopoly meant that pins continued to be imported, particularly during the Civil War period (*ibid.*, 245). Similarly it is impossible to determine whether the two pins had been used as sewing pins or to fasten clothes; of the 15 pins recovered from the

6. https://belowthesurface.amsterdam/nl/vondst/NZR2.00522MTL041 (accessed 26 September 2019).



Figure 11.14 Pewter button (3359; © Historic England Archive, photograph James O. Davies, © Historic England, drawing Aleksandra Osinska)

Mary Rose none was found holding clothing together, while eight were found in storage (Every 2005, 328). Given the presence of at least one woman among the 25 survivors of the calamity (Latham 1996b, 138) a utilisation for fine female garments has to remain among the pins' possible functions (see Margeson 1993, 11).

Button

A pewter button (3359) is of solid discoidal form (diameter 28.6–29.6mm) with a convex front decorated with a recessed octofoil, which could be described alternatively as piriform recesses forming an eight-spoked wheel (Fig. 11.14). There is a central sub-rectangular perforation for the attachment of a, now missing, separate wire shank which was possibly made of iron. On the reverse a coarse rim around the central perforation is likely to derive from where the shank had been pressed into the partly solidified metal.[7]

Although no exact comparison for the button (3359) is known to the author, discoidal solid buttons with convex fronts displaying similar decoration are known from late 16th/17th-century contexts (e.g. Read 2010, 76 no. 286); a more ornate gilt copper-alloy button with a separate iron wire shank was found on the Thames foreshore in London (*ibid.*, 103 no. 418).

Grooming and toilet equipment

Comb

A double-sided comb (3325 from grid square G10, Fig. 5.11) was revealed by zooarchaeology by mass spectrometry (ZooMS or collagen peptide mass sequencing) analysis (S. Presslee, University of York) to be made of African elephant ivory.[8] Combs with narrow-set teeth on one side would have been an essential piece of equipment for personal hygiene in the cramped conditions aboard a ship, providing the first line of defence against the ubiquitous nits, lice and fleas. The comb's coarser side has 6 teeth per inch (spaced 2mm apart), the other, finer side 29–30 teeth per inch (spaced 0.2mm apart). The two sides are separated by a central bar or solid zone on which the line of teeth describes a slightly double-concave line. Only one of the thicker teeth remains to a length of 20.9mm, all others are broken off. At either end the comb sides are flanked by straight rectangular end bars, tapering in thickness to the straight, slightly rounded, ends. It is likely that the type developed out of the late medieval–early post-medieval small one-piece double sided combs of Ashby type 14b, which are common finds on either side of the English Channel and across northern Europe (Ashby 2011). More drastic measures would have included the application of various, often mercury-containing ointments and unguents (e.g. *unguentum de Mercurio* or *argentum viuum*, see Woodall 1617, 51, 114). Although it has been observed that the use of ivory increased during the 17th century (Egan 2005, 64–5; Cubitt *et al.* 2019, 15), the use of ivory is also likely to be indicative of the owner's elevated social status. Only one of the 82 combs found on the *Mary Rose* (1545) was made of ivory, with the majority (80) made of boxwood (Maddocks and Richards 2005, 156, 159–60, figs 3.49 bottom right and 3.50, 79A0461/1–2, boxwood, with 7 and approximately 27 teeth per inch). The three combs from 16th–18th-century layers at Church Court and Hare Court in the Inner Temple in London are all made of ivory (Gaimster 2005, 92–3, fig. 87.1–3). By contrast, a poorer community appears to be represented by the eight later 17th-century combs from Tilbury Fort, only one of which was made of ivory, probably from elephant, the rest were made of bone (Moore 2000, 82–3 with note 388, fig. 52, 261–8).

7. XRF-analyses have shown that the button was made from a very heterogeneous alloy, with tin values between 14.5% and 50.4%, the lead content varying between 47.2% and 85.4% and copper between 0 and 2.8% (Ströbele and Schuster 2019, 17).
8. First assessed by P. Baker; initial identification by S. Greep and S. O'Connor pers. comm.; taxon subsequently confirmed by collagen peptide mass fingerprinting analysis.



Figure 11.15 Chamber pot (3053; © Historic England Archive, photograph Steven Baker)

A better preserved example, also made of ivory, was found on the *Elizabeth and Mary* (1690), which provides an especially close comparison as the solid zone has the same double-concave curvature as the example from the *London* (Ringer 2008, 40, fig. 75). The bone combs from an early–mid-18th-century well at Oyster Street, Portsmouth, all display this curvature (Fox *et al.* 1986, 240–2, figs 153, 13 and 154, 3–4), whereas it is absent from the ivory combs, predominantly recovered from 17th–18th-century contexts, in Norwich (Margeson 1993, 66–8, figs 35–36). The double-concave curvature is however, not confined to ivory, as indicated by a 16th-century wooden example from Moorfields, London (Cubitt *et al.* 2019, fig. 17, 45). It must remain open whether this curvature has any chronological relevance or is an artefact of the individual comb-maker's craft tradition.

Chamber pot

A pewter pot (3053) has a globular body approximately 165mm in diameter, a very slight step to a narrower neck and an everted, upwardly curved rim, which flares very slightly and has a straight, horizontal edge. A circular pedestal ring is soldered onto its base and a gentle ridge/seam runs along the upper third of the pedestal. The pot is now distorted and broken into two large body fragments (joining along one break; from grid square H17; Fig. 11.15) and the base, as well as six smaller fragments. The entire surface is covered in corrosion pustules, obscuring any surface detail; no touchmark was identified on the X-radiograph. The vessel was made from a tin alloy with high lead content, i.e. not 'company grade', supporting its identification as a receptacle not intended to contain food (Ströbele and Schuster 2019, 17, 25). The closest comparison for this vessel comes from the *Mary Rose*, where it is assumed to have been located originally in an officer's quarters in the stern quarter (Richards 2005, 161–2, 164, fig. 3.54). While pottery chamber pots are common on post-medieval sites (see e.g. Pearce 2016, 204), another rare archaeological find of a pewter chamber pot comes from Baconsthorpe Castle in Norfolk (Homer 2002, 66, fig. 36, 105) and a similar vessel, possibly made of pewter, is illustrated on the cover or frontispiece of Thomas Heywood's 1635 play 'Philocothonista' (Weinstein 2011, 58, fig. 3). If it is a chamber pot, the handle is missing.

Tools/equipment

Knife/tool handle

An oval-sectioned handle (3397, from grid square I7), widening towards its rounded terminal measures 90.4mm long and has an oval socket hole in its base (diameter 5.8–6.8mm; Fig. 11.16). Initially thought to have been made of ivory, as suggested by visible lateral striations, ZooMS analysis (S. Presslee, University of York) identified the handle as cattle bone. Although a use with some type of tanged tool cannot be discounted, the handle was most probably attached to a whittle tang knife, of which contemporary ivory examples are known, for instance, from the *Lastdrager* (Sténuit 1974, 250, fig. 31, left: with octagonal cross-section) or, in bone, from the Duart Castle wreck (Martin 2017, 227, illus. 305, 222); two very closely comparable knife handles, made of ivory, were also recovered from the 1690-wreck of the *Elizabeth and Mary* (Ringer 2008, 34, fig. 58).

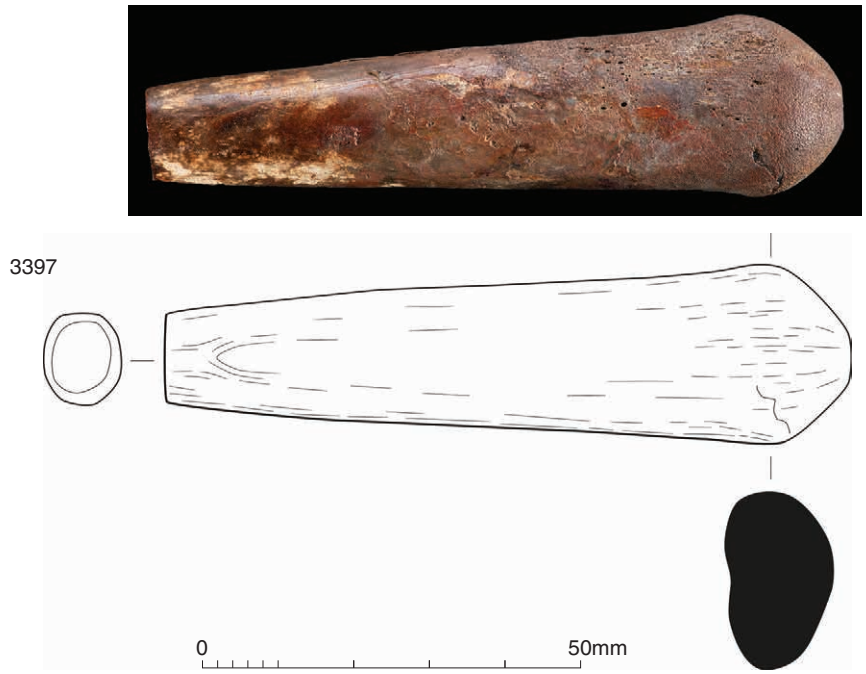


Figure 11.16 Bone handle (3397; © Historic England Archive, photograph James O. Davies, © Historic England, drawing Aleksandra Osinska)

Hammer

A claw hammer (3732, Fig. 5.5) has a 105.7mm long head with a straight-forked front pane, although one of the forks is missing, and a circular rear face. The X-radiograph shows an iron wedge reaching from the top of the handle to the opposite end of the eye. Although the shape of the eye is obscured by corrosion, the upper part of the 283mm-long wooden handle has a square cross-section (21.2x22.5mm) right up to the rounded cheek; the lower part is subcircular-sectioned (diameter 21–21.8mm). The handle's wood was determined as cf Betulaceae group 1, which includes trees like birches, alders, hazels, and hornbeams (Hazell and Aitken 2019, 15, 47). Simple claw hammers are multipurpose tools used by woodworkers and other craftsmen like blacksmiths or farriers; straight or gently curved claws are a feature of medieval hammers, whereas hammers with a pronounced down-curve, better suited to extracting nails from wood, tend to be a feature of many modern claw hammers (Goodall 2011, 27). The shape of the *London* hammer is similar to a claw hammer recovered from the later 16th/early 17th-century demolition layers at Camber Castle near Rye, East Sussex (Scott 2001, 277, fig. 7.12, 195). The length of the *London* handle fits well into the range of between 265mm and 317mm represented by the five hammer handles from the *Mary Rose*, where none of the iron heads survived (McKewan 2005, 306).

Ring/washer

A small ring (3530) has a flat, rectangular-sectioned, 2mm-wide hoop with an outer diameter of 21.5mm. The ring is made of a very heterogeneous brass/gunmetal (Ströbele and Schuster 2019, 16). Such a simple ring could have had a multitude of uses, including as a strap or chain distributor for a boatswain's call (see e.g. *Mary Rose*: Redknap 2005, 288–9, figs 7.21–2).

Ingot

A lead ingot (3087; Fig. 11.17) of irregular circular cone-section shape (found in grid square F13), it has a sub-circular dimple in its narrower base and a casting flaw hole in the sunken centre on the top side. At 32mm high, the diameter of the wider top ranges between 66.2mm and 70.1mm; it weighs 790g. It is most probably a piece of raw material that was suitable for making all manner of objects, for

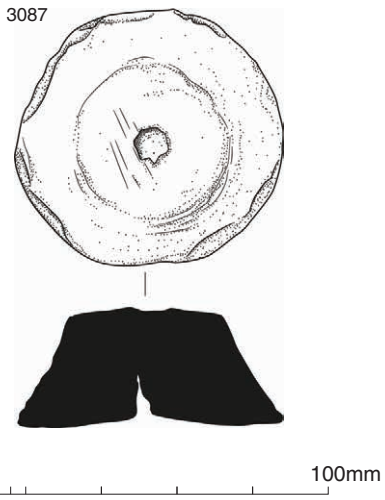


Figure 11.17 Lead ingot (3087; © Historic England, drawing Aleksandra Osinska)

instance lead shot, sheeting or patches. It does not conform to any obvious multiple of an avoirdupois pound and is thus unlikely to have been intended for use as a balance pan weight comparable to the set of three weights from the Duart Castle wreck, whose surfaces also exhibit evidence of post-casting shrinkage. Unlike this ingot (3087) the Duart Castle weights were adjusted subsequently for specific weights and were stamped with control and verification marks (Martin 2017, 223–5, illus. 302–3).

Lead patches and a roll of sheet metal

The 12 lead patches are all of more or less sub-rectangular shape, with multiple sub-square nail holes along most or all of their outer edges. They range in length from 82.7mm to 661mm and from 52mm to 99.6mm wide, weighing between 74.5g and 511.8g. The thickness of the five pieces that could be accurately measured showed remarkably close values between 2.6mm and 3mm. The thickness of the 2.7kg roll of lead sheet metal (3119; Fig. 11.18a) is of similar dimensions, measuring between 2.3mm and 4.5mm. Many holes are surrounded by sub-circular impressions of the nail heads while some holes are torn. In most cases the nails are no longer present but fragments of iron nails were found in two of the lead patches (3125 and 3128; Fig. 11.18b). There is no evidence of nails made from materials other than iron despite the adverse effects of electrolytic reaction between lead and iron. One patch (3125) had a very large nail hole (8.5 x 10.2mm) inward from the smaller, edge-parallel holes; the smaller hole dimensions across all patches range from 1.9–5.9mm to 3.0–6.3mm, with head diameters between 6.1–7.5mm and 10.3–12.7mm. Similar nail dimensions were reported for the composite lead-copper/copper sheathing applied to the sternpost and rudder of the VOC ship *Vergulde Draak*, wrecked 120km north of Perth, Australia, in 1656 (van Duivenvoorde 2015b, 4).[9]

Knowledge of lead sheathing had reached England by 1553 but it was not until April 1671 that it was approved for the Royal Navy. It was a further one hundred years before it was discontinued in 1770, although the observation that '[lead] may be venomous to iron' was noted in a report by the Portsmouth Commissioner Sir John Kermode on 17 April 1677 (Bingeman *et al.* 2000, 219, with additional references).

The practice of lead sheathing was not officially endorsed by the Royal Navy until six years after the sinking of the *London* and there is, as yet, no evidence that the *London* was lead sheathed. It is, therefore, most likely that these lead fragments were used to patch small holes in the hull

9. The problem of electrolytic reaction and the consequent potential for structural failure of iron fittings in their vicinity is discussed by van Duivenvoorde (2015a, 194, 205; 2015b, 350–1) as one of the reasons for the abandonment of lead sheathing by the VOC after 1606, alongside high maintenance, cost and weight, which she considers might have been less of an issue (see also Parthesius 2010, 102–3).

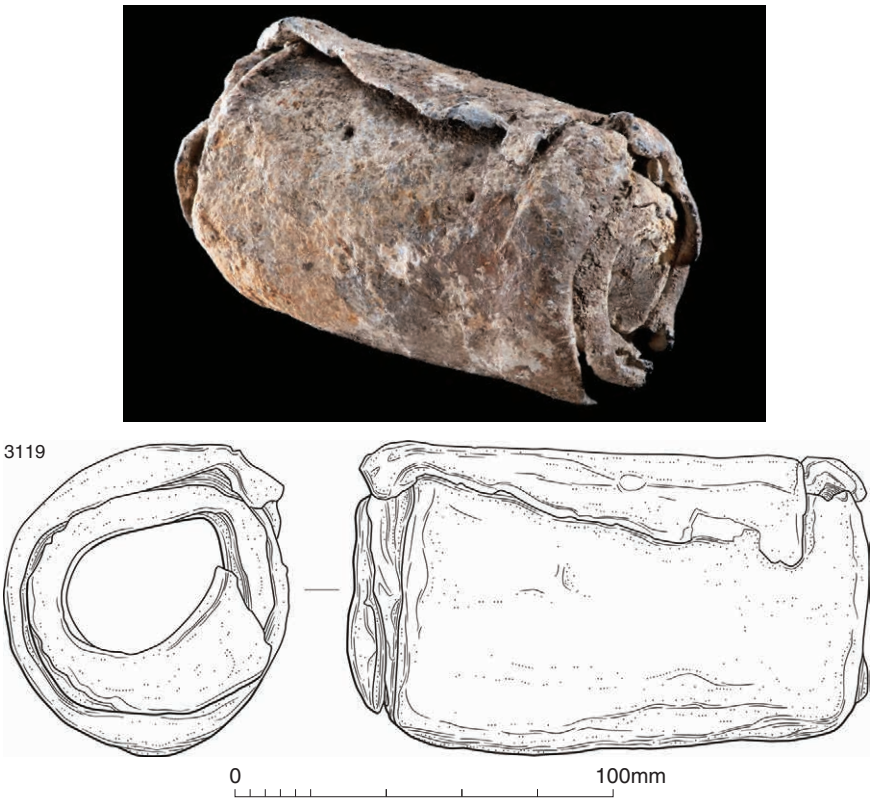


Figure 11.18a Lead patch (3119; © Historic England Archive, photograph James O. Davies, © Historic England, drawing Aleksandra Osinska)



Figure 11.18b Lead patches (3081 and 3128; © Historic England Archive, photographs James O. Davies, © Historic England, drawings Aleksandra Osinska)

(R. Endsor pers. comm.) or along seams, as noted on the Spanish Emanuel Point vessels lost off the coast of Florida during the 16th century (Marr 2012, 35–42). The latter method of fixing was, however, different as none of the *London* patches display rows of tack holes running along the centre of the patches, which was most likely intended to keep caulking in the seams between planks resulting in partial hull coverage. In other words the individual lead patches were not of sufficient width to overlap and cover the hull. This partial coverage would have kept both weight down and expenses low (*ibid.*, 46–7).

Weaponry

Further weapon-related finds are discussed in the chapter on cannon and ordnance (Chapter 7, Pascoe *et al.*).

Pistol handle

The handle (3634) of a pistol (from trench 3 of S2), has a sub-circular-sectioned stave made of walnut (Hazell and Aitken 2019, 42 table A2). The description of the butt cap is based on what is visible in the X-radiograph (Fig. 8.21), as the base and part of the middle and top of the handle were initially obscured by adhering iron concretion. The shallow, domed iron butt cap with lateral long-triangular spurs reaches halfway up the preserved fragment of the wooden handle; the end of the spurs overlap with the beginning of the rear strip of the trigger guard. A comparable handle was found in the Pedro Bank V wreck, believed to be one of the four vessels of the Tierre Firme Fleet, which sank on Pedro Bank off Jamaica on 2 June 1691. All the stocks of the 54 pistols recovered from that wreck were made of walnut (Marr 2012, 26–7, fig. 9 left). There is no indication of what type of lock was used on the pistol. A more complete example of a probably similar pistol, with all the wooden but none of the iron parts of the stock still preserved, was found on the *Elizabeth and Mary* (1690; Rodley 2012, 23, fig. 8b) and another on the *Dartmouth* (C. Martin pers. comm.).

Calipers

Two pairs of wing calipers (3135 and 3380, recovered respectively from grid squares F13 and J10) made of brass[10] are of slightly different form. One pair (3135) is severely bent and distorted, probably as a result of the explosion or its immediate aftermath. The instrument is almost complete but, when first discovered, it was partly encrusted in iron concretion (Fig. 11.19). The arms are joined by a scarf-jointed hinge with a domed rivet and rove; the upper lengths of both arms up to the curved wing are flat inside and of trapezoidal section. The wing is embedded in a rectangular-cuboid section held with a flush-set rivet in one arm and possibly a screw in the other (the top of the screw is missing; it might originally have been winged but there is no evidence for this). While the lower length of the screw arm has an octagonal cross-section tapering to a now missing tip, the lower length of the fixed arm probably also has an octagonal cross-section but is now more rounded and very corroded in its lower part which ends in a drop-shaped blob; the latter might have been partly melted in the explosion or may simply have been more exposed to the marine environment, while the side encased in the concretion appears to be slightly better preserved.

The wing of 3135 has a semi-circular end with a notched hole either side and it is marked with number scales and lettering (readable with the ends of the arms facing away from the reader). On one side the area of the wing between the two arms is stamped 'YSE[R]' above a central double line and 'I' (for number 1) below. The outer section of the wing, beyond the arm, is marked with a scale on the outer edge that runs from [0] to 50, with marked increments of '1', '5' and '10'. The scale on the inner edge runs up to '7', with '4' being the lowest readable increment. The reverse of the wing between the arms is stamped 'LOOT' above the central double line and '[..?]EW' below. It is possible that the beginning of the word is obscured by the cuboid section. The scale on the outer edge reflects the scale on the obverse with visible increments from '10' to '50' but possibly extending to '60'. Only one marking is discernible on the scale on the inner edge (located below '50' of the outer scale).

The other pair of wing calipers (3380) is in much better condition and differs from the other instrument as the lower sections of its octagonal-section arms both have longitudinally set 11mm-deep rectangular notches that must have housed extensions; both contain residues of the iron or steel arms and tips that have completely disintegrated (Fig. 11.20). At the top the arms are joined by a scarf-jointed hinge with a flush-set rivet. The upper lengths of both arms up to the curved wing have a flat inside and are of trapezoidal section. The wing is again set in a rectangular-cuboid section held with a flush-set rivet in one arm and a winged screw in the other. The side of the wing opposite the screw is marked with number scales but no lettering. The scale beyond the arm is marked I|2|I|4|I|?6|I|8|?I? towards the profiled outer end, marked with half interval increments. Between the arms there is a visible number scale ?|?6|5|4|3|2|?1, with similar increment markings. Apart from the outer arm being bent slightly backwards the instrument is not bent or distorted.

While winged calipers can be used for a variety of purposes, such as carpentry or coopering, the letters on the various scales of one caliper (3135) point to a use related to artillery. The scales are labelled YSE[R] and LOOT, which

10. All the calipers were made from brass but with small, variable, amounts of lead and tin. These alloys are heterogenous on a microscopic scale and corroded but nevertheless different parts of the calipers appear to have slightly different compositions, some parts with a very low tin content (<0.2%) and others with more tin (between 0.7% and 1.4%). For instance one of the arms of 3135 contains 0.1wt% tin while the other contains 0.9wt%; the arms of 3380 have tin contents of 0.9wt% and 1.4wt%. The wings of 3135 and 3380 both contain more lead than other parts of the calipers (3.1wt% and 6wt% respectively), potentially to aid with their casting (Ströbele and Schuster 2019, 15–16 and table 2). This suggests that the calipers were assembled from parts made in different casting events.





Detail

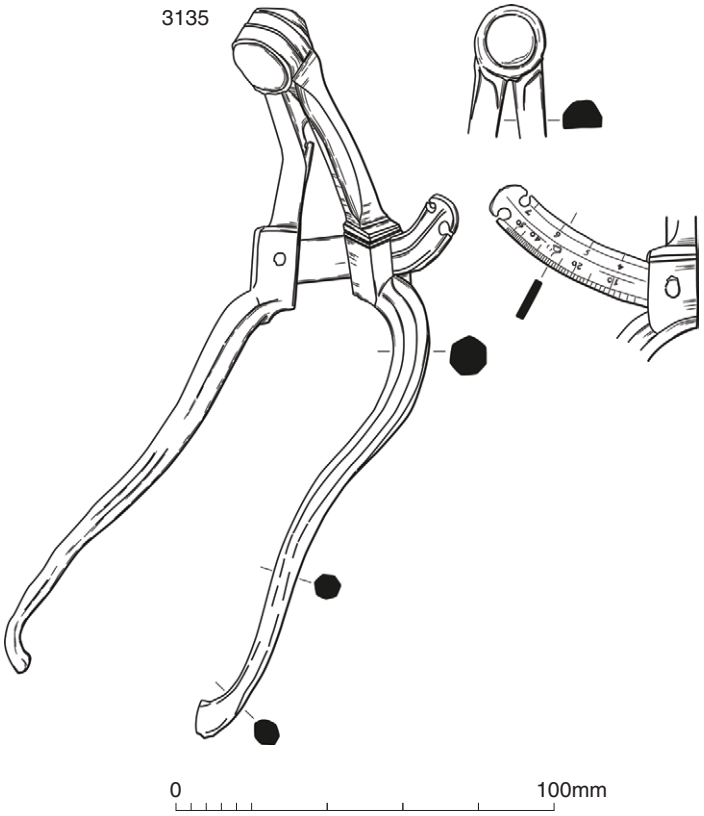


Figure 11.19 Brass wing calipers (3135; © Historic England Archive, photographs James O. Davies, © Historic England, drawing Aleksandra Osinska)

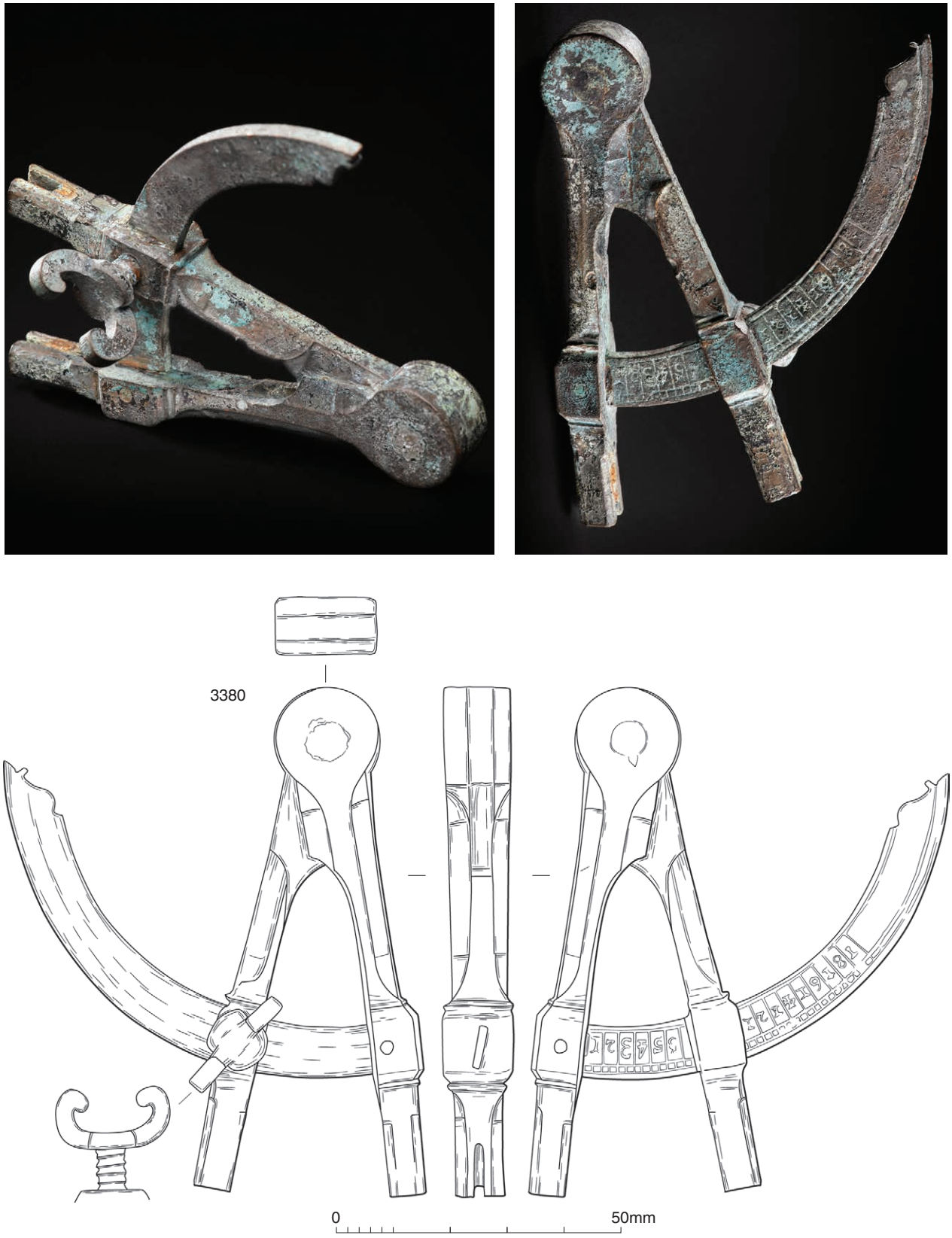


Figure 11.20 Brass wing calipers (3380; © Historic England Archive, photographs James O. Davies, drawing Aleksandra Osinska)

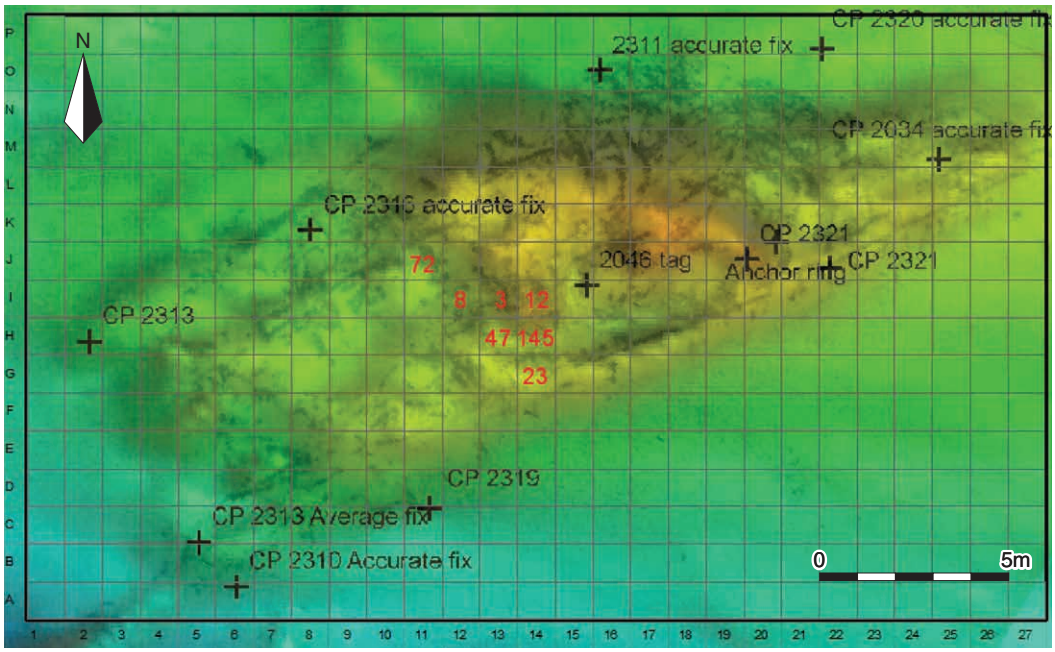


Figure 11.21 Distribution of balls recovered from S2 (© Historic England, distribution Jörn Schuster)

are the antiquated spellings for the modern Dutch words 'ijzer' and 'lood' meaning iron and lead, suggesting that the instrument was used to measure cannon balls made of iron and lead. Similarly, if the partial word [..?]EW represents the word 'sten', meaning stone, then the third scale was used for measuring stone shot.

The presence of a Dutch gunner's instrument is rather ironic considering the ship was being prepared for action against the Dutch but as the ship's artillery included several Dutch guns that were captured by the English during the First Anglo-Dutch War (Fox 2012) its presence is not so surprising.

The 'YSER' scale roughly agrees with the shot diameters and weights listed in both a table comparing dimensional data from a manuscript (B.L. MS Cotton Otho E.IX, fol.366-7) and with a brass gunner's rule from the later 16th century (Walton 1999, 139–40 and table 4.2). The shot diameter for a demi-culverin, given as 4" in both the manuscript and the rule, relates to a shot weight of 10lb on the rule scale and 9lb in the manuscript. So the values marked on the *London* caliper (3135) accord most closely with those of the gunner's rule.

The values for culverin shot (5") relate to a shot weight of 18lb on both the rule and in the manuscript, while on the caliper (3135) scale 5" relates to a weight just below 20lb, which accords better with the value for a whole culverin of 19½lb recorded in the *Table of Ordinary proportions allowed for English Ordnance* (Norton 1628, 53). The values also agree *grosso modo* with the scale displaying the measurement for iron, stone and lead shot shown on the fold-out plate between pp. 86 and 87 (see also table on p. 94), which also illustrates a simple pair of wing calipers; the plate appears to be a reproduction of a continental publication as all captions are given in French and German only. The scale on the wing of the other calipers (3380) might relate to points of gun elevation to achieve certain calculated distances (see, for example, those calculated by Thomas Harriot in the late 16th century (1 point = 7.5°) based on experiments by Luys Collado with a falconete gun (Walton 1999, 347) but increments of the calipers scale are set apart roughly 2.75° to 3°, so they must relate to a different scale.

Priming iron

The priming iron (3715), made of copper alloy, has been described above (see Chapter 7, Pascoe *et al.*).

Iron ring

A large iron ring (3261, from trench 3) has a diameter of 181mm and was held by a probable loop with a large 186mm long sub-rectangular-sectioned bar. The entire object with adhering concretion is 249mm long. Found in the area of the gun position, it could be part of the gun carriage fastening or possibly the gunport lid; such rings appear to be fitted to the insides of all the gunports of the main and middle gundecks on van de Velde's etching of the *London* (see Fig. 1.1).

Lead bullets

Analysis of the 321 lead bullet dimensions, recovered from the centre of S2 (Fig. 11.21),[11] reveals two discrete groups: one group of 183 pieces weighing 12.5g each with an average diameter of 13mm, and a second group of 138

11. Most (310) were recovered from only seven grid squares and an additional two groups comprising 11 balls were retrieved from S2 on 1 August 2016. A distribution map (Fig. 11.21) of the balls recorded by grid square shows that they come from an area in the centre of S2, measuring only 5.6m in a north-west–south-easterly direction and 3m from north-east to south-west.

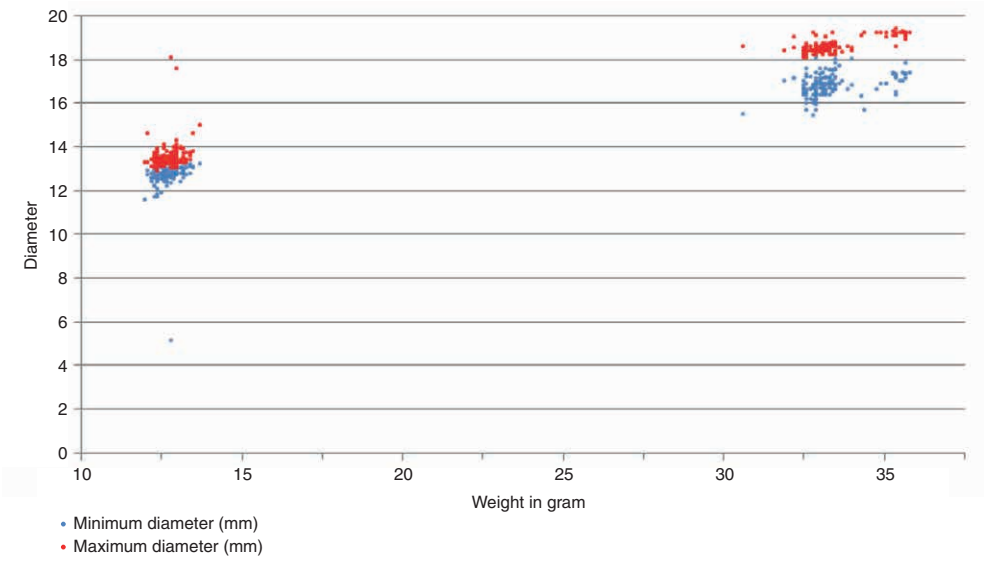


Figure 11.22 Graph displaying dimensions of lead bullets (© Historic England, drawing Jörn Schuster)

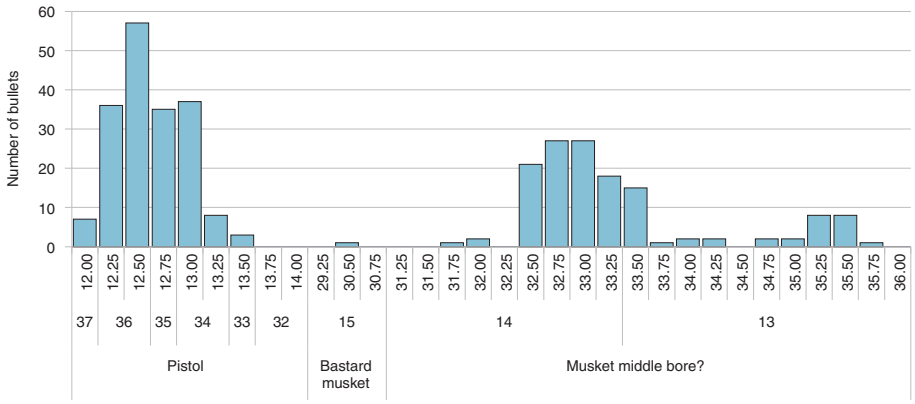


Figure 11.23 Bullet calibre at 0.25g interval, gram above, bore below (© Historic England, drawing Jörn Schuster)

pieces weighing approximately 33g each with an average diameter of 17.5mm (Fig. 11.22). The calibre of the first group (33–37 bore) indicates pistol shot, while the second group is in the range for middle bore muskets (Fig. 11.23). The sprue of the single 15 bore bullet has been nipped very low, creating a very uneven ball, and its surface is covered in many deep pit marks and cuts; it is likely that with less interference this ball could have been on the lighter end of 14 bore.

According to Foard (2017, 181; 2008, 108) 'fourteen- and 12-bore were the two standard calibres still in use for muskets in the 1660s after the Restoration'. Comparisons between the 13 and 14 bore calibre graphs from the Duart Castle wreck (1653; Foard 2017, 179, illus 248) and those from the *London*, are highly compatible, although the 102 bullets from the Duart Castle wreck clearly have a wider range, including one 16 and several 15 bore bullets. There is also a distinct peak of 12 bore bullets, a calibre of full bore musket shot which has so far not been recorded from the *London*. A very discrete calibre distribution was observed in the bullets stored in casks found on the *Vasa*, mainly comprising the equivalent of English 14 or 15 bore (Foard 2008, 289, fig. 25). The range of calibre groups is much more discrete in these three wreck sites compared to Civil War battle sites such as Edgehill (Foard 2008, 288–9, figs 22–24) or Cheriton (Claxton 2018, 7, fig. 4) but a large proportion of the bullets from those sites is affected by impact damage, which is rare in wreck assemblages. Storage of bullets with mixed calibre is seen in the enormous assemblage of more than 300,000 bullets from *La Belle* wreck (1686) intended for Native American customers (Bruseth and Turner 2005, 95–6; Rodley 2012, 16, 18, fig. 7).

At present there is no clear distinction between pistol and musket shot recovered from the *London*. If they were stored as found, they would have required sorting before use, although it is possible that they were stored in separate containers that have since disintegrated or they became mixed during the wrecking process or through disturbance on site in the succeeding years. The Chatham Ledger records the issue to the ship of pistols, matchlock and snaphaunce muskets, musketoons and blunderbusses (Fig. 11.24a–b; see Chapter 7, Pascoe *et al.*). While these weapons would require different quantities of powder, the calibre of shot

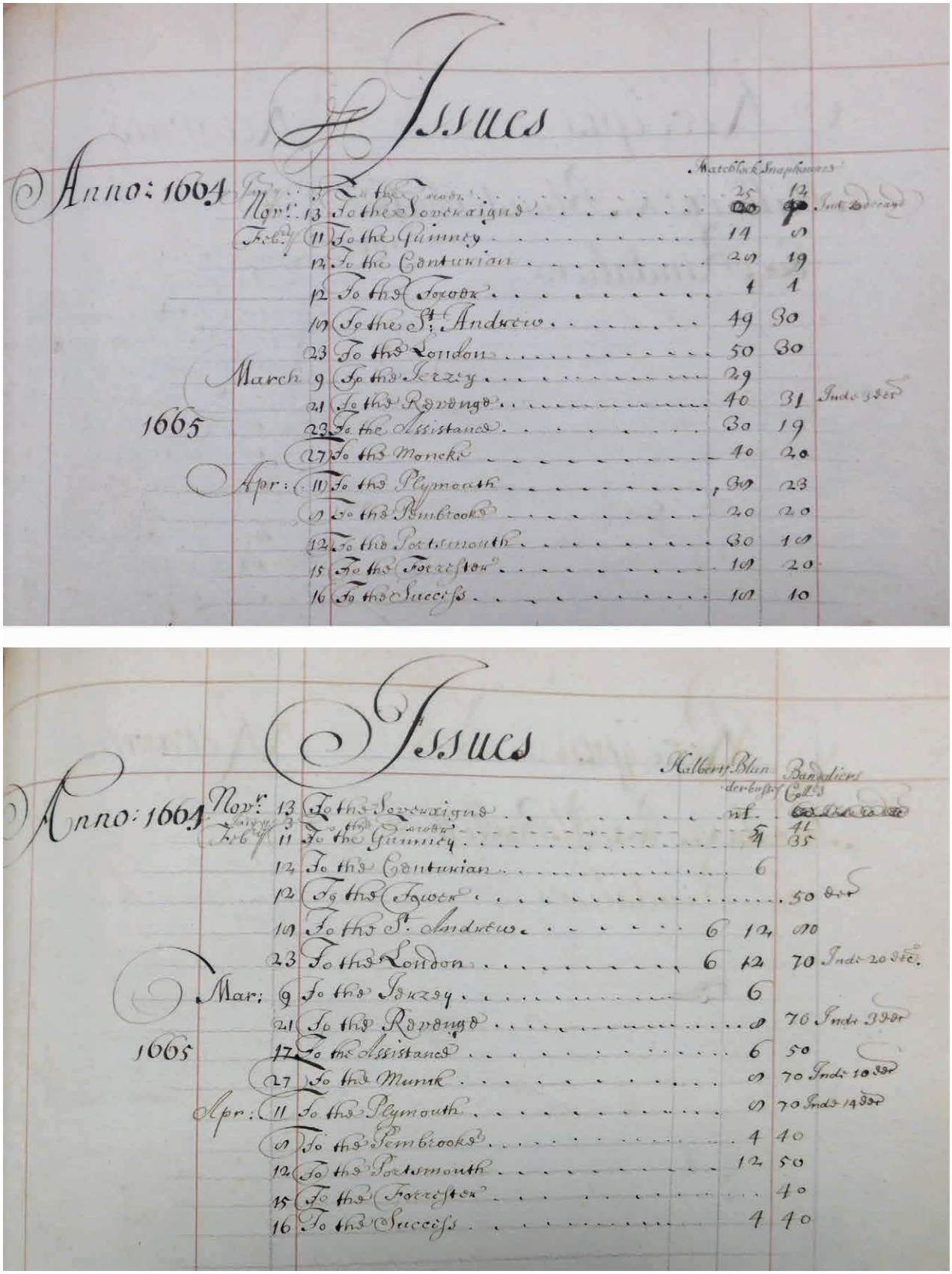


Figure 11.24a Weaponry issued to the London *recorded in the Chatham Ledger (TNA 55/1667; © TNA, photographs Michael Walsh)*

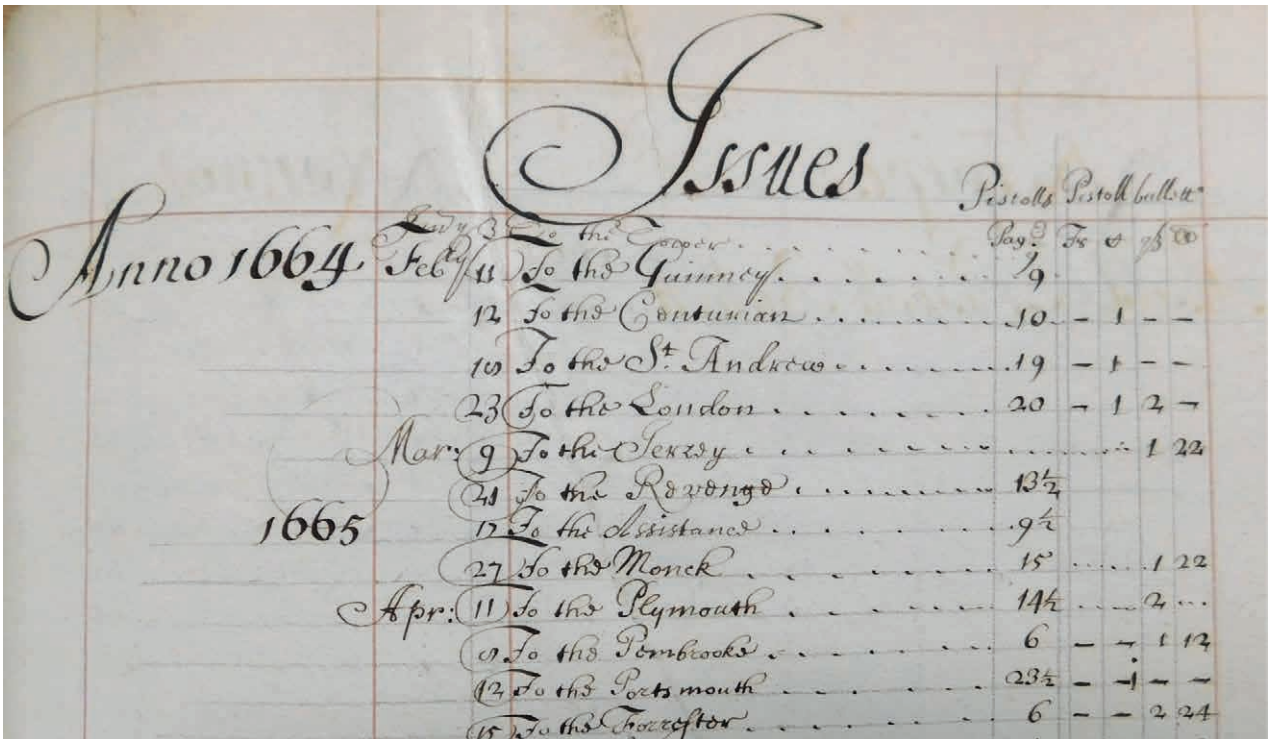


Figure 11.24b Weaponry issued to the London *recorded in the Chatham Ledger (TNA 55/1667; © TNA, photographs Michael Walsh)*

recovered from the *London* would probably have been sufficient for these weapons. This is commensurate with the decrease of calibres in the later Civil War era, when the purchase of bullets by the ton in 1645 specify three calibres, for pistol, musket and bastard musket (Foard 2008, 108).

Most of the 321 bullets show typical surface features resulting from the techniques employed in their manufacture, including a snipped sprue.[12] Another feature of the balls is a line around the equator from the join of the mould, which was at times not quite flush, resulting in a slight offset of the two halves (Foard 2009, 19, fig. 18). Other balls display distinct concentric lines below the sprue that are likely to derive from grooves in the mould (*ibid.*, 21, fig. 21; Foard 2017, 180, illus. 249d).

Many of the lead bullets from the *London* have surfaces that were deliberately roughened by cutting, gouging and/or pitting to varying degrees; even those recorded as smooth often have a few small pits, although with the latter it is uncertain whether these pits were intentional. This treatment may be what, in contemporary sources, has been described as 'burred' shot, although this term encompasses a number of features that might have changed slightly over time (Foard 2008, 152–3; 2017, 182). An inventory of shot in the Ordnance Office Stores of 1592, for instance, lists a significant quantity of '*Burre shot alias Haileshott*' (Walton 1999, 228, table 6.4).

When compared with the Duart Castle wreck (1653), the proportion of 'burred' lead bullets from the *London* (221; almost 69%) is ten times higher.[13] At Edgehill the proportion is even smaller, comprising only 2.5%, again all musket balls (Foard 2017, 182). Apart from the much larger proportion, the *London* assemblage is also different in that only one third of the 221 'burred' bullets are musket balls, whereas two thirds are pistol shot.

This large proportion of burred bullets raises the interesting question as to whether bullets were modified in this way by individual musketeers after issue, as is commonly assumed (Foard 2008, 153; 2009, 22; 2017, 182) or whether this may have been undertaken during a later stage of the production process. The large proportion of modified lead bullets would appear to suggest the latter but none of the groups of bullets recovered from the *London* comprised only modified or unmodified balls, which might be expected had modified bullets been supplied by the Ordnance Office Stores.

The fact that captured Royalists were executed at Colchester when found in possession of burr shot (Martin 2017, 161 quoting Carlton 1992, 322–3) suggests an element of personal guilt attached to the adaption of bullets, which might not have been the case had this been a centrally supplied, and therefore state-sanctioned, form of ammunition.[14]

As cited above, burr shot was frequently associated with hail shot, also known as case shot. Seller (1691, 159) states: '… you ought to make the Bags for Hail for the Guns above, and fill them with Stones, small Shot, or Pieces of

12. Where the bullet was cut off from its casting channel. This cut was so close on 138 bullets that it cut into the surface, leaving a flat area on the ball.
13. Only 6.7% of 102 balls, all of 12 bore musket calibre, were treated in this way on the Duart Castle wreck.
14. This is currently no more than speculation by the present author.



Figure 11.25 Brass strip (3100; © Historic England Archive, photograph James O. Davies)



Figure 11.26 Lead bar (3015; © Historic England Archive, photograph James O. Davies)

old Iron, which may be a great annoyance to the Enemies [*sic*] Men'.

The canvas bags or 'cartouches' used to load case shot into the barrel should not be confused with the canvas cartridges for gunpowder for artillery. Wooden shot cases are known from the Duart Castle wreck (Martin 2017, 160–2, illus. 221–2), as well as from the *Batavia* and *Vasa*, and in 1639 Ward describes metal cases (Foard 2008, 130–1, 301, fig. 63). No cases or canvas bags have yet been found on the *London* and finds in the vicinity of the bandoliers (see Chapter 7, Pascoe *et al.*) indicate that at least some of the bullets were intended for individual use in muskets and pistols. No 'slugs' (elongated non-spherical bullets of varying forms)[15] were identified on either the *London* or the Duart Castle wreck (Foard 2017, 179).

As with the Duart Castle wreck, only one bullet (3069.04), a pistol shot weighing 12.8g, had been discharged.[16] How this damage occurred cannot be ascertained but ships engaged at close quarters are likely to have had bullets embedded in their timbers (Foard 2017, 182). Other indications of possible use in the *London* assemblage include facets, potentially from a ram rod, found on a pistol shot and on two musket bullets, which came from the area with the highest density of lead shot on the wreck.

Objects of uncertain use

A thin brass strip (3100; from grid square I17), 301.5mm long and between 3.1mm and 18.3mm wide, has corroded ends and a flat ovoid section with rounded edges (Fig. 11.25). It is possible that this might have been a reinforcement strip for some kind of staff or stick, or perhaps for a firearm.

A rectangular-sectioned lead bar (3015; from grid square I12), weighing 2.7kg and measuring 385 x 43 x 24mm, has holes similar to those recorded on the lead patches, with sub-rectangular-sectioned holes at either end (Fig. 11.26). One narrow side has multiple transverse hammer cross-pane marks, while the holes are round with bevelled/countersunk sides. The surface on the opposite side displays longitudinal ridges and imprints from a wooden surface (probably the surface onto which it was cast); here the holes are rectangular with material pushed outwards. Morphologically the lead bar closely resembles sash weights like the five examples recovered from the wreck of HMS *Colossus*, lost off the Isles of Scilly in 1798, although these have only one hole near a bent end (Camidge 2015, 54, fig. 54). It is, however, questionable whether the bar from the *London* can be explained in a similar way as the use of weighted sash windows was only just emerging in the mid-

15. For a definition see Foard 2008, 121–5; 2009, 9–10, figs 3–4.
16. From grid square H13 with one side flan-shaped and concave and the other flat with an irregular surface created on impact (the outlier in the pistol group in Fig. 11.21).

Table 11.2 Results of the copper-alloy object analyses by XRF, wt% (where no value is reported = below detection)

No./object/part	Material		S	Fe	Ni	Cu	Zn	As	Ag	Sn	Sb	Pb	Bi	#N
3392	brass	average	–	0.33	0.18	76.2	19.8	0.3	–	1.15	–	2.0	0.01	3
map divider		min	–	0.30	0.15	66.0	15.7	0.3	–	0.67	–	1.7	–	–
arm 1		max	–	0.42	0.21	77.5	21.1	0.6	–	1.47	–	15.8	0.03	–
3392	brass	average	–	0.78	0.17	69.1	21.8	0.3	0.01	0.70	–	7.1	–	5
map divider	leaded	min	–	0.66	0.15	64.9	19.8	0.1	–	0.43	–	2.3	–	–
arm 2		max	–	0.89	0.18	72.7	23.4	0.4	0.02	1.01	–	13.3	–	–
3477	brass	average	–	0.37	0.11	75.0	22.2	0.2	0.01	0.96	–	1.2	–	4
map divider		min	–	0.36	0.10	73.8	21.9	0.1	–	0.74	–	0.6	–	–
arm 1		max	–	0.37	0.12	75.8	22.5	0.2	0.04	1.14	–	2.1	–	–
3477	brass	average	–	0.33	0.10	74.8	22.7	0.1	0.01	1.03	–	0.9	–	4
map divider		min	–	0.32	0.10	74.5	22.5	0.1	–	0.50	–	0.6	–	–
arm 2		max	–	0.33	0.11	75.7	23.0	0.2	0.04	1.91	–	1.2	–	–
3530	brass	average	–	1.87	0.10	60.7	9.3	0.9	0.13	3.63	0.69	22.7	–	5
ring	leaded	min	–	1.61	0.08	45.3	7.5	0.7	0.06	3.14	0.52	11.1	–	–
		max	–	2.09	0.13	72.3	11.1	1.1	0.18	4.58	0.77	40.7	–	–
3122	brass	average	–	1.27	0.06	73.6	23.0	0.1	0.07	0.76	–	1.1	<0.01	4
spoon		min	–	0.87	0.06	72.2	22.6	0.1	–	0.44	–	0.5	–	–
main mass		max	–	2.30	0.07	74.5	23.2	0.2	0.18	1.09	–	1.4	0.01	–
plating		average	5.3	3.59	0.07	55.2	24.0	0.2	0.16	7.78	–	3.7	–	20
3760	brass	average	0.1	0.29	0.12	70.9	26.4	0.1	0.01	0.02	–	2.0	–	3
map divider		min	0.1	0.26	0.09	70.1	24.5	0.1	–	–	–	1.8	–	–
arm 1		max	0.1	0.30	0.13	72.6	27.4	0.1	0.02	0.03	–	2.2	–	–
3760	brass	average	0.1	0.33	0.11	71.1	26.8	0.1	0.01	–	–	1.5	–	4
map divider		min	0.1	0.31	0.10	70.7	26.5	0.1	–	–	–	1.1	–	–
arm 2		max	0.1	0.34	0.11	71.5	27.3	0.1	0.03	–	–	1.8	–	–
3760	brass	average	0.2	0.27	0.18	76.4	21.7	0.1	–	0.18	–	1.0	–	4
map divider		min	0.1	0.26	0.17	76.0	21.3	0.1	–	0.07	–	0.8	–	–
rivett		max	0.2	0.28	0.18	76.6	21.9	0.1	–	0.29	–	1.2	–	–
3040	brass	average	–	0.67	0.13	75.6	20.5	0.2	0.02	1.04	0.02	1.8	0.04	20
pipe stopper		min	–	0.55	0.12	74.3	18.2	0.1	–	0.47	–	1.2	–	–
		max	–	0.98	0.15	78.0	21.4	0.3	0.07	1.34	0.10	2.6	0.26	–

3041	brass	average	–	0.93	0.12	73.2	21.9	0.2	0.06	1.31	0.02	2.3	–	5
map divider		min	–	0.51	0.08	72.1	20.0	0.1	0.01	0.77	–	1.8	–	–
arm 1		max	–	2.11	0.14	74.1	22.5	0.4	0.15	2.12	0.06	3.0	–	–
3041	brass	average	–	0.63	0.12	75.9	20.5	0.1	0.01	1.29	0.01	1.5	–	7
map divider		min	–	0.47	0.09	74.9	17.9	0.1	–	0.95	–	1.0	–	–
arm 2		max	–	0.99	0.13	77.3	21.6	0.2	0.40	1.90	0.05	2.3	–	–
3056	brass	average	–	0.47	–	75.8	22.1	0.1	0.04	0.04	–	1.6	–	4
spoon		min	–	0.44	–	74.0	20.8	<0.1	–	–	–	0.9	–	–
main mass		max	–	0.53	–	77.5	23.4	0.1	0.06	0.06	–	2.0	–	–
plating		average	9.3	1.02	–	67.1	11.2	0.2	0.19	8.13	–	2.9	–	5
3072	gunmetal	average	–	0.67	0.46	78.0	5.8	0.9	0.07	3.99	2.72	7.3	–	16
weight		min	–	0.52	0.39	68.1	5.0	0.3	0.01	2.77	1.83	1.4	–	–
		max	–	1.19	0.57	83.1	8.0	1.3	0.13	5.21	4.16	18.2	0.03	–
3100	brass	average	–	0.67	0.08	71.5	26.8	0.1	0.01	0.05	0.00	0.9	0.01	10
Cu bar		min	–	0.60	0.06	69.5	23.8	<0.1	–	–	–	0.4	–	–
		max	–	0.75	0.13	73.9	27.7	0.1	0.03	0.26	0.00	2.2	0.03	–
3135	brass	average	–	0.40	0.18	71.6	23.1	0.1	0.02	1.43	0.04	3.1	–	5
caliper		min	–	0.35	0.15	69.9	22.6	0.1	–	0.72	–	2.0	–	–
circle		max	–	0.50	0.22	73.7	23.5	0.2	0.05	2.09	0.11	5.6	–	–
3135	brass	average	–	2.16	0.18	70.8	24.3	0.1	0.02	0.88	0.00	1.6	–	5
caliper		min	–	1.51	0.16	69.8	23.6	0.1	–	0.67	–	0.8	–	–
arm 1		max	–	2.95	0.20	71.8	25.1	0.1	0.04	1.11	0.02	2.5	–	–
3135	brass	average	–	0.37	0.16	73.6	24.8	0.1	–	0.10	–	0.9	–	5
caliper		min	–	0.34	0.15	71.6	21.9	0.1	–	0.05	–	0.4	–	–
arm 2		max	–	0.45	0.20	76.9	26.6	0.1	0.01	0.13	–	1.5	–	–
3135		average	1.4	20.71	–	72.8	3.4	0.1	–	–	–	1.6	0.03	5
caliper		min	0.5	4.57	–	35.5	0.4	–	–	–	–	0.4	–	–
loose rivett		max	3.7	47.73	–	93.3	9.1	0.2	–	–	–	3.8	0.13	–
3165	brass	average	–	0.51	0.08	76.5	19.3	0.2	0.03	0.79	0.23	2.4	–	5
sundial		min	–	0.42	0.03	72.7	10.6	0.2	–	0.55	0.16	1.8	–	–
lower casing		max	–	0.75	0.10	84.8	22.3	0.2	0.10	1.28	0.39	4.2	0.02	–

Table 11.3 Results of the pewter object analyses, XRF, wt% (where no value is reported = below detection, #N = number of analyses)

No./object/part	Alloy		Cu	Sn	Sb	Pb	Bi	#N
3153	fine	average	1.3	96.1	0.01	2.6	0.01	8
spoon		min	0.1	93	0.01	1	–	–
		max	5.4	98.5	0.01	4.3	0.02	–
3110	lay	average	0.1	85.9	0.01	13.9	0.01	6
jug		min	0.1	61.3	0.01	38.6	–	–
		max	0.3	97.4	0.01	2.6	0.1	–
3359	lead alloy	average	0.9	31	–	68.2	0.1	10
button		min	–	14.5	–	47.2	–	–
		max	2.8	50.4	0.01	85.4	0.01	–
3430	fine	average	2	96	0.01	1.2	0.73	10
spoon		min	1.6	94.3	0.01	0.5	0.13	–
		max	2.6	97.6	0.01	2.2	1.28	–
3032	lead alloy	average	0.4	77.8	0.01	21.6	0.19	6
spoon		min	0.2	60.4	0.01	12.5	–	–
		max	1.1	87.2	0.01	39.4	1.08	–
3039	fine	average	1.9	96.2	0.01	1.3	0.62	4
jug handle		min	0.7	94.9	0.01	0.5	0.3	–
		max	2.6	98.6	0.01	1.7	0.8	–
3043	lead alloy	average	0.2	12.7	0.11	87	0.01	9
threaded end		min	0.1	5.2	–	60.5	0.01	–
		max	0.4	38.6	0.5	94.7	0.01	–
3053	lead alloy	average	0.7	61.5	0.02	37.4	–	28
chamber pot		min	–	24.4	0.01	6	–	–
		max	2.7	91.6	0.2	75.6	0.01	–
3600	lay	average	3.6	84.1	0.01	12.3	0.01	10
spoon		min	–	70.3	0.01	4.1	–	–
		max	21.3	93.2	0.01	29.7	0.05	–

17th century, with the earliest surviving vertically sliding double-hung sash windows apparently dating to 1701 (Pickles *et al.* 2015, 13). In contrast, archival and graphic evidence suggest that only casement windows were fitted to ships of the *London* period (R. Endsor pers. comm.). Given the similarity of the nail head imprints to those on the lead patches it seems likely that this lead bar was used to fill joints in the planking to keep the gundecks watertight (S. Ellis pers. comm).

Conclusion

Even though only a limited area of the *London* has so far been investigated the assemblage discussed above has provided a multifaceted glimpse of life on board this naval vessel. On a purely quantitative level these facets are clearly dominated by the primary military purpose of the vessel, with the intriguing aspect that some of the weapons were being made ready to be turned against their makers, as in the case of the Dutch calipers for the measurement of cannon balls and indeed the Dutch cannon. The assemblage of lead bullets provides an important resource for future discussions about who was responsible for making burr shot, whether it was a centralised (state-sanctioned) supply or done by the individual gunman.

Then there are the objects employed in the operation of the ship, including the deadeyes as part of the rigging, and the navigational implements like the dividers for chart work and the sounding weight for fathoming the depth of coastal waters. The significance of being able to carry out running repairs is evidenced by the 12 lead patches, the roll of lead sheet, possibly the lead bar as well as the so far not very diverse range of tools, only comprising a hammer and a possible tool or knife handle, both of which might have been employed in the working of the lead patches.

The final group of objects are concerned with the more personal sphere, with very few items, like the brass pins and the pewter buttons, related to the garments of the men (and possibly women). The diverse range of spoons found on board suggests that they were individual possessions rather than being centrally supplied by the Navy and the mark of an unmarried man on one of them would appear to support this assumption. Whether the case bottle thread and the fragment of a flagon or measure belonged to one or more individuals or whether they might have been used to share out portions of beverages from the ship's provisions remains

undetermined. The pewter chamber pot and probably also the ivory comb were most probably not used for the comfort of a simple deck hand but more likely belonged to the ranks of his superiors.

Lastly the discovery of a urethral syringe demonstrates the dispensing of medical services for the crew, in this case probably related to the results of activities of crew members when on shore leave.

Analyses of copper-alloy and pewter objects

by Florian Ströbele and Jörn Schuster

The Pewterers' Company defined various alloys (grades) of pewter, such as fine pewter, which was lead-free and intended for tableware (sadware) and cutlery, and lay pewter, where the percentage of lead was not exactly defined. Seventeen copper-alloy and 11 tin-alloy objects were analysed using XRF (Ströbele and Schuster 2019). The compositions of the objects were compared to reference material from other sites in order to determine overall trends in metal composition. The results show that the most appropriate alloy was chosen relating to the type and function of the object (Tables 11.2 and 11.3).

Copper-alloy objects

The copper-alloy objects, including the navigational dividers (3041, 3392, 3477 and 3760), the calipers (3135 and 3380) and the sundial (3165 and 3328), were made mainly of brass of consistent composition. Most of the dividers and calipers have zinc contents of around 20%, which is comparable with instruments from other contemporary wrecks; this alloy probably had a good cost/material property ratio as these instruments had to be precise and needed to maintain this precision throughout their working lifespans. The pins (3166 and 3338; Fig. 11.13) contained the highest zinc contents whereas the ring/washer (3530) and weight (3072; Fig. 11.1) were more complex alloys containing much less zinc and higher lead contents.

Two brass spoons with surviving tinned areas (3056 and 3122) have maker's marks (or touchmarks). The marks are similar, although one (3122) is incomplete, and the spoons have similar compositions so this analysis supports the theory that these came from the same manufacturer. The bottom case of the sundial (3165) also has a distinctive composition, with small amounts of antimony, tin and lead, which is closely matched by the composition of what is thought to be the lid of the sundial (3328); this confirms that they belonged to the same object.

Pewter objects

The pewter objects were especially heterogeneous. Most of the cutlery and tableware was made from Guild-specified tin-rich alloys, whereas other types of object, including the button (3359), the possible chamber pot (3053) and the threaded screw-cap spout (3034), contained more lead.

The analyses of the pewter objects showed that the rules of the Pewterers' Company regarding the lead content had been obeyed in most cases for the tableware and cutlery objects. Only two spoons (3032 and 3600; Fig. 11.3) were made from higher lead alloys. Rather than naval issue, at least one spoon (3600) appears to have been a personal possession, brought aboard presumably by the owner. This and the two brass spoons (3056 and 3122) cited above raise the question as to whether the Navy had a 'certified' supplier of utensils or bought them as and when required.

The other pewter objects that were not made from 'company-grade' metal, including the button (3359, Fig. 11.14), the threaded screw-cap spout (3043, Fig. 11.4) and the possible chamber pot (3053, Fig. 11.15), were not intended for use associated with food and therefore did not have to meet the standards.

Chapter 12
Pottery, Brick and Tile

Duncan H. Brown with a contribution by Richard Endsor

Pottery

Twenty pottery fragments were recovered from the *London* wreck site. Two of those (3385 and 3752) are in 19th-century refined earthenware so are clearly much later than the shipwreck and will not be discussed further. Four of the remaining pieces (3062, 3146, 3748 and 3749) are from the same pot but no other pieces can be matched up, so 15 individual vessels are represented by 18 fragments.

The assemblage was characterised by ware and vessel type and quantified by vessel count, although rim percentages were also taken. Vessel forms and the shapes of component parts were identified in accordance with the classification produced by the Medieval Pottery Research Group (MPRG) (1988). Three groups of ware-type could be identified, including English earthenware (vessels 1–5), Frechen stoneware (vessels 6–12) and Seville coarseware (vessels 13–15; Table 12.1).

Vessel 1 (3753) is in a fine, slightly sandy, whiteware that suggests an origin at the kilns on the Surrey–Hampshire border (Pearce 1992), although the pale green glaze is unusual for a product that is typically glazed bright green or yellow. The diameter of this plain body sherd suggests a jar.

Vessels 2 (3147), 3 (3723), 4 (3062, 3146, 3748, 3749) and 5 (3750) are all in red earthenware (Fig. 12.1). Vessel 4 has the characteristic thickened and squared rim seen in the well-known tripod cooking pots, or grapen, from the Low Countries (MPRG 1988, 4.4). The precise origins of vessel 4 cannot be ascertained but it is likely to be English. The fabric is quite hard-fired and has a reduced grey core, while the glaze has a greenish tinge. The combing on the body has not been executed very tidily and appears to be an attempt to replicate the rilling that characterises the Low Countries products. All those factors may indicate an English origin. The other redwares are also likely to be English although where they were made is unclear.

Seven Frechen salt-glazed stoneware pots are represented (vessels 6–12). Vessel 6 (3073) is a small, plain narrow-necked jug that, apart from a broken handle, survives complete (Fig. 12.2). All the other stoneware finds are almost certainly from Bartmann-style jugs. Vessel 7 (3037) is also almost complete, only lacking the rim and handle (Fig. 12.3). The abstract design of the medallion resembles an upside-down face. The other examples of Frechen stoneware (vessels 8–12: small find numbers 3145, 3693, 3746, 3747 and 3793) are smaller fragments, none of which can be matched with each other. Frechen stoneware was the most common Rhenish ceramic product brought into England in the 17th century and is also regularly found on contemporary shipwreck sites (e.g. Martin 1995, 22). Durable and reliable, the Frechen-type narrow-necked stoneware jugs are ideal for use on ships to store liquids such as wine or spirits and it is no surprise that several are associated with the *London*.

The remaining three finds (vessels 13–15: 3101, 3109 and 3137) are fragments of Seville-type olive jars, including a rim, a base and a body sherd. It is not possible to ascertain that all three fragments derived from the same pot but it is unlikely that the ship carried only one such jar. Spanish olive jars are also common finds on 16th and 17th-century shipwrecks (e.g. Brown and Curnow 2004) and are typically characterised as containers for olive oil. Whatever they held, olive jars are associated with provisioning and are likely therefore to have been associated with the galley.

This small assemblage includes pottery types that could be seen as typical of shipwreck assemblages of 17th-century date, including redware cooking or storage vessels, stoneware jugs and olive jars. There is little information to indicate whereabouts in the ship they were located during a voyage but, given the explosive nature of the ship's demise, that will probably remain difficult to establish. These are all utilitarian products most closely associated with the galley, well suited to the environment of a warship.

In a shipwreck assemblage it is never easy to establish when or where specific pots were brought on board and there are therefore often several possibilities for their origins. A starting point of Chatham for the *London's* final voyage might suggest that the redwares were produced in Kent but vessel 3, at least, has the appearance of having been well used, thus pre-dating any provisioning that occurred early

Table 12.1 Details of the pottery assemblage in vessel number order

Vessel no.	Object no.	Ware type	Vessel type	Description
1	3753	Post-medieval whiteware	Jar	Body sherd with internal pale green glaze
2	3147	Post-medieval red sandy ware	Jar	Plain, rounded, upright rim sherd, 140mm diameter, rim percent 12, glossy internal and external greenish-clear lead glaze
3	3723	Post-medieval redware	Jar	Upright, slightly thickened rim sherd, 140mm diameter, rim percent 20. Internal and external clear lead glaze, flaking off the external surface
4	3062, 3146, 3748, 3749	Post-medieval redware	Cooking pot	2 rim and 2 body sherds of a *grape*-style cooking pot, with thickened, squared rim, 200mm diameter, rim percent 20. All-over external clear lead glaze and combed horizontal lines on the shoulder and body, partial internal clear lead glaze towards base
5	3750	Post-medieval redware	Jar	Body sherd with external clear lead glaze
6	3073	Frechen stoneware	Narrow-necked jug	Small, plain, in pale grey-brown salt glaze. Complete profile with missing handle. 115mm tall
7	3037	Frechen stoneware	Bartmann jug	Complete base and body with rim and handle missing and partial face. Single oval medallion on front has the appearance of a face applied upside down. Dark brown salt glaze. 180mm from base to broken edge below the rim
8	3145	Frechen stoneware	Jug	Handle with dark brown salt glaze
9	3693	Frechen stoneware	Jug	Body sherd with brown salt glaze
10	3746	Frechen stoneware	Jug	Body sherd
11	3747	Frechen stoneware	Jug	Body sherd
12	3793	Frechen stoneware	Bartmann jug	Face mask fragment
13	3101	Seville-type coarseware	Olive jar	Rim sherd 90mm diameter, rim percent 16
14	3109	Seville-type coarseware	Olive jar	Base fragment, probably from a rounded olive jar
15	3137	Seville-type coarseware	Olive jar	Body sherd

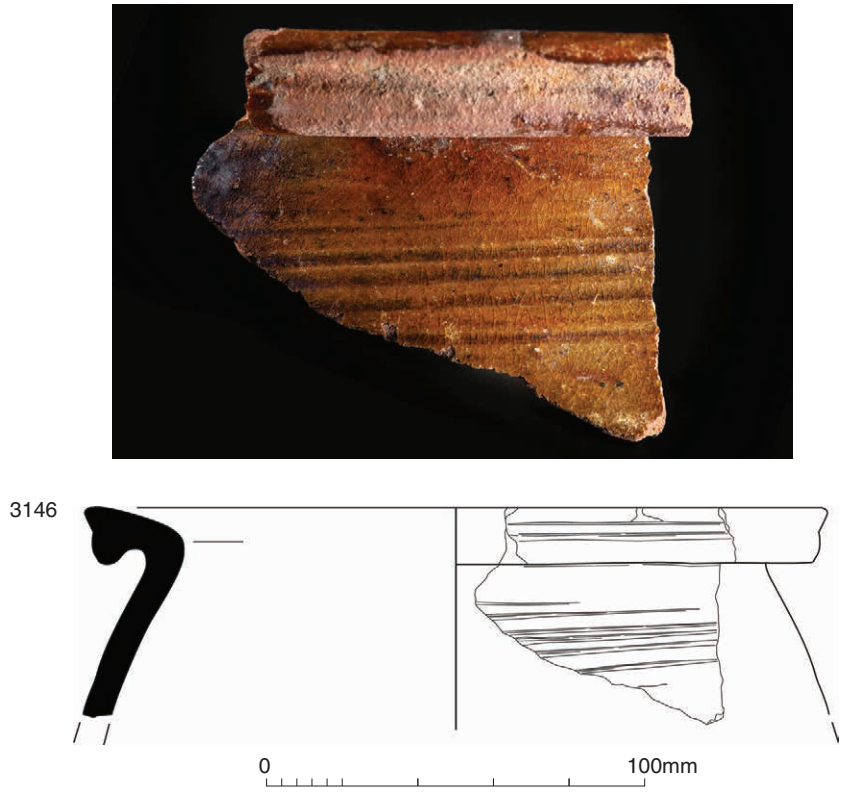


Figure 12.1 Red earthenware rim sherd (3146; © Historic England Archive, photograph James O. Davies, © Historic England, drawing Aleksandra Osinska)

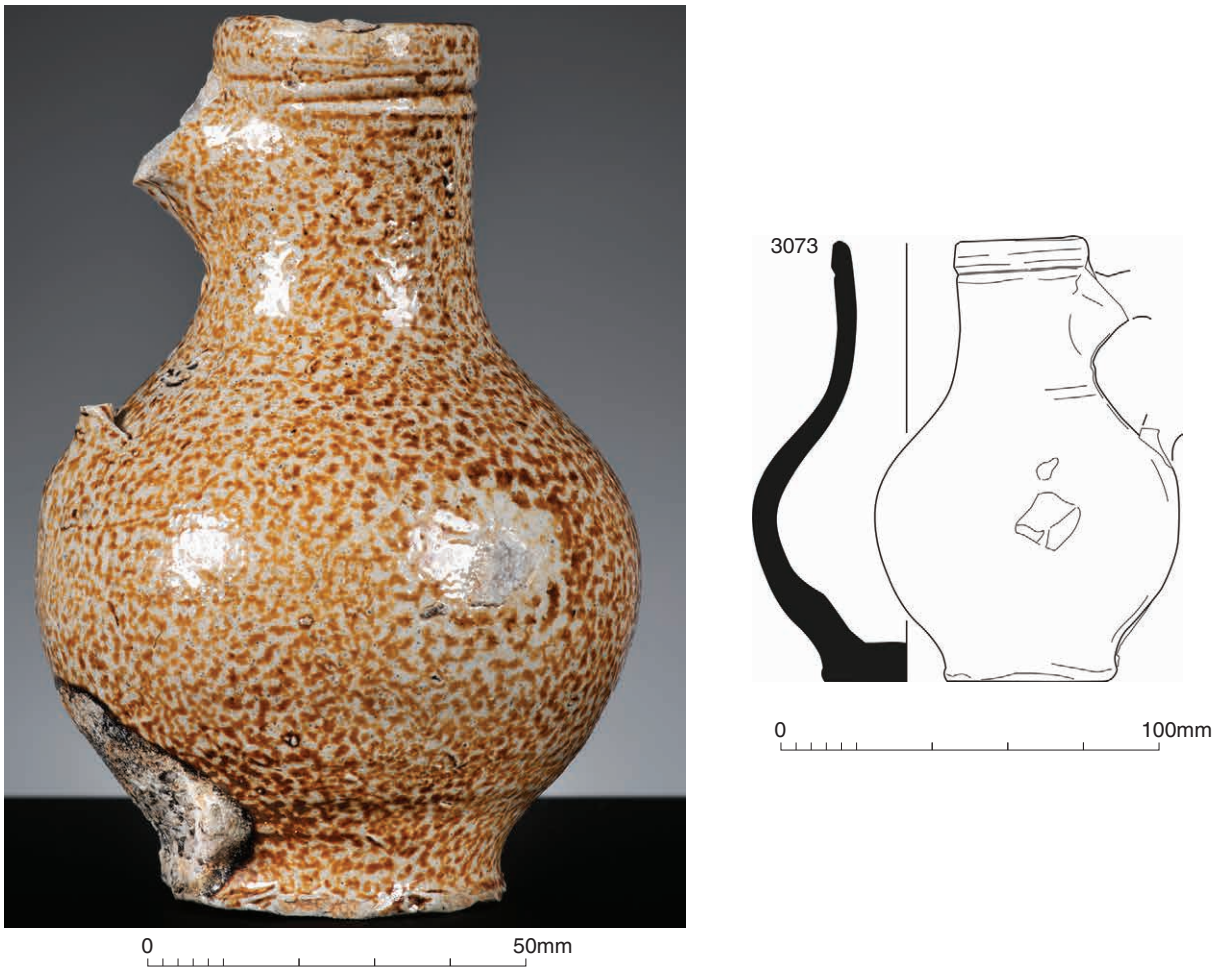


Figure 12.2 Small Frechen narrow-necked jug (3073; © Historic England Archive, photograph James O. Davies, © Historic England, drawing Aleksandra Osinska)

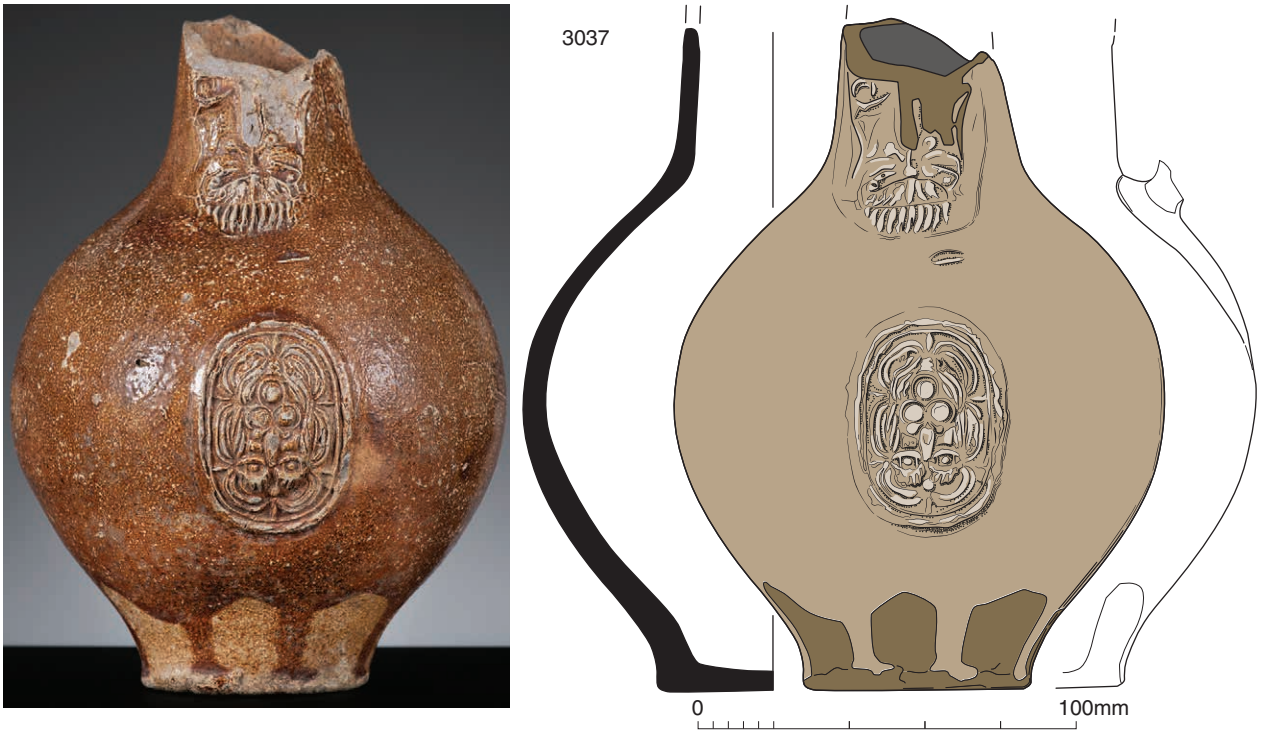


Figure 12.3 Bartmann-style jug (3037; © Historic England Archive, photograph James O. Davies, © Historic England, drawing Aleksandra Osinska)



3179



3334



3339

0 50mm

Figure 12.4a Fragments of a tin-glazed tile (3179, 3334 and 3339; © Historic England Archive, photographs James O. Davies)



Figure 12.4b Fragments of a tin-glazed tile (3179, 3334 and 3339; © Historic England, drawings Aleksandra Osinska)

Table 12.2 A descriptive list of the brick and tile

No.	Object no.	Fabric description	Object type	Length (mm)	Width (mm)	Thickness (mm)	Description
1	3179, 3334, 3339	tinglazed	wall tile	–	–	8	blue painted floral design with fox-type animal
2	3751	tinglazed	wall tile	–	–	9	blue painted floral pattern
3	3063	sandy red-brown	peg tile	–	145	13	lower part
4	3124	sandy red-brown	peg tile	–	145	13	two fragments of upper part, two square holes
5	3131	sandy red-brown	peg tile	v	145	13	lower part
6	3482	sandy red-brown	peg tile	265	145	13	almost complete; two square holes; 1019g weight
7	3553	sandy red-brown	peg tile	–	145	13	top half; two square holes
8	3058	red sandy	brick	222	110	54	almost complete
9	3765	red sandy	brick	–	–	30	stabbed hole in upper surface; heavily burned upper surface

in 1665. A base on the Thames closer to London would suggest that most of the pottery was derived from that city, in which case Essex might be the more likely source for the redwares. Either way, vessel 4 would have been used in the galley and the same is probably true of the other English pots.

Brick and tile

Eleven brick and tile fragments were recovered, three of which came from the same tin-glazed tile (3179, 3334 and 3339), representing a total of nine individual items (Table 12.2). The longest dimension (length), width and thickness were recorded for each object, while fabrics have been characterised on a simple, visual examination, mainly to establish how many different types are represented. The composition of the assemblage is shown in Table 12.2. There are fragments from two tin-glazed tiles. Object 1 occurs in two fragments. One (3179) has a blue-painted animal, probably a fox, of which the hindquarters and a bushy tail survive. That figure is enclosed in a floral surround in blue and orange, a motif that is repeated on 3334, probably another fragment of the same tile (Fig. 12.4). Another small fragment (3751) has a blue-painted floral design. In a terrestrial context these are wall tiles and, if they were used on board the ship, they were probably located in the captain's or officers' quarters. In the 17th century tin-glazed tiles such as these were produced in the Low Countries and these examples are likely to belong to that tradition.

Five peg tile fragments (3063, 3124, 3131, 3482 and 3553) were recovered, which were probably used to line the walls of the cook room. They are made of the same fabric, a pale red-brown sandy ware with no other visible inclusions, and seem to have the same dimensions, so were probably brought on board and fitted as a single consignment. The most complete example (3482), missing just one of the top corners, weighs 1019g which, with the number of tiles likely to have been used, indicates how much weight the cook room would have carried. Where peg holes survive (3124, 3482 and 3553) they are all square in shape, which may suggest the use of metal nails; medieval roof tiles, which were fixed with wooden pegs, have circular holes.

Production values may not have been particularly high, as the holes are not consistently positioned. In one (3553) they are squarely in line with the top of the tile, while in others (3124 and 3482, Fig. 12.5) they are diagonal in relation to the top. In one of these (3124) the holes are located very close together, slightly to one side.

An almost complete galley brick (3058, Fig. 12.6) has a dense, red, sandy fabric with some red clay pellets. Another small fragment of brick (3765) has a similar red sandy fabric but is not identical. It has a hole stabbed in the upper surface, which has been burned to a dark grey colour. These bricks, which would have lined the cook room floor, with the tiles would have protected the ship's oak structure from the fires that burned in the cook room. The peg tiles and bricks are most likely English in origin, made close to Chatham, where the ship had been fitted out. This small assemblage provides a glimpse into the use of ceramic building materials on the *London*.

The location of the cook room

by Richard Endsor

There is some conjecture regarding the general location of cook rooms on ships in the middle of the 17th century. In earlier times they were situated amidships down in the hold, as in the *Mary Rose*, but Captain John Smith noted in *A Sea Grammar* (Goell 1970) that they were fitted in the forecastle in some merchantmen. The Navy, however, was generally conservative to change, so the cook room on the *London* may still have been situated in the hold. By the 1670s, however, the cook rooms of Navy ships had been moved into the forecastle where they remained until the end of the days of sail. Although a great deal is known about cook rooms in the forecastle position, very little is known about the arrangement in the 1650s. The cook room of the

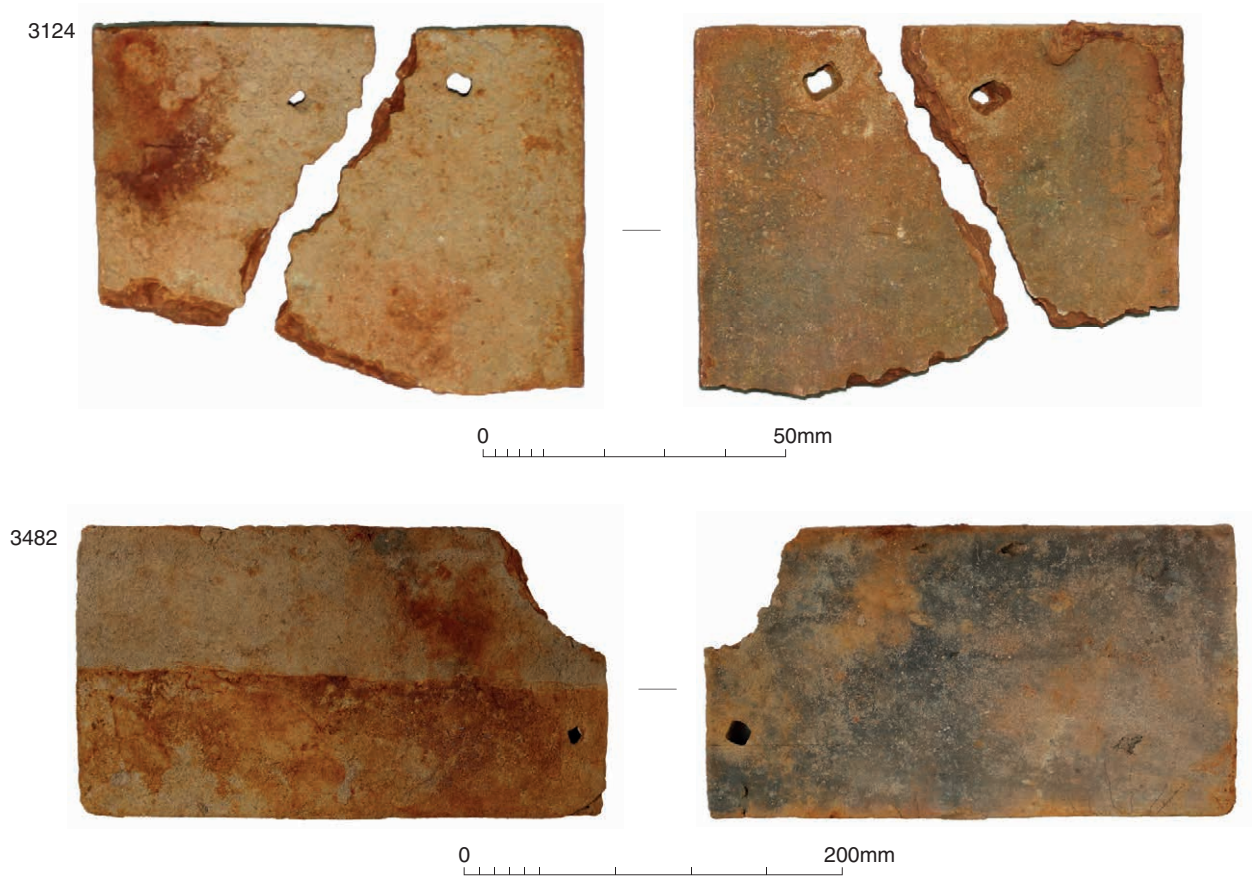


Figure 12.5 Peg tile fragments (3124 and 3482; © Historic England, photographs Angela Middleton)



Figure 12.6 Galley brick (3058; © Historic England, photographs Angela Middleton)

ships of 1677 (Endsor 2009, 63),[1] which were the same size as the *London* with the same gunport arrangement, contained 2000 bricks, 12 paving tiles and 500 plain tiles (Fig. 12.7).

The galley tiles, brick and possible firewood associated with the cook room and the concentrations of musket and pistol shot associated with the gunners' storeroom provide clues to the surviving area of the ship. At this time, these were located on a platform in the hold at the bow (Fox 2012, 61; Pascoe 2017, 33). The main powder room was deep in the hold, immediately abaft the foremast, with a forward platform over it. This platform had storerooms for the boatswain, the carpenter and the gunner (also known as the upper powder room), lit with protected lighting (Fox 2012, 58), the Muscovia langhorns listed in the Chatham Ledger (moscovia lanthorns, see Chapter 3).

1. Endsor refers specifically to one ship, *Lenox*, but other ships of the period were built in a similar manner.

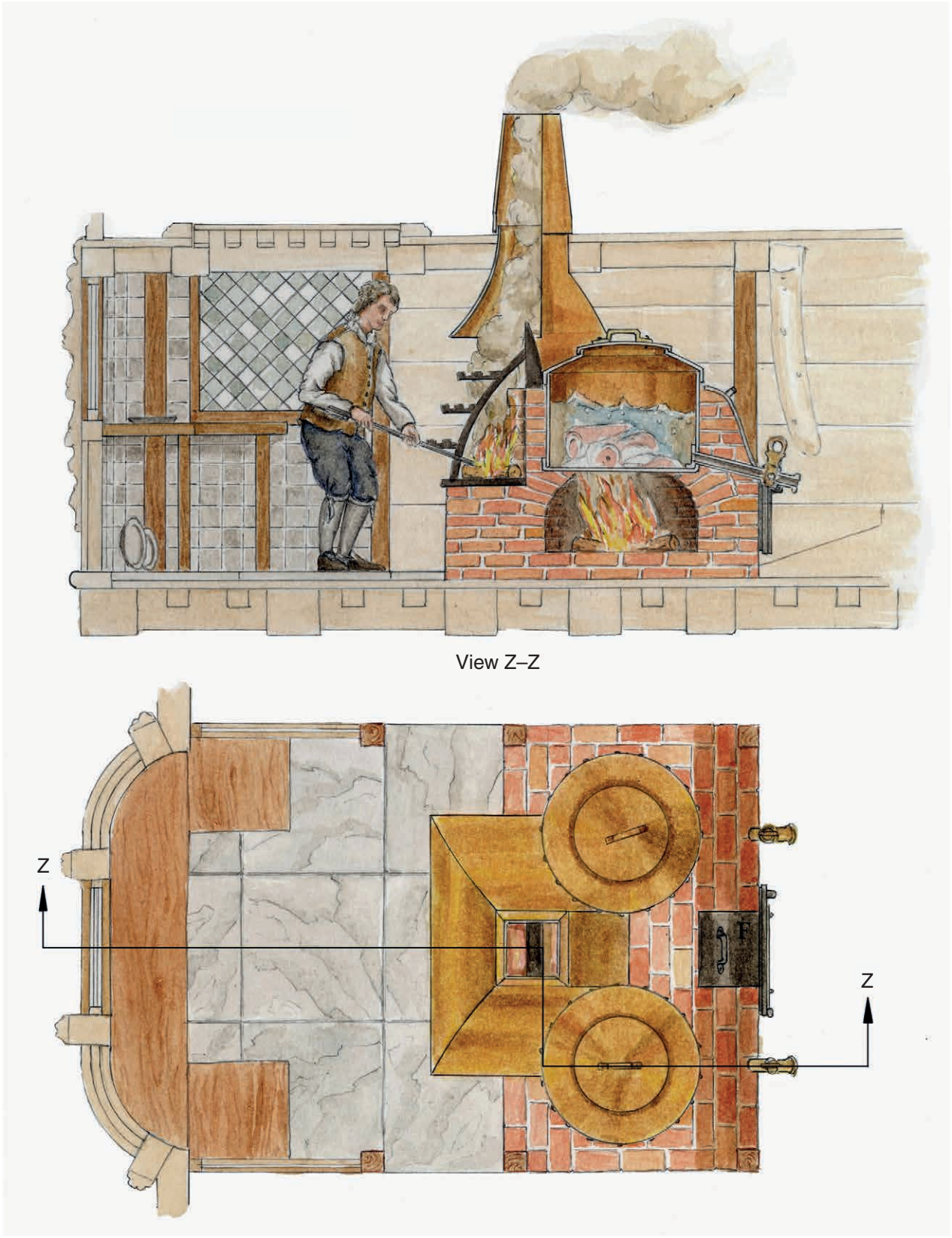


Figure 12.7 Reconstruction of a cook room for a ship the same size as the London *showing paving tiles on the deck, plain tiles on the partitions and the bricks of the furnace (© Historic England, drawing Richard Endsor)*

Chapter 13
Glass

Sarah Paynter

A number of glass objects were recovered including green glass bottles, two adjoining fragments of colourless flat glass, some unidentified green glass fragments and a brass pocket sundial/compass containing colourless and green glass components (Table 13.1). Chemical analysis was used to investigate where the glass was made and how it was sourced; the results are given in Table 13.2.[1]

Background

The composition of the glass made and used in England changed over time, reflecting developments in glassmaking technology and changes to the types of raw materials used. The date that the *London* was lost (1665) just preceded the introduction of lead-fluxed glass (flint glass or lead crystal) and the widespread introduction of sash windows in England (Historic England 2018). Two types of glass were present in the *London* assemblage; colourless glass and green, sometimes called high lime low alkali (HLLA), glass, both of which were developed by glassmakers on the Continent and introduced to Britain in the later 16th century. HLLA glass was made utilising the calcium-rich ashes from hardwood species like oak and beech (Mortimer 1993; 1996).

Colourless *façon de Venise* glass was used for high status drinking vessels and specialist objects like mirrors. Although it resembled renowned Venetian crystal it was made at glassworks all over Europe, including in the Low Countries, the Rhineland and Britain, using *barilla* plant ashes from Spain (De Raedt *et al.* 2001). Shortly before the *London* was lost the Vauxhall glassworks in London also began making plate from colourless glass (Dungworth 2006), which could be made to a larger size and polished to a good finish, for mirrors and carriage windows. Common green glass was used for most windows, as well as for bottles and lower status vessels.

The flat glass

Two adjoining fragments (3105 and 3031) from a colourless flat glass square or rectangular object were recovered, including a corner fragment (3105) with about 150mm of each edge surviving. The glass is between 2.2 and 2.3mm thick. Although the body of the glass is very clear, containing a small number of slightly elongated bubbles from the blowing process, the glass appears slightly opaque and matt because the surface is pitted with numerous small rounded holes. There is a bevel, 20mm wide, along both original edges on the front surface only (the slightly contrasting band visible in Figure 13.1).

The analyses confirm that this object is *façon de Venise* glass, but it is not possible to determine where the glass was made because *façon de Venise* glass varied very little regardless of where in Europe it was made (Cagno *et al.* 2012; Table 13.3).

Façon de Venise glass was used generally in specialist applications such as timepieces, mirrors, optical glass and lighting (Caluwe 2006; Schalm *et al.* 2007). The bevel around the edge of this object suggests that it was probably



Figure 13.1 Colourless flat glass (3105) with original grozed and bevelled edges to the bottom left (© Historic England Archive, photograph James O. Davies)

1. Very small chips of glass (a few mm in size) were removed from each glass object and mounted in epoxy resin, polished to a 1 micron (µm) finish, carbon-coated and analysed using scanning electron microscopy with energy dispersive spectrometry (SEM-EDS). An FEI Inspect SEM and an Oxford Instruments EDS system were used. The conditions used were 25KV and 4.5nA. The detection limit is around 0.1wt% for most elements rising to 0.3wt% for Sb_2O_5, SnO_2 and BaO. Corning glass standards of known composition were analysed to check accuracy and precision.

Table 13.1 Composition of the London *glass, determined by SEM-EDS, average of 3 analyses, normalised (bd = below detection limit)*

Artefact type	SF	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	MnO	Fe_2O_3	BaO	PbO
Sundial green	3165	0.53	3.90	2.95	58.11	1.83	0.21	bd	6.87	21.76	0.23	1.58	0.84	0.47	bd
St dev		*0.05*	*0.05*	*0.02*	*0.12*	*0.05*	*0.05*	*0.01*	*0.02*	*0.03*	*0.03*	*0.01*	*0.03*	*0.08*	–
Flat colourless	3105	14.79	4.05	1.09	63.97	0.31	0.28	1.04	2.04	10.66	bd	0.66	0.42	bd	bd
St dev		*0.07*	*0.03*	*0.06*	*0.07*	*0.03*	*0.03*	*0.05*	*0.01*	*0.01*	–	*0.01*	*0.00*	–	–
Sundial colourless	3165	13.01	3.32	2.27	62.66	0.22	0.18	1.01	5.04	10.35	bd	0.49	0.74	bd	bd
St dev		*0.21*	*0.01*	*0.01*	*0.18*	*0.06*	*0.02*	*0.04*	*0.03*	*0.10*	–	*0.01*	*0.02*	–	–
Case bottle base	3177	0.99	2.44	2.84	57.00	2.44	0.54	0.22	5.94	24.00	0.24	0.37	1.68	bd	bd
St dev		*0.02*	*0.02*	*0.03*	*0.10*	*0.01*	*0.03*	*0.01*	*0.00*	*0.15*	*0.02*	*0.03*	*0.02*	–	–
Case bottle base	3178	0.92	2.37	2.69	57.40	2.68	0.45	0.25	6.33	23.56	0.21	0.33	1.53	bd	bd
St dev		*0.06*	*0.02*	*0.05*	*0.15*	*0.01*	*0.02*	*0.01*	*0.03*	*0.07*	*0.06*	*0.02*	*0.00*	–	–
Shaft/globe bottle neck	3436	1.30	2.74	2.72	57.07	2.70	0.44	0.29	5.80	23.61	0.20	0.36	1.69	bd	bd
St dev		*0.03*	*0.04*	*0.03*	*0.07*	*0.02*	*0.03*	*0.01*	*0.02*	*0.06*	*0.03*	*0.01*	*0.04*	–	–
Shaft and globe bottle	3011	1.20	3.18	2.56	54.61	2.66	0.44	0.18	7.24	24.89	0.20	0.29	1.51	bd	bd
St dev		*0.02*	*0.02*	*0.03*	*0.06*	*0.05*	*0.02*	*0.01*	*0.02*	*0.10*	*0.03*	*0.01*	*0.02*	–	–
Case bottle neck	3061	1.01	2.52	2.94	56.11	2.75	0.44	0.26	6.30	24.26	0.26	0.42	1.80	bd	0.11
St dev		*0.04*	*0.02*	*0.03*	*0.12*	*0.04*	*0.05*	*0.01*	*0.03*	*0.06*	*0.05*	*0.03*	*0.02*	–	*0.05*
Assorted fragments	3140	1.12	2.57	2.94	57.28	2.45	0.51	0.27	6.03	23.55	0.22	0.36	1.71	bd	0.11
St dev		*0.06*	*0.02*	*0.02*	*0.14*	*0.04*	*0.04*	*0.02*	*0.01*	*0.18*	*0.03*	*0.03*	*0.00*	–	*0.03*
Case bottle base	3156	1.00	2.35	3.00	57.66	2.39	0.49	0.25	5.68	23.65	0.24	0.41	1.74	bd	0.11
St dev		*0.05*	*0.05*	*0.05*	*0.23*	*0.04*	*0.04*	*0.03*	*0.06*	*0.05*	*0.03*	*0.01*	*0.03*	–	*0.04*

Table 13.2 Analysis of Corning D glass standard by SEM-EDS, compared against known standard composition, normalised (bd=below detection limit)

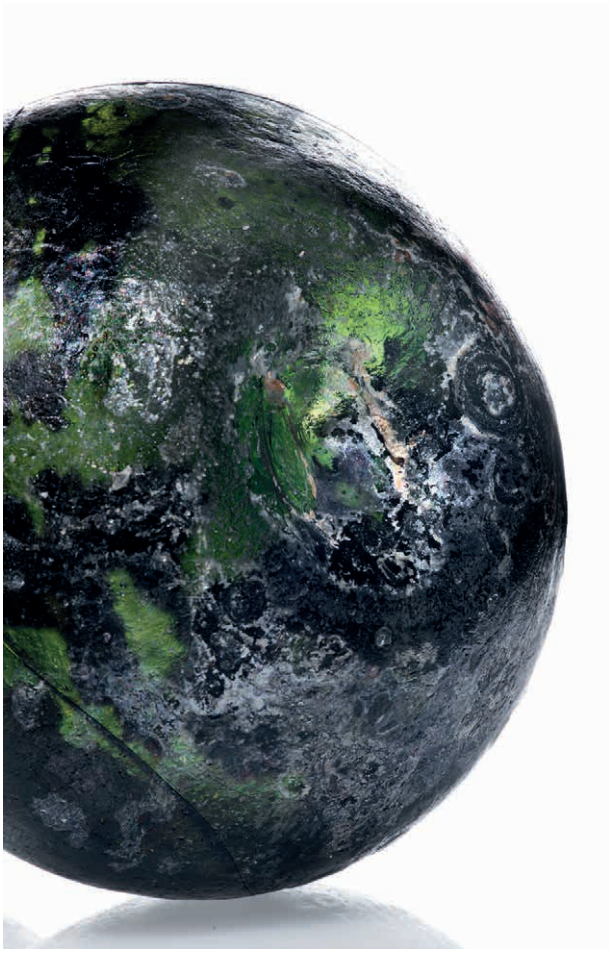
	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	MnO	Fe_2O_3	CuO	ZnO	SnO_2	Sb_2O_5	BaO	PbO
	1.33	4.06	5.21	54.88	4.03	0.25	11.34	15.05	0.38	0.58	0.54	0.40	bd	0.51	0.82	0.33	0.22
	1.26	4.09	5.21	54.70	3.86	0.27	11.42	15.16	0.46	0.58	0.50	0.34	0.12	0.56	0.89	0.37	0.21
	1.29	4.07	5.14	54.78	3.93	0.24	11.33	15.16	0.47	0.55	0.55	0.36	0.13	0.52	0.96	0.29	0.23
	1.35	4.04	5.24	54.77	3.98	0.26	11.32	15.10	0.42	0.58	0.53	0.41	bd	0.40	0.93	0.32	0.25
Av.	1.30	4.06	5.20	54.78	3.95	0.26	11.35	15.12	0.43	0.57	0.53	0.38	0.11	0.50	0.90	0.33	0.23
St dev	*0.04*	*0.02*	*0.04*	*0.07*	*0.07*	–	*0.05*	*0.05*	*0.04*	*0.01*	*0.02*	*0.03*	*0.02*	*0.07*	*0.06*	*0.04*	*0.02*
Known	1.2	3.94	5.3	55.24	3.93	0.23	11.3	14.8	0.38	0.55	0.52	0.38	0.1	0.1	0.97	0.29	0.24

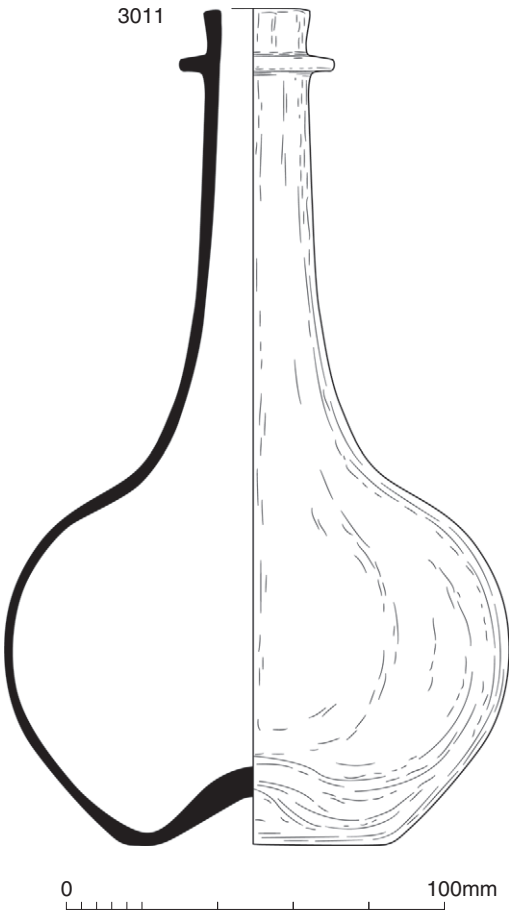
Table 13.3 Composition of façon de Venise *glass from the* London *wreck (flat glass SF 3105 and sundial colourless lens SF 3165) compared to average compositions of colourless glass from various glasshouses. From top: Old Broad Street, London (Mortimer 1993), Old Broad Street and Antwerp, Belgium (De Raedt* et al. *2001; Cagno* et al. *2012) and Vauxhall, London (Dungworth 2006) (bd = below detection, – = not reported)*

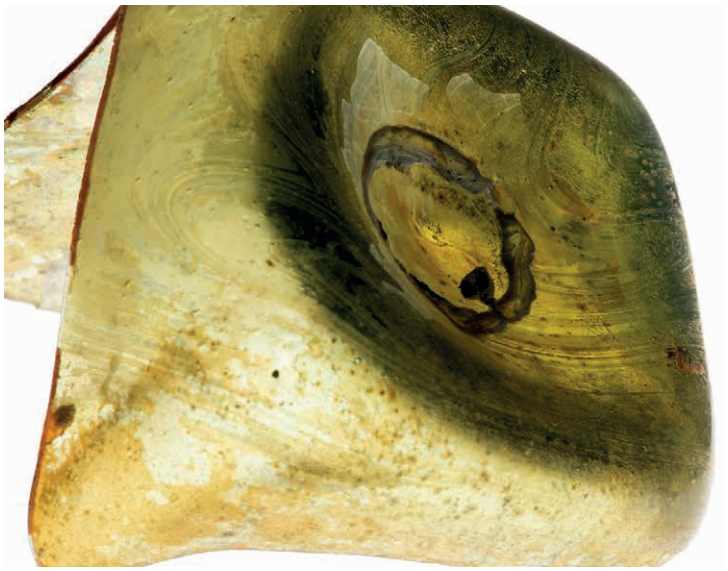
Type	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	MnO	Fe_2O_3	SrO
SF 3105 colourless	14.79	4.05	1.09	63.97	0.31	0.28	1.04	2.04	10.66	bd	0.66	0.42	–
SF 3165 colourless	13.01	3.32	2.27	62.66	0.22	bd	1.01	5.04	10.35	bd	0.49	0.74	–
Old Br'd St	12.0	3.9	1.0	69.0	0.3	0.1	0.4	2.4	10	–	0.5	0.5	–
Old Br'd St	13.0	3.1	1.8	64.5	0.3	0.2	0.6	5.0	9.7	–	0.8	0.6	–
Antwerp	15.0	2.9	1.5	64.0	0.3	0.1	0.7	6	10	–	0.3	0.4	–
Vauxhall	11.8	3.1	1.5	67.4	0.4	bd	0.6	3.2	9.9	0.1	1.2	0.6	0.07



Figure 13.2 Neck and shoulders of green glass case bottle (3061; © Historic England Archive, photograph James O. Davies, © Historic England, drawing Aleksandra Osinska)







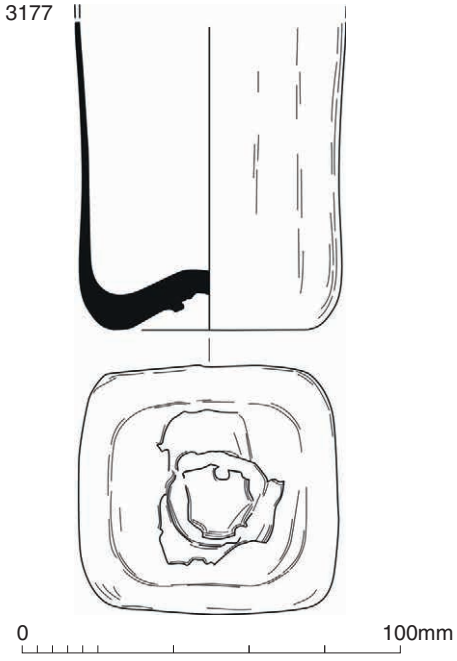


Figure 13.3a Pontil marks on the base of case bottle (3177) and wine bottle (3011) (© Historic England Archive, photographs James O. Davies, © Historic England, drawings Aleksandra Osinska)

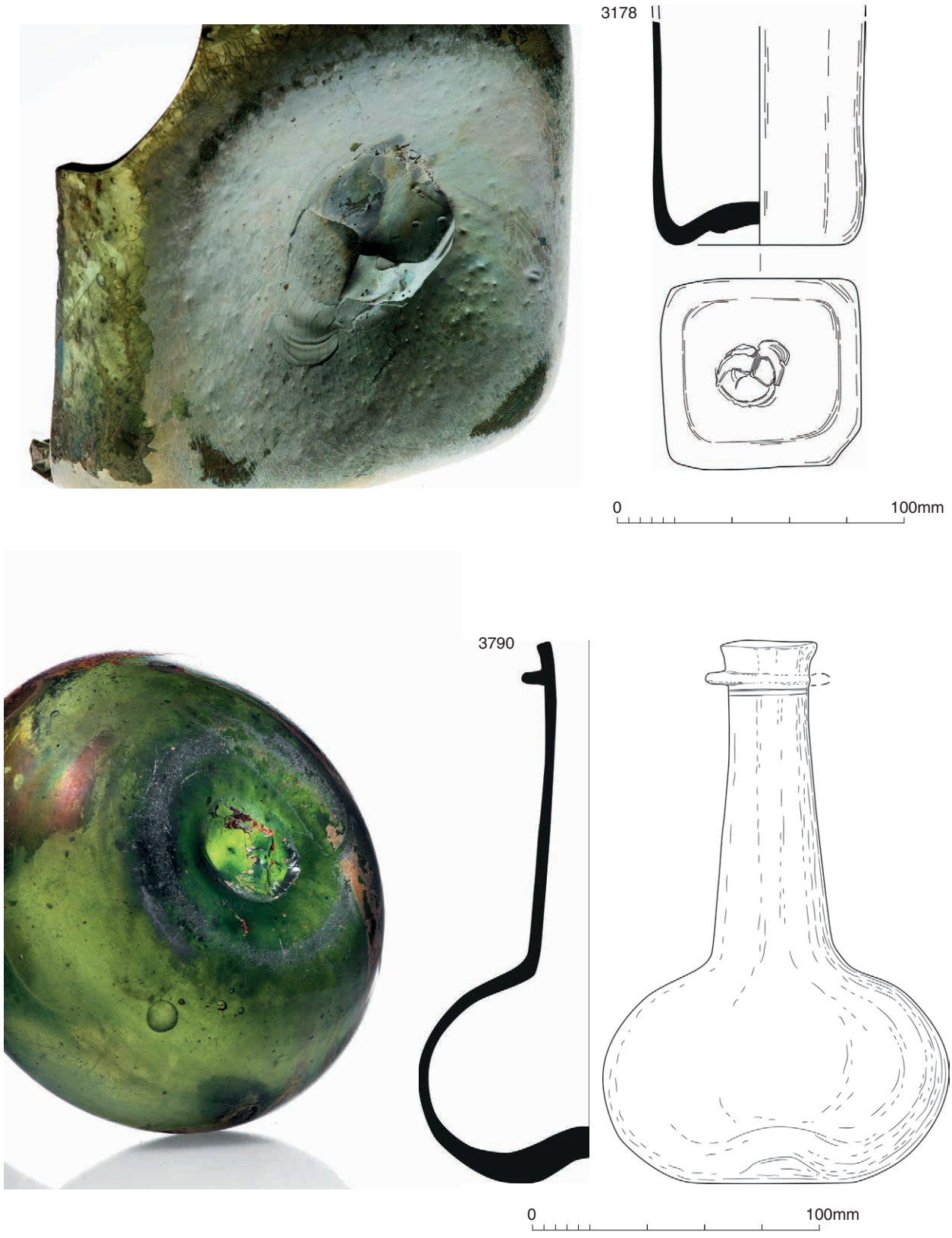


Figure13.3b Pontil marks on the base of case bottle (3178) and wine bottle (3790) (© Historic England Archive, photographs James O. Davies, © Historic England, drawings Aleksandra Osinska)

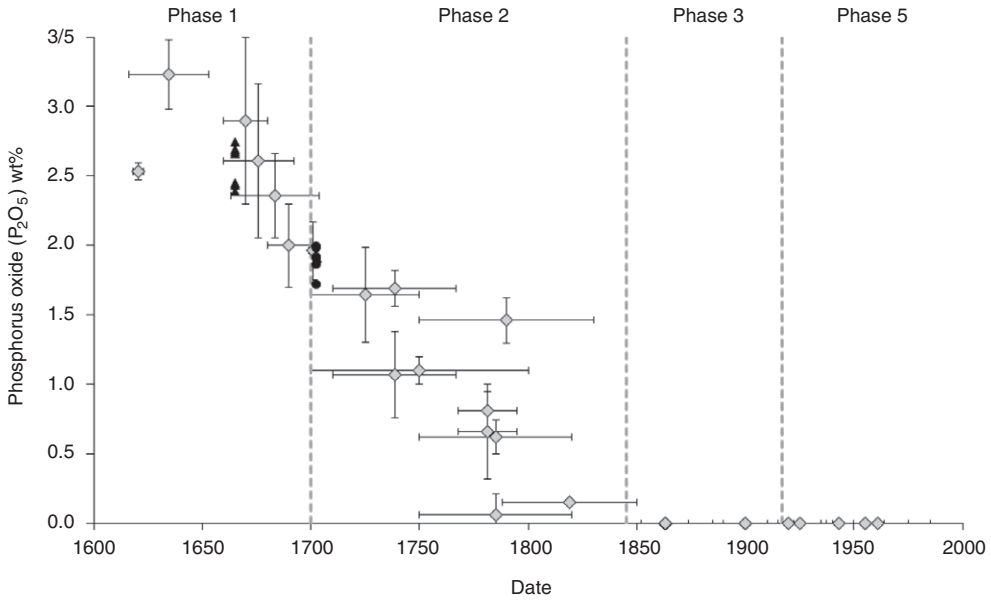


Figure 13.4 Bottles from the London *(black triangles) and the* Stirling Castle *(black circles) shown against a plot of changing phosphorus content over time for dated English bottles (redrawn from Dungworth 2012) (© Historic England)*

a mirror, although other specialist uses are possible. As the import of specialised glass to England was prohibited in 1663, the mirror may have been made using English plate glass, perhaps even in London at the Vauxhall glassworks (Dungworth 2006). The reflective metallic surface has been lost, as is typical in marine environments (F. Hocker pers. comm.). Analysis using a portable XRF spectrometer failed to detect traces of either the mercury or the tin that would have been present in the tin amalgam surface (Hadsund 1993). A mirror is an unexpected find on a warship but it could have belonged to a (more affluent) family member of the crew who had visited the ship. It is unlikely that the owner was on board at the time of the accident as no senior officers were present; alternatively the mirror may have been used to amplify light on board.

Weathering has created some small flaky iridescent patches on the surface of the glass and probably also caused the surface pitting. The pitting is present on both faces and on the grozed edges of the fragments but is less noticeable or absent from fresher breaks. Colourless glass (containing a small amount of lead oxide) with similar surface pitting was recovered from the *Stirling Castle*, lost in 1703 (Dungworth *et al.* 2020), so it appears to be a characteristic of this type of glass when recovered from marine environments. Despite being made of the same type of colourless glass, the lens from the sundial (3165) is much better preserved (see below and Table 13.2), probably as a result of the protection afforded by the brass sundial case.

The bottles

The bottles include fragments of shaft and globe wine bottles (including an intact one) and some square-sectioned case bottles; the tapered shape of the latter was formed using a dip mould. Both the case and the shaft and globe bottles are made from greenish HLLA glass, as was typical for England and continental Europe at the time. If, as they appear, these bottles are English (see analyses) they are quite early examples; the earliest English bottles are attributed to only a few decades earlier; the Worshipful Company of Glass Sellers was established in 1664 (Wilmott 2002), only a year before the sinking. The exact origin of the form is uncertain but an example with a seal dated 1650 is known from London and fragmentary examples were identified from Shinrone glasshouse, County Offaly, Ireland where the last firing was determined as between 1620 and 1650 (Farrelly *et al.* 2014).

The case bottles have a square cross-section and a tapered profile, being slightly wider at the top than at the bottom. This shape suits a dip mould, where the glass gather was blown in the mould to form the four flat sides of the square profile, while the tapered form enabled easy extraction from the mould. The date at which dip moulds came into use at English post-medieval glassworks is not known with certainty but the size and shape of the *London* case bottles is fairly uniform and this would be difficult to achieve by other means. The thickness of the glass in the case bottles is uneven and there is some distortion of the shape but this could have occurred while the neck and rim were shaped when the bottle was still hot (Fig. 13.2). Both the case and the shaft and globe wine bottle bases feature shallow round pontil marks (Fig. 13.3) where a pontil was attached to hold the bottle whilst the neck was finished.

As stated, HLLA green glass was made using plant ashes, which gave the glass mix a diagnostic phosphorus content, but there was a reduction in the amount of phosphorus used

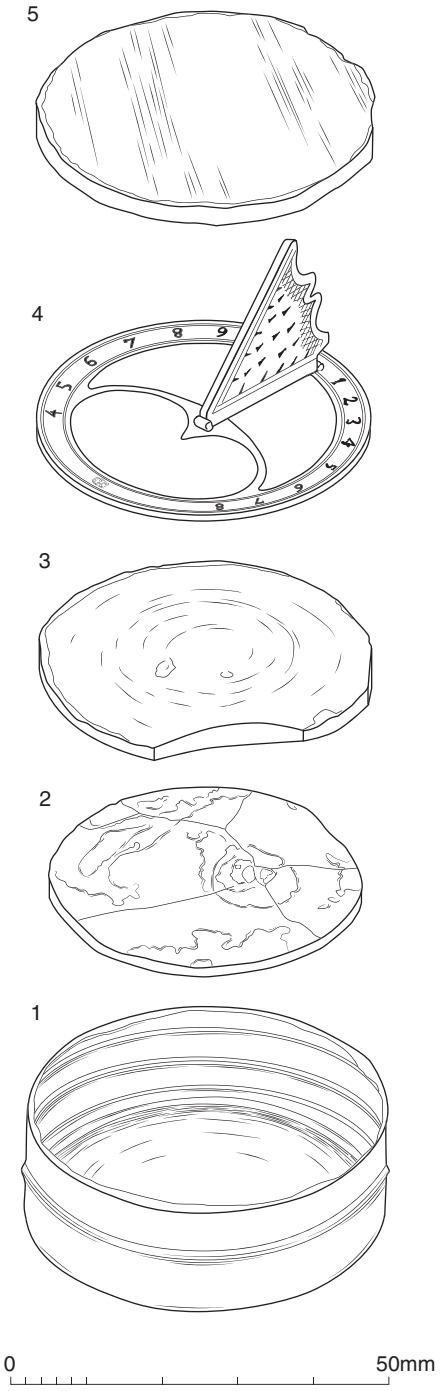


Figure 13.5 Five components from the disassembled pocket sundial compass (3165) showing a flat green glass disc (5), a brass chapter ring with folding gnomon (4), a lenticular colourless glass lens (3), and a severely weathered green disc (2), all of which fitted into a brass case (1) (© Historic England, drawing Aleksandra Osinska)

in English bottle glass during the second half of the 17th century, which appears to be characteristic of English-made HLLA glass (Dungworth 2012). This change coincided with the transition from wood-fuelled to coal-fuelled furnaces in Britain, which presumably had an impact on the availability of plant ashes. The bottles from the *London* have been compared to other English bottles of known date (Fig. 13.4) and they contain the expected amount of phosphorus for English glass made in *c.* 1665.[2] So they are very likely to be English.

The compositions of the shaft and globe wine bottles and the case bottles are not precisely the same but slight variation is expected because the raw materials for glassmaking, plant ashes and sand, are themselves variable. Overall the bottles are so similar in composition that they may have been made in the same glasshouse and purchased from a single supplier in large volume.

The sundial glass

The sundial includes both green HLLA and specialised colourless *façon de Venise* glass components. The colourless glass lens has a lenticular profile which has a magnifying effect and is made from *façon de Venise* glass (Table 13.3).

The green glass discs in the sundial had been cut from flat glass and have grozed edges. The basal green glass disc is badly corroded so could not be analysed but the upper disc was found to be HLLA glass (Fig. 13.5, see also Figs 11.11 and 11.12). This green HLLA glass is subtly different from the English HLLA glass used for the *London* bottles, however, as it contains lower levels of sodium, iron and phosphorus oxides and considerably more manganese oxide (compare Tables 13.1 and 13.4).[3] Based on the composition the green glass in the sundial is likely to have originated from Germany or the bordering areas.

Conclusions

The *London* glass assemblage is very useful for future studies as it includes some specialised artefacts and a wide range of glass types, all dated precisely to 1665. The glass bottles were made from green HLLA glass, and share very similar compositions, suggesting that they were sourced together as part of a larger consignment, perhaps from a single glassworks, although not necessarily all made from the same batch of glass. The composition is as expected for the products of English glasshouses at that date, in which case these represent quite early examples of English-made bottles. A similar pattern was noted on the *Stirling Castle*, with all but one bottle having a similar composition

2. There are not enough published data for well-dated bottles to build a similar compositional chronology for other European manufacturers, so other origins cannot be completely ruled out, but an English glassworks is most probable.
3. It is unusual to find levels of sodium oxide below 1wt% in English-made glass (Dungworth 2011; Dungworth and Paynter 2010) and glass from France tends similarly to contain several weight percent of sodium oxide (Barrera and Velde 1989). In contrast HLLA-type glass from medieval and post-medieval Germany often has a very low soda content and is also found in the regions bordering Germany (eastern France, north Poland, Belgium etc.) (Schalm *et al.* 2007).

Table 13.4 Composition of the sundial green glass compared with 17th-century windows, England (Dungworth 2011); 15th–17th-century Group D windows, Belgium (Schalm et al. *2007) and 17th-century vessels, NE France, similar glass to neighbouring Germany (Barrera and Velde 1989) (bd = below detection limit, – = not reported)*

Type	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	MnO	Fe_2O_3	SrO
Sundial green	0.53	3.90	2.95	58.11	1.83	0.21	bd	6.87	21.76	0.23	1.58	0.84	–
English window 17th	2.4	3.0	3.0	60.9	2.1	0.40	0.2	5.1	21.1	–	0.24	1.31	0.07
St dev	*1.4*	*0.7*	*1.3*	*2.0*	*0.6*	*0.2*	*0.1*	*1.9*	*1.7*	–	*0.2*	*0.29*	*0.01*
Belgian window 15th–17th	0.7	3.5	3.9	59	2.2	0.2	0.2	7	21	0.8	0.9	0.5	–
St dev	*0.6*	*0.5*	*0.9*	*1*	*0.7*	*0.1*	*0.1*	*1*	*2*	*0.2*	*0.3*	*0.1*	–
NE French vessel 17th	0.29	2.58	2.38	57.72	2.53	–	–	5.44	24.77	–	0.88	0.78	–
St dev	*0.06*	*0.52*	*0.71*	*1.63*	*0.26*	–	–	*1.46*	*1.85*	–	*0.23*	*0.36*	–

to the rest and bottles of the same type coming from the same batch (Dungworth *et al.* 2020), indicative of bulk purchasing.

The large piece of colourless flat *façon de Venise* glass (3105) is probably a blown-plate glass mirror, although thinner than typical at just over 2mm, with a ground, bevelled edge. By 1665 production of plate glass was tightly controlled, so the glass for this mirror may have been made in England, perhaps even London.

The sundial also contains a polished magnifying lens of colourless *façon de Venise* glass and two discs of flat green HLLA glass, grozed to shape. Analysis of the green HLLA glass disc indicates that it does not match contemporary English HLLA glass, however, corroborating the findings of the typological study of the pocket sundial (Chapter 11, Schuster) which suggests that it originated from the Continent, perhaps southern Germany. So the green glass inserts are either original to the piece or were added before the sundial was brought to England. Such items were widely traded but, as the *London* had travelled to the Netherlands a few years prior to the accident, some items could have been acquired there.

Chapter 14
Coins

Katie Marsden and Kathryn E. Rankin

Two concreted lumps (Fig. 14.1, see also Fig. 1.7) that resembled groups of coins were recovered during the excavations. It was not possible to destructively micro-excavate these groups of fused coins owing to advanced corrosion, so the lumps were 'excavated' virtually using a non-destructive imaging technique, X-ray micro-computed tomography (μ-CT) scanning (Fig. 14.2).[1] The image analysis of the μ-CT scans carried out on the concreted lumps provides the only record of the contents of these groups.

A total of 212 coins were identified (Table 14.1),[2] including eight coins in group A (3078; Fig. 14.3)[3] and 204 coins in group B (3382; Figs 1.7 and 14.4).[4] This represents a minimum number of coins as it is highly probable that more are present, especially in group B, but the amount of material present in this group gave a poor signal-to-noise ratio, making it difficult to resolve individual coins in the central section. In addition thin coins and lower denominations may have been obscured by larger or thicker coins, may have been lost to corrosion or may have been missed when realigning the volume with the simple registration technique.[5]

The coins in group B appear to be arranged in vertical 'stacks' in varying orientations, suggestive of a close-fitting container such as a pouch, purse or similar, although no evidence of any such container was identified.

The amount of information available for identification has been diminished, in some cases, by corrosion which has rendered some coins elliptical in shape, with the edges appearing to taper to a point (Fig. 14.5). Consequently many legends were either illegible or were missing entirely. In these instances broad identifications were possible, based on variation to shield design. Interestingly, reverse faces survived better than obverse faces, although this phenomenon is difficult to explain; the thickness of the surface topography was potentially less than the spatial resolution, which would result in partial volume effects with X-ray absorption averaged with that of the surrounding features, or abnormal wear patterns. Where possible coin diameter measurements were taken using the caliper tool in order to determine probable denomination, as post-medieval coinage size, from the 16th century, remained fairly standardised.

Results

Of the 212 coins, 30 (14%) were identified, with a degree of certainty, to a specific issuer. The smaller group (A) contains fewer coins, which are proportionally more identifiable to issuer than the coins in group B. The majority of coins in group A (5 or 66%) were issued by Charles I (1625–1649)

1. A specimen is rotated 360 degrees about a single axis as thousands of two-dimensional (2D) X-radiograph projection images are acquired with micrometric spatial resolution. The projection images then undergo tomographic reconstruction to generate a three-dimensional (3D) volume made up of voxels (cubic pixels), which depict the amount of X-ray absorption at each point (Landis and Keane 2010).
2. Each concreted lump was mounted in a Perspex tube on a rotation stage. μ-CT projection images of the concreted lumps were acquired using a micro-focus 450kV source with a Tungsten reflection target, together with a Perkin Elmer XRD 1621 CN03 HS detector, housed within a custom built dual source 225/450kV walk in room (the Hutch) at the μ-VIS X-ray Imaging Centre, University of Southampton (Fig. 14.2).
3. The small concretion (group A) was scanned using a peak voltage of 420kVp and 214μA current and 4mm copper pre-filtration of the beam. With the beam conditions used, the focal spot size (which determines the spatial resolution) can be expected to be around 50μm. The source to object distance and source to detector distance were set to 141.6mm and 699.6mm respectively, resulting in a reconstructed voxel resolution of 0.0428mm. A total of 1801 projection images were acquired during a 360-degree rotation, with 128 frames averaged per projection, 134ms exposure time and 24dB analogue gain.
4. The large concretion (group B) was scanned using a peak voltage of 425kVp and 234μA current and 2mm copper pre-filtration of the beam. The beam was collimated into a fan geometry with the aim of reducing scatter artefacts; 52 scans covered the full height of the concretion with 3mm translation between each scan. The source to object distance and source to detector distance were set to 257.4mm and 900.7mm respectively, resulting in a reconstructed voxel resolution of 0.0572mm. A total of 2701 projection images were acquired during a 360-degree rotation, with four frames averaged per projection, 250ms exposure time and 18dB analogue gain. Reconstructions were performed using filtered back projection algorithms implemented within CTPro3D and CTAgent software packages (Nikon Metrology, UK).
5. The 52 reconstructed volumes covering group B were concatenated and the 32 bit raw volumes were converted to 8 bit using ImageJ/Fiji (Rasband, W.S., ImageJ, U.S. National Institutes of Health, Bethesda, Maryland, USA, https://imagej.nih.gov/ij/, 1997–2019). The 8 bit raw volumes of group A and group B were then imported into VGStudioMax 2.1 (Volume Graphics GmbH, Germany) and the simple registration tool was used to align the orthogonal planes with each coin, such that the volume was resliced in plane with the coin face for possible identification. Each coin was marked with an indicator as it was identified and added to a region of interest to avoid duplication. These regions are referred to as 'stacks' where groups of coins were closely aligned within the concretion.

Table 14.1 List of coins from the two concreted lumps

Group	Coin no.	Ruler	Denomination	Obverse	Reverse	Diameter (*c.* mm)
A	1	Charles I or II	shilling	[…] MAG BRI […]	round shield with inner circle; [CHRI]STO AVS	35
A	5	Charles I or II	–	–	round shield	–
A	6	Charles I or II	halfcrown	–	quartered-quarters shield	36
A	7	Charles I or II	halfcrown	–	round shield	35
A	8	Charles I or II	–	[…] MAG B[…]	round shield	–
A	3	Charles II	shilling	[CHRISTO] AVSPICE [RE]GNO	quartered-quarters shield	33
A	4	Charles II	crown	bust	four shields, dated 1664	38
A	2	trade token	trade token	IOHN [L]VCAS AT THE D…N	HIS HALF PENY / TAVE[RNE] CORNH[I]LL	19–20
B	8	Elizabeth I	–	–	square-top shield	–
B	21	Elizabeth I	–	–	square-topped shield	–
B	23	Elizabeth I	–	–	shield	–
B	93	Elizabeth I	sixpence	–	AD/IVTORE[M] long cross div. legend	25
B	96	?Elizabeth I	–	–	AD/IVTOR/E[M] long cross fourchee div. legend	23
B	125	Elizabeth I	sixpence	–	square-top shield, long cross div. legend, dated 1561 or 1567	26
B	128	?Elizabeth I	–	–	square-top shield, long cross div. legend, dated 1563?	25
B	131	?Elizabeth I	–	Ruffles around neck	POVI; square-top shield with long cross div. legend	27
B	132	?Elizabeth I	?sixpence	–	square-top shield; leg. div by cross fourchee	?24
B	203	?Elizabeth I	–	–	AD/VI	–
B	65	Elizabeth I – James I	poss. Farthing	–	ROSA	26
B	170	?James I	–	poss. IACOB?	square-topped quartered quarters shield	–
B	6	Charles I	sixpence	–	square-top shield	–
B	7	Charles I	–	–	round shield	–
B	11	Charles I	shilling	–	square-top shield	–
B	26	Charles I	sixpence	CARO[…]. Thin face	[…] AVSPICE […]	–
B	134	Charles I	shilling	XII behind bust facing left	–	–
B	4	?Charles I	–	[…]REG[…]	–	–
B	9	?Charles I	–	square-top shield	–	–
B	38	?Charles I	–	square-top shield	–	–
B	2	?Charles I or II	?farthing	–	–	–
B	19	Charles I or II	–	[…]REX	[A]V[SP]ICE	–
B	22	Charles I or II	–	–	round/oval shield	–
B	24	Charles I or II	–	–	round/oval shield	–
B	32	Charles I or II	halfcrown or shilling	–	CHRISTO […] square-topped shield	34
B	50	Charles I or II	–	–	[…] REGNO	31
B	53	Charles I or II	–	–	quartered quarters	28
B	57	Charles I or II	–	CAROLVS […]	–	25
B	59	Charles I or II	–	–	round shield with decoration	30
B	66	Charles I or II	–	[CHRI]STO A[VSPICE…]	–	33
B	74	Charles I or II	–	CARO[…]	–	30
B	77	Charles I or II	–	–	[…] AVSPICE […]	31
B	79	Charles I or II	Halfcrown	CAROLVS D.G. […]	–	34
B	85	Charles I or II	–	–	[…] REGNO	35
B	89	Charles I or II	–	–	round shield with decoration	–
B	90	Charles I or II	–	–	CHRISTO AV[SPICE REGNO]	–
B	95	Charles I or II	–	–	CHR[ISTO...]	26
B	99	Charles I or II	–	–	[…] REGNO	–
B	100	Charles I or II	sixpence	–	poss. round shield	24
B	104	Charles I or II	–	–	quartered quarters shield	30
B	111	Charles I or II	–	–	[CHRIS]TO[…] round shield	–

Table 14.1 Continued

Group	Coin no.	Ruler	Denomination	Obverse	Reverse	Diameter (*c.* mm)
B	114	Charles I or II	–	–	CHRISTO […]	36
B	116	Charles I or II	–	[…] REX	round shield	32
B	117	Charles I or II	–	CA[ROL]VS […]	–	29
B	136	Charles I or II	–	–	[…] AVSPICE REGNO	33
B	151	Charles I or II	–	[CAR]OLVS […]	quartered quarters shield	–
B	161	Charles I or II	–	–	round shield	–
B	162	Charles I or II	–	CHRIS[…]REX	square-topped quartered quarters shield	–
B	181	?Charles I or II	–	–	prob. Charles shield	–
B	5	Charles II	–	–	oval shield	–
B	17	Charles II	–	–	cross shield, interlocked Cs	–
B	28	Charles II	shilling	CARO…	oval shield	29–30
B	30	Charles II	crown	CARO…REX 16	round shield	–
B	31	Charles II	halfcrown	–	four shields	33
B	35	Charles II	halfcrown	–	four shields	34
B	39	Charles II	–	REX	four shield type	–
B	41	Charles II	–	–	four shield type	–
B	80	?Charles II	–	G	–	34
B	195	Charles II	crown	–	four shields	40
B	196	Charles II	–	–	oval shield	–
B	204	Charles II	–	–	oval shield	–
B	45	uncertain	shilling	Crowned bust, XII behind head	quartered quarters reverse	–
B	46	uncertain	shilling	[…]MAG[…]. XI[I] behind head	quartered quarters reverse	–
B	144	uncertain	shilling	XII behind head	quartered quarters shield	–
B	1	unident.	–	–	–	–
B	3	unident.	–	–	[…]O AVS[…]	26
B	10	unident.	–	–	–	–
B	12	unident.	–	–	–	–
B	13	unident.	–	–	–	–
B	14	unident.	–	–	–	–
B	15	unident.	–	–	–	–
B	16	unident.	–	–	–	–
B	18	unident.	–	–	–	–
B	20	unident.	–	–	–	–
B	25	unident.	–	–	–	–
B	27	unident.	–	–	–	–
B	29	unident.	–	–	–	–
B	33	unident.	?sixpence	–	poss. flat top shield	26
B	34	unident.	–	–	–	38–39
B	36	unident.	–	–	–	34
B	37	unident.	–	–	–	–
B	40	unident.	–	–	–	–
B	42	unident.	–	–	–	–
B	43	unident.	–	–	–	21
B	44	unident.	–	–	–	44
B	47	unident.	–	–	–	24
B	48	unident.	–	–	quartered quarters reverse (inner circles)	–
B	49	unident.	–	–	quartered quarters reverse	–
B	51	unident.	–	–	–	21
B	52	unident.	–	–	SIPE?	26
B	54	unident.	–	–	–	–
B	55	unident.	–	–	–	27
B	56	unident.	–	–	–	26
B	58	unident.	–	–	long cross over shield	28
B	60	unident.	–	–	–	–
B	61	unident.	–	–	–	–

Table 14.1 Continued

Group	Coin no.	Ruler	Denomination	Obverse	Reverse	Diameter (*c.* mm)
B	62	unident.	–	–	–	–
B	63	unident.	–	EN	–	–
B	64	unident.	–	–	shield	–
B	67	unident.	sixpence	–	square-top shield	25
B	68	unident.	–	–	quartered quarters shield	31
B	69	unident.	–	–	quartered quarters shield	33
B	70	unident.	–	–	–	24
B	71	unident.	–	[…]M[A]G[…]	shield	28
B	72	unident.	?shilling	XII	–	–
B	73	unident.	–	–	–	–
B	75	unident.	–	–	–	31
B	76	unident.	–	crowned bust	–	25
B	78	unident.	–	–	–	34
B	81	unident.	–	–	–	34
B	82	unident.	–	–	shield	–
B	83	unident.	–	SC or CS	–	–
B	84	unident.	–	–	quartered quarters shield	36
B	86	unident.	–	–	–	–
B	87	unident.	–	–	–	–
B	88	unident.	–	–	–	–
B	91	unident.	–	–	quartered quarters shield	30
B	92	unident.	–	–	quartered quarters shield	–
B	94	unident.	–	–	–	26
B	97	unident.	shilling	XII behind head	quartered quarters shield	–
B	98	unident.	shilling	–	shield	30
B	101	unident.	–	–	–	–
B	102	unident.	–	–	–	–
B	103	unident.	–	–	–	–
B	105	unident.	–	–	square-top shield	–
B	106	unident.	–	–	square-top shield	–
B	107	unident.	–	–	–	28–29
B	108	unident.	–	–	quartered quarters shield	–
B	109	unident.	–	–	quartered quarters shield	–
B	110	unident.	–	–	quartered quarters shield	–
B	112	unident.	–	–	shield	–
B	113	unident.	–	–	–	–
B	115	unident.	–	–	–	–
B	118	unident.	–	–	–	32
B	119	unident.	–	–	–	–
B	120	unident.	–	–	–	–
B	121	unident.	–	–	–	–
B	122	unident.	–	–	–	–
B	123	unident.	–	–	poss. quartered quarters shield	–
B	124	unident.	–	–	–	–
B	126	unident.	–	–	–	–
B	127	unident.	–	–	quartered quarters shield, large	33 min
B	129	unident.	–	–	quartered quarters shield, large	29
B	130	unident.	–	–	quartered quarters shield	–
B	133	unident.	–	–	–	33
B	135	unident.	–	–	–	27
B	137	unident.	–	–	–	23
B	138	unident.	–	–	–	–
B	139	unident.	–	–	quartered quarters	–
B	140	unident.	–	–	–	–
B	141	unident.	–	–	–	–

Table 14.1 Continued

Group	Coin no.	Ruler	Denomination	Obverse	Reverse	Diameter (*c.* mm)
B	142	unident.	–	–	–	–
B	143	unident.	–	–	–	–
B	145	unident.	–	–	square-top shield	–
B	146	unident.	–	–	quartered quarters shield	–
B	147	unident.	sixpence or shilling	poss. XI[I] behind head	–	–
B	148	unident.	–	–	quartered quarters shield	–
B	149	unident.	–	–	quartered quarters shield	–
B	150	unident.	–	–	quartered quarters shield	–
B	152	unident.	–	–	quartered quarters shield	–
B	153	unident.	–	–	–	–
B	154	unident.	–	–	–	–
B	155	unident.	–	–	–	–
B	156	unident.	–	–	–	–
B	157	unident.	–	–	–	30
B	158	unident.	–	–	–	–
B	159	unident.	–	–	–	–
B	160	unident.	–	–	shield	31
B	163	unident.	–	–	–	–
B	164	unident.	–	–	–	–
B	165	unident.	–	–	–	–
B	166	unident.	–	–	–	–
B	167	unident.	–	–	quartered quarters shield	–
B	168	unident.	–	–	–	–
B	169	unident.	–	–	square-top shield	–
B	171	unident.	–	–	square-topped quartered quarters shield	–
B	172	unident.	–	–	?squareish shield	–
B	173	unident.	–	–	square-top shield	30
B	174	unident.	–	–	square-top shield	–
B	175	unident.	–	–	quartered quarters shield	35
B	176	unident.	–	–	–	–
B	177	unident.	–	–	–	–
B	178	unident.	–	–	–	–
B	179	unident.	–	–	–	–
B	180	unident.	–	–	–	–
B	182	unident.	–	–	–	–
B	183	unident.	–	–	–	–
B	184	unident.	–	–	–	–
B	185	unident.	–	–	–	–
B	186	unident.	–	–	–	–
B	187	unident.	–	–	–	–
B	188	unident.	–	–	quartered quarter shield	–
B	189	unident.	–	–	–	–
B	190	unident.	?crown	–	shield	37
B	191	unident.	–	–	shield	–
B	192	unident.	–	–	–	–
B	193	unident.	–	–	–	–
B	194	unident.	–	–	–	–
B	197	unident.	–	–	–	–
B	198	unident.	–	–	–	–
B	199	unident.	–	–	–	–
B	200	unident.	–	–	–	–
B	201	unident.	–	–	–	–
B	202	unident.	–	–	–	27



Figure 14.1 Concreted coin lumps (3078; © Historic England Archive, photograph James O. Davies)

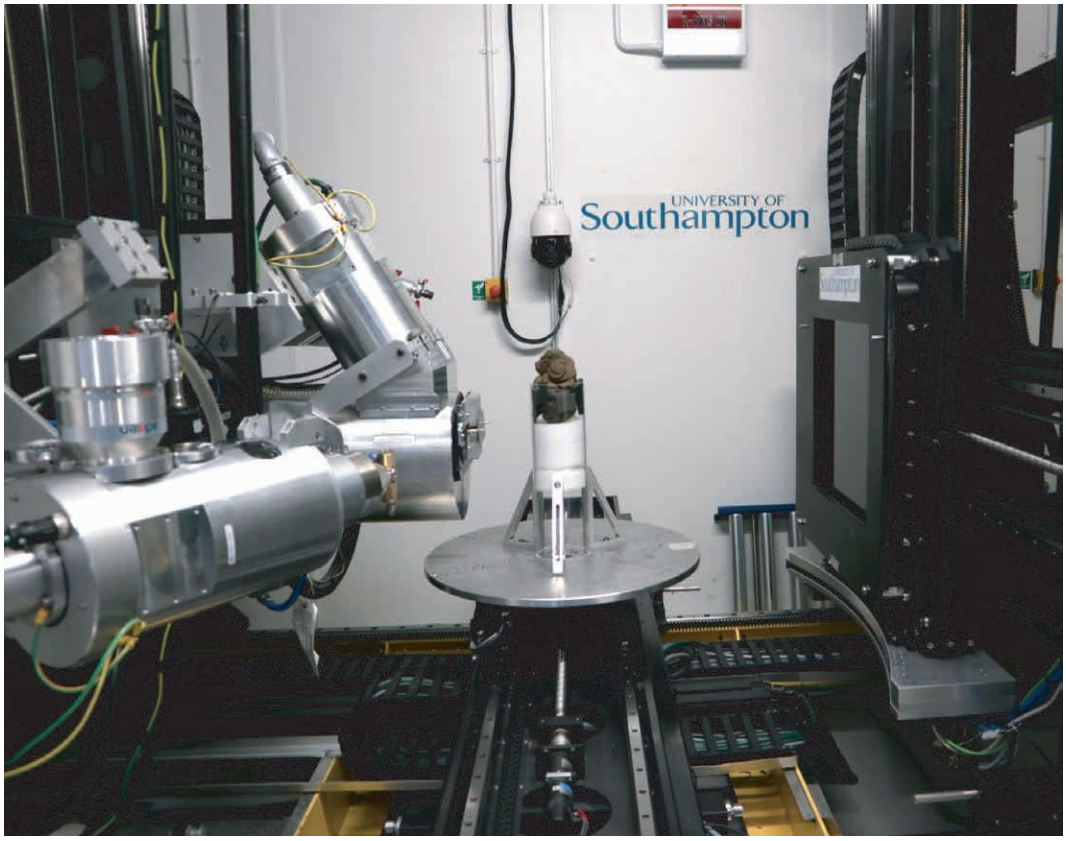


Figure 14.2 Large concretion positioned for μ-CT on the rotate stage in the Hutch scanner (© Historic England, photograph μ-VIS X-ray Imaging Centre Southampton)

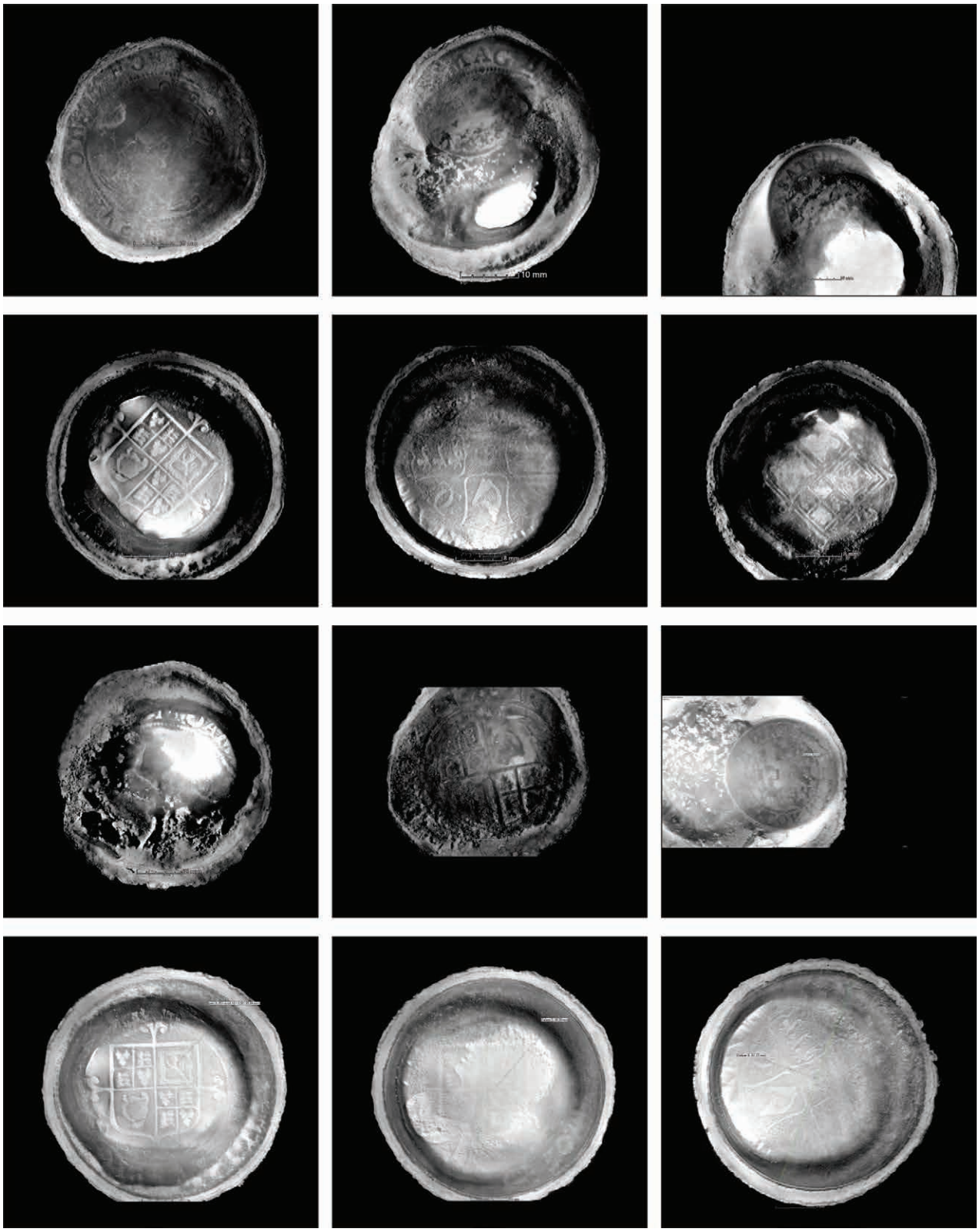


Figure 14.3 Coin group A (3078; © Historic England, image μ-VIS X-ray Imaging Centre Southampton)

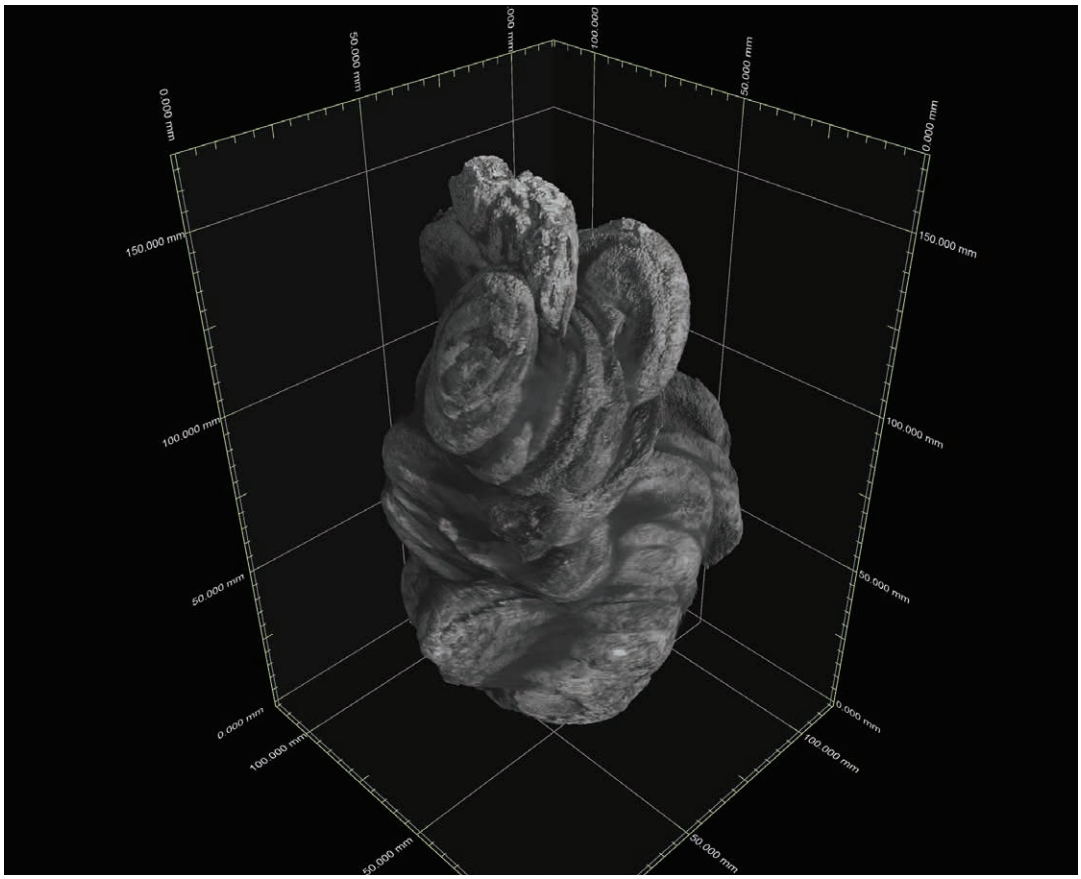


Figure 14.4 Coin group B, μ-CT scan (3382; © Historic England, image μ-VIS X-ray Imaging Centre Southampton)



Figure 14.5 Side profile of coins showing edge corrosion (© Historic England, image μ-VIS X-ray Imaging Centre Southampton)

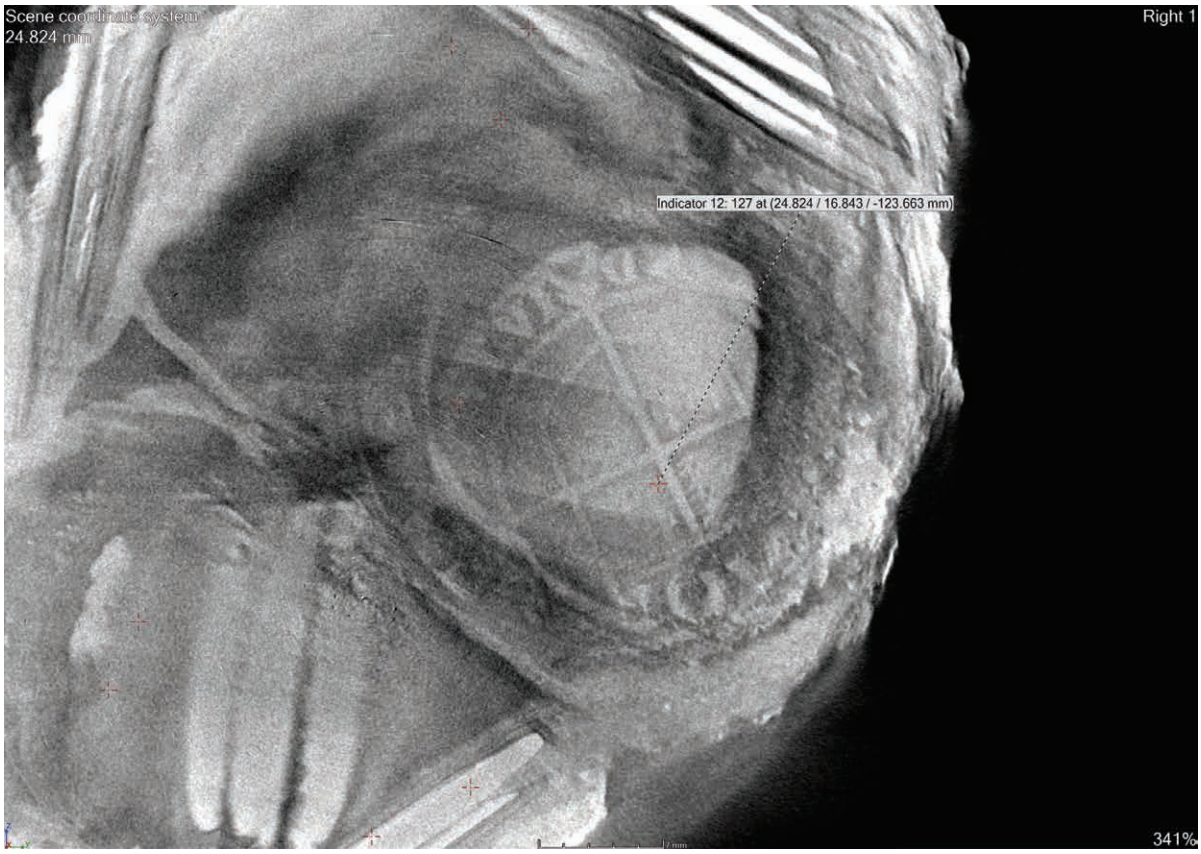


Figure 14.6 Coin of Elizabeth I (© Historic England, image μ-VIS X-ray Imaging Centre Southampton)

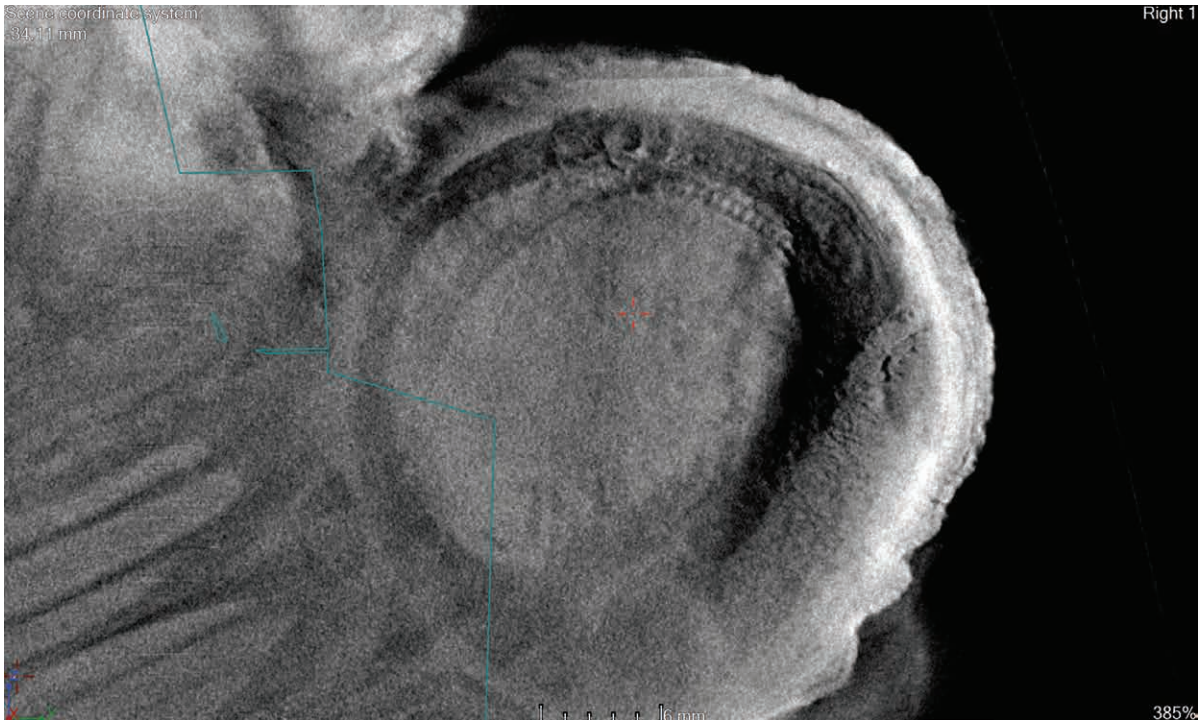


Figure 14.7 Coin, probably of James I (© Historic England, image μ-VIS X-ray Imaging Centre Southampton)

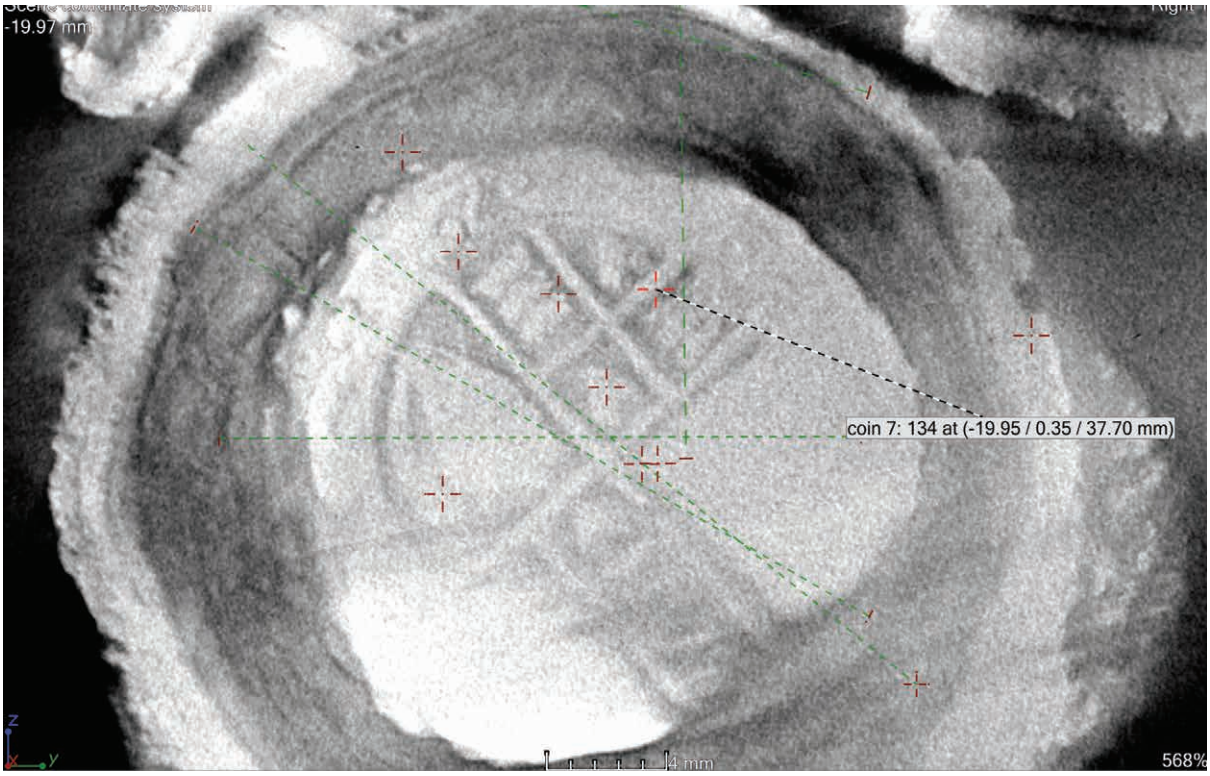


Figure 14.8 Coin of Charles I (© Historic England, image μ-VIS X-ray Imaging Centre Southampton)

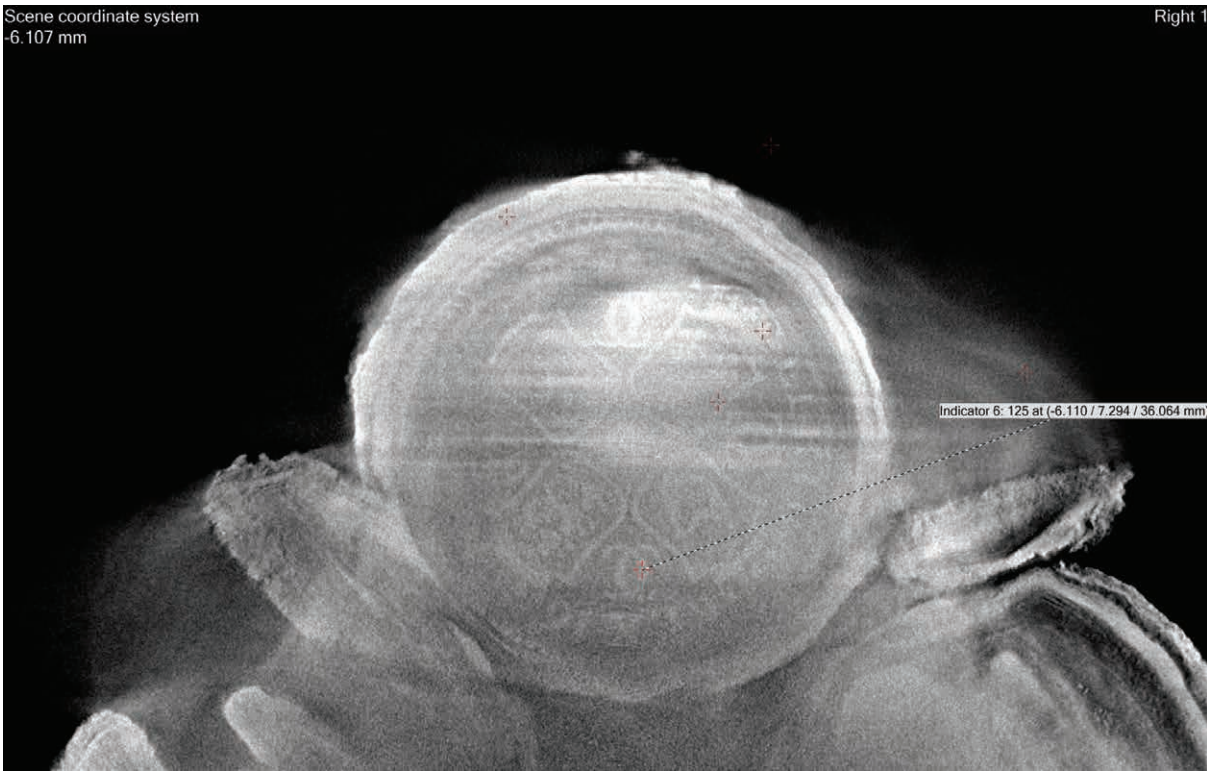


Figure 14.9 Coin of Charles II (© Historic England, image μ-VIS X-ray Imaging Centre Southampton)

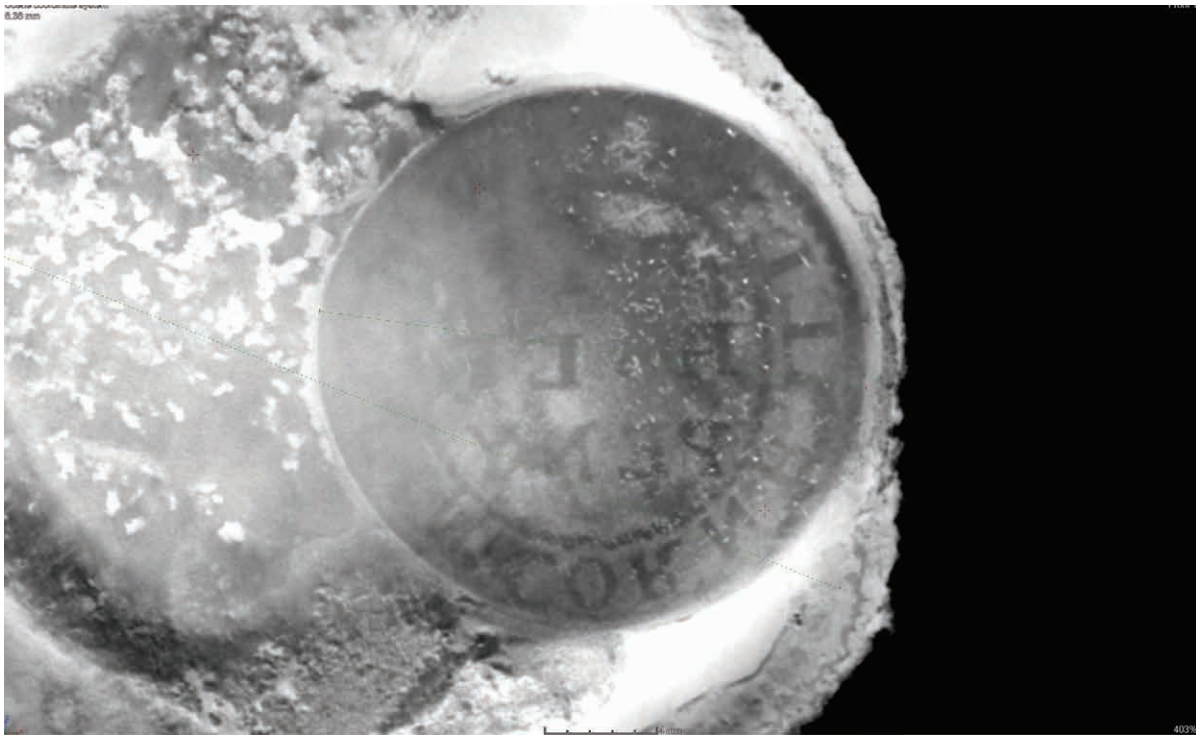


Figure 14.10 Trade token of John Lucas (© Historic England, image μ-VIS X-ray Imaging Centre Southampton)

or Charles II (1660–1685); two were issues of Charles II, while three were identified only as issues of either Charles I or Charles II.

The coins in group B include ten coins of Elizabeth I (1558–1603; Fig. 14.6), one of James I (1603–1625; Fig. 14.7), five of Charles I (Fig. 14.8) and 12 of Charles II (Fig. 14.9). A further 32 coins were identified only as issues of either Charles I or Charles II.

A total of 33 coins (15% of the combined total) were identifiable by denomination, representing 6 coins (75%) from group A and 27 coins (13%) from group B. The smallest denominations are two probable farthings, one of Tudor issue (Elizabeth I or James I) and one of Charles I or Charles II issue. Eight sixpences, 11 shillings, 5 halfcrowns and 4 crowns were also identified, with two coins being on the cusp of identification, with one sixpence or shilling and one shilling or halfcrown.

A single copper-alloy item (Fig. 14.10) identified in group A represents a trade token; these were issued on licence by boroughs and businesses during the 17th century to address a shortage of low denomination coins in circulation. This token was issued in London by John Lucas at the Dolphin Taverne in Cornhill (near Bank).[6] It accords with Williamson (1889, 573 no. 725) and the centre of the obverse bears the inscription 'his half peny'.

Discussion

Although the percentages of coins, identified by either issuer or denomination, seems low, given the condition of the coins the use of high-powered CT scanning of two-coin groups has proven invaluable in determining any information at all. While it may seem unusual, the presence of the coins of Charles I, executed in 1649 (16 years before the sinking) and the absence of Civil War era coins is not surprising. At the time of the sinking Charles II had been the reigning monarch for only five years, following the Restoration. The absence of Commonwealth coins can be explained by the Navy's official allegiance to the Crown. Coins of Elizabeth I and James I are, however, particularly interesting, suggesting a long period of circulation or a lack of recall of old coinage by the Royal Mint.

The combined value of the identified coins in both groups equates to £2 7s 6½d, although the true value, especially of group B, is obviously considerably higher. The inclusion of a trade token in group A is interesting, suggesting that someone on board had visited the Dolphin Tavern prior to boarding the ship. Pepys (Latham 1996a, 94, 158; 1996b, 100, 161, 327; 1996c, 194; Wheatley 1894) mentions two public houses in London named the *Dolphin*, one on

6. The Royal Exchange, where Pepys worked, is on Cornhill, although the current version is the third building. The first was destroyed in the Great Fire.

Bishopsgate and one on Tower Street, either of which could have issued this token. Bishopsgate is on the northern limit of the modern ward of Cornhill, while Tower Street is just beyond the south-eastern limit; neither is likely to have survived the Great Fire of the following year. Incidentally, the *Dolphin* in Tower Street had been one of the locations, following the First Anglo-Dutch War, in which John Lawson (the captain of the *London*) had met with other supporters of a free Parliament (Blanchard 2017, 88). The inclusion of the token suggests that this coin group in particular could represent the contents of a personal purse. This is supported by the lower value of this group (estimated at a total value of 12 shillings).

If the remaining unidentified coins in group B (totalling 177) were of smaller denomination, such as sixpences, the total value would be £6 6s and if crowns (the maximum value of silver denominations, based on the assumption from the coin styles that no gold coins were included) the maximum value would total £46 12s 6d. It seems likely, from the value of group B especially, that it represents the personal possession of a high-ranking officer or petty cash reserves for expenses incurred during the ship's service (or 'commission').

During both peacetime and times of war it was expected that officers would subsidise the costs of operating their vessels (Thrush 1991, 130), so it stands to reason that cash reserves would have been carried on board. In 1637, for example, Sir Henry Mervyn replaced biscuits ruined by rats at a cost of £35 (Thrush 1991, 141). At this time, before the invention of canning, wheaten biscuits were an important part of the Naval diet (regularised by Samuel Pepys to one pound daily) as they could withstand long journeys (Royal Museums Greenwich 2020).

Moreover, the value of group B seems too low to represent crew wages and crew pay was a problem at this time (see Chapter 17, Walsh). The *London's* full complement in 1665 was 450 men, although at the time of the sinking it was not fully manned (Fox 2012, 57); Pepys (Latham 1996b;) wrote that 25 people survived and 'above 300' drowned. The estimated higher value of group B (£46 12s 6d) would be sufficient to pay one monthly wage of only 49 ordinary seamen or 38 able seamen (HMS *Richmond* 2019).

Chapter 15
Biological Evidence

Simon Mays, Michael Taylor, Sarah Paynter, Gordon Turner-Walker, Polydora Baker, Michael J. Grant, Sarah F. Wyles, Greg Campbell and Philip L. Armitage

Human remains

by Simon Mays, Michael Taylor, Sarah Paynter and Gordon Turner-Walker

A total of 34 human bones plus two unidentified fragments were recovered from the *London* (Table 15.1). All bones were adult sized. The minimum number of individuals (MNI) represented, given by femora, is five. The condition of the material was highly variable, sometimes even within the same bone, ranging from intact cortical surfaces to areas showing significant superficial erosion. There was also variability in bone colour, with some surfaces stained dark brown or black, while other parts were light brown. Areas of dark staining tended to show intact cortical surfaces, whereas lighter areas were more eroded. It may be that the darker parts lay within sediments but the lighter, more eroded, surfaces lay exposed; in a watery environment current-driven sediments tend to abrade bone surfaces (Haglund and Sorg 2002a, 213).

These light, abraded areas also showed evidence for encrustations from marine-dwelling micro-organisms. One cranium (0049) had a barnacle (*Balanus crenatus*) adhering to the ectocranial surface of the frontal bone. This species is mostly subtidal and common around Britain. The basal diameter measured 10mm but can reach a diameter of 20mm in a year, so it is not necessarily indicative of prolonged exposure of the frontal parts of the cranium on the seabed.

Many elements bear thin white mat-like encrustations (Fig. 15.1). This appears to be a marine bryozoan (Sorg *et al.* 1997), probably *Membraniosa membranacea*, which has a habitat in intertidal and sub-littoral zones. In addition to these encrustations many of the light-coloured bone surfaces display pores and channels up to several millimetres long (Fig. 15.2). In places these coalesce to produce larger areas where there is loss of the cortical surface. The causes of this taphonomic effect are unclear but one possibility is that boring sponges, which tend to colonise calcareous objects, are responsible.

In order to shed light on the preservation of bone at the microscopic level a section was cut from the cranial vault of one cranium (3030), mounted in resin, polished flat, carbon-coated and subjected to examination under a scanning electron microscope (SEM-EDS).[1]

The cross-section (Fig. 15.3) showed that beneath both the ectocranial and endocranial surfaces there was diagenetic alteration with formation of multiple tunnels approximately 5–7μm diameter. The morphology of these alterations is consistent with bioerosion by marine cyanobacteria (Turner-Walker 2008). These are phototrophic organisms, whose range is restricted to waters less than a few metres deep. In addition, as seen here, their penetration into bone is characteristically confined to within 1mm from the surface. Beyond this depth the microstructure of the bone is well preserved. The observation that both ectocranial and endocranial surfaces show bioerosion is consistent with the broken cranium being at least partially exposed on the seabed. This type of bioerosion has been observed in other human skeletal remains from marine and freshwater contexts (Bell and Elkerton 2008; Turner-Walker 2008).



Figure 15.1 Humerus 0098. Bryozoan encrustation. Scale in mm (© Historic England, photograph Simon Mays)

1. The microscope was an FEI Inspect operated at 25KeV with an Inca X-act energy dispersive spectrometer (EDS) for analysis of the composition.

Table 15.1 Inventory of human remains from Site 2

Object no.	Grid	Identification	Notes
3167	I9	L femur M80%	
3313	–	R femur M80%	
0049	I9	Cranium lacking facial bones	Male, approx. 30–50yrs. Crindex=79.5
0050	I9	L tibia D90%	Pathology
0051	I9	L rib M60%	
0098	–	R humerus M80%	
3012	I11 centre	Cranium (frontal and parietal bones)	Male, approx. 15–30yrs. Pathology
3029	I11 centre	R humerus, complete	HHD=49.6
3030	I11 centre	Cranium (incomplete calvaria)	?Male, approx. 30–50yrs. Pathology
3036	H17	L femur P80%	
3038	K10	Cranium (incomplete calvaria)	?Male, ?>40yrs. Crindx=78.9
3044	I9	R femur M80%	
3045	E7	L femur D80%	
3054	H17	R femur M80%	
3057	F10	R femur M80%	
3060	K12	L tibia M50%	
3066	K9	R rib(?8th), P75%	Unfused head epiphysis
3067	K9	Lumbar vertebra (?L2), complete	Annular epiphyses partially fused
3074	K10	L femur, complete, damaged ends	Adult-sized (diaphyseal length approx. 410), all epiphyses unfused
3075	F11	L femur M80%	
3076	K11	R rib M70%	
3077	K12	Mandible, left condyle missing	Approx. 20–30yrs. For further details see Table 15.2 below
3086	F15	L humerus, complete	HuL1=322, HHD=47.6, proximal epiphysis partially fused
3102	G11	R femur P80%	Pathology
3114	J10	L clavicle, complete, sl. damage	
3123	J10	R 10th rib, complete	Unfused head epiphysis
3154	J8	R 3rd metatarsal, complete	
3158	I9	5th lumbar vertebra	
3167	I9	L femur M80%	
3313	–	R femur M80%	
3441	–	L clavicle M70%	
3498	–	L os coxa, ca. complete, sl. damage	Male, ischial tuberosity partially unfused, iliac crest damaged but at least partially unfused
3734	–	L middle rib M70%	
3735	–	L tibia M80%	
3756	–	L 5th metacarpal, complete	

Key: Identification L, left; R, right; M, midshaft; P, proximal; D, distal; %, percentage of element present.

Notes: all measurements in mm; measurement abbreviations after Brothwell (1981, 79–83), except HHD = humerus head diameter (Bass 1987); Crindx, cranial index = 100xB/L (Brothwell 1981, 82). Pathology, bone shows signs of disease or injury (see relevant section below); all epiphyses fused unless stated

Table 15.2 Mandible 3077 dental formula

0	.C	*	.	.	X	X	X	X	X	X	X	X	.	.	0
8	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
LEFT								RIGHT							

Key: X = socket present, tooth missing; . = tooth present in socket; C, caries cavity; 0, tooth congenitally absent; * tooth lost *ante mortem*

Measurements (Brothwell, 1981, 83, except MCL and M> which follow Buikstra and Ubelaker 1994, 78, measurements 33 and 34): GoGo=95.4; ZZ=43.6; RB'=29.3; H_1=34.8; ML=117; CrH=59; MCL=81; M>=131). In mm, except M>, in degrees.

Wear stages of molars (Brothwell 1981, 72): M1=3; M2=2.

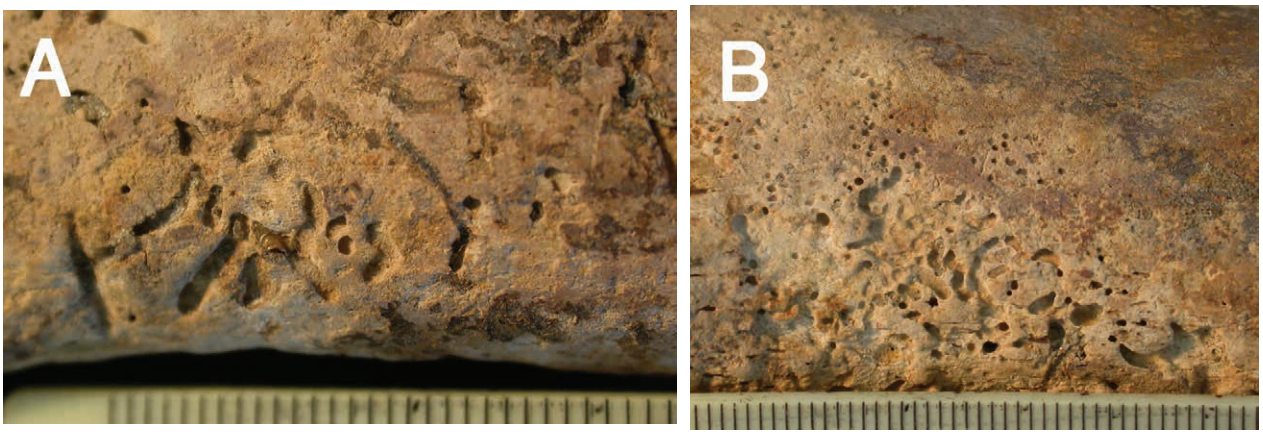


Figure 15.2 Surface taphonomic alterations, possibly due to sponge boring, scales in mm (A) Humerus 3086 (B) Femur 3045 (© Historic England, photographs Simon Mays)

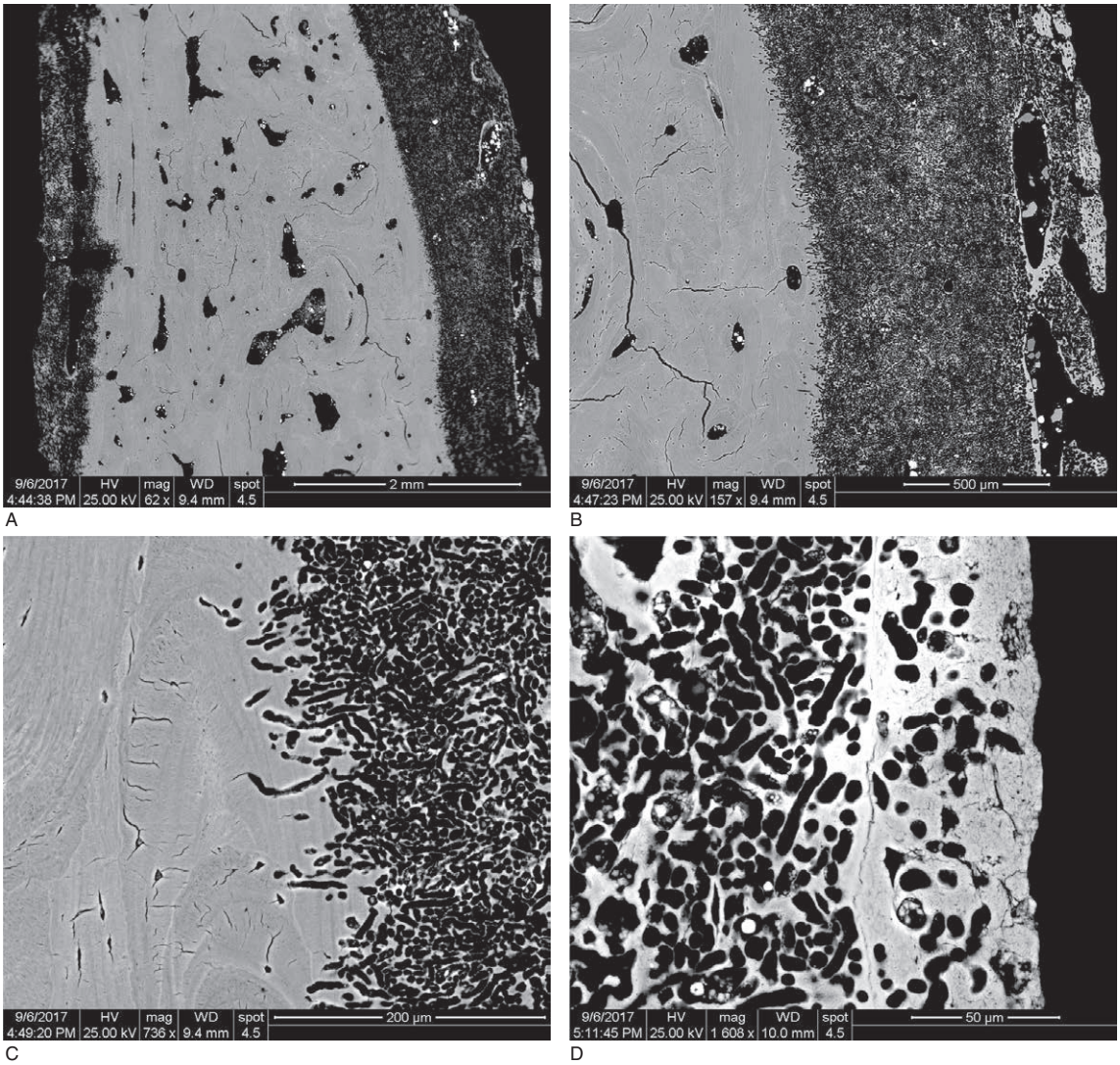


Figure 15.3 Cross-section of cranial vault, cranium 3030, under scanning electron microscopy. (A) Complete cross-section, endocranial surface is at left. Post-depositional bioerosion is evident as dark colouration indicating demineralisation extending from both endocranial and ectocranial surfaces. (B) Boundary between bioeroded bone (toward right) and unaffected bone. (C), (D) Detail of bioeroded bone (© Historic England, Sarah Paynter)

Table 15.3 Estimated ages for elements showing unfused or incompletely fused epiphyses

Object no.	Identification	Estimated age at death (yrs)	Reference
3066	Rib	<21	Rios and Cardoso (2009)
3067	Lumbar vertebra	17–22	Cardoso and Rios (2011)
3074	Femur	approx. 17	Cardoso (2008a) and estimated bone length
3086	Humerus	14–19	Cardoso (2008b)
3123	Rib	<21	Rios and Cardoso (2009)
3498	Os coxa	15–21	Cardoso (2008a) Webb and Suchey (1985)

The bright, distinctively-shaped particles observed under scanning electron microscope (SEM) in some Haversian canals and other void spaces (Fig. 15.3) are pyrite framboids, an identification supported by EDS which confirmed the presence of iron sulphide. These are formed by anaerobic sulphate-reducing bacteria commonly found in marine sediments (Turner-Walker 1998; 2008). The bio-eroded areas of cranium also contain slightly higher concentrations of iron, manganese, silicon and chlorine than the unaltered areas; these elements from the burial environment have permeated the bone in the porous, tunnelled regions.

Of the 34 bones, inference of sex could be made for four crania and one os coxa (pelvic bone) (using the criteria of Brothwell 1981, 59–63). In each case sex was clearly or probably male. The sex of one cranium (3030) was determined by aDNA evidence. Head diameter (Bass 1987, 148) measurements were taken for two of the humeri. This measurement shows significant sexual dimorphism and the values obtained (47.6mm and 49.6mm) are, as expected, for males. Mean values from 18th–19th-century London Spitalfields comprised 45.3mm for males and 39.5mm for females (Molleson and Cox 1993, table 2.4).

The sutural closure (Perizonius 1984) of the crania suggests ages at death ranging from adolescent/young adult to middle-aged adult but the imprecision of this ageing method precludes closer analysis. The dental wear on one mandible (3077) (Table 15.2) places it in the range 17–25 years (according to the scheme of Brothwell 1981, 72), although this is valid only until the medieval period. It is probable that the rate of wear had begun to fall by the 17th century (Moore and Corbett 1978) but this may apply only for some urban groups; heavy wear continued to characterise some rural groups until the earlier 19th century (Mays 2007, 137). These observations suggest that the age at death in this mandible may potentially be somewhat older than the 17–25 year range. Six of 17 postcranial elements in which at least one epiphyseal area was preserved showed unfused or partially unfused epiphyses (see Table 15.3 for estimated ages at death).

Stature can be estimated in two cases (Trotter and Gleser 1952, White male formula). Two humeri (3039 and 3086) give stature estimates of 1.696m and 1.764m respectively (assuming male sex in each case).

There is a roughened groove at the insertion of the pectoralis major of one humerus (3086). This represents a benign cortical defect. Benign cortical defects are considered anatomical variants and are common findings in adolescents/young adults (Mann and Murphy 1990, 85).

There is an irregular deposit of sclerotic bone in the fibular notch of one tibia (0050) and a thick osteophyte on the posterior malleolus and at the site of insertion of the posterior tibiofibular ligament. These alterations are probably from an old injury to the ankle that traumatised the distal tibiofibular synostosis (Hermans *et al.* 2010). This may simply have been a sprain, as there is no fracture to the tibia. There is a thin layer of striated well-remodelled bone upon the middle third of the tibial shaft. The deposit is most substantial on the medial (subcutaneous) surface. This may have resulted from a haemorrhagic or infectious process in the lower leg. The lesion was clearly inactive at time of death but whether it relates to the same incident that caused the ankle injury is uncertain.

There is porosity in both orbital roofs of one cranium (3012). Lesion morphology indicates marrow hyperplasia, probably due to an episode(s) of anaemia during childhood (Mays 2018).

There is a smooth thickening of the subperiosteal bone on the medial side of the diaphysis of one femur (3102) at around the junction of middle and distal thirds of the shaft (Fig. 15.4). The lesion measures 60mm in its long axis (parallel to the long axis of the bone shaft) by 20mm wide. The surface of the lesion is indistinguishable from the normal cortex, with which it blends imperceptibly at its margins. Post-depositional damage reveals that there is no alteration to the contour of the endosteal surface. The diagnosis is uncertain. The gross appearance is perhaps suggestive of osteoid osteoma, a benign tumour, but radiography provided no evidence for a radiolucent nidus at the core of the lesion, a feature that characterises the osteoid osteoma (Steinbock 1976, 333–6). A more likely diagnosis may be an ossified subperiosteal haematoma. These form when a collection of blood adjacent to a bone ossifies. They are a feature of scurvy and in that condition are most frequent in the lower limb (Hess 1920, 85, 95). In scurvy ossified haematomas are usually multiple and may affect more than one bone but, given the disarticulated nature of the remains, whether multiple bones were affected in this individual is unknown.

Scurvy was recognised as a threat to sailors in the 17th century but it was not yet the bane of naval life that it was later to become (Sauberlich 1997; Harvie 2002). Ossified subperiosteal haematoma may also occur in the absence of vitamin C deficiency as a response to trauma (Resnick and Niwayama 1988, 4251). In such instances they are often solitary but they are more often seen on bones with only a thin covering of soft tissue (Aufderheide and Rodríguez-

Martin 1998, 27) rather than, as in the current case, at locations beneath thick layers of muscle. If it is an ossified subperiosteal haematoma the episode of disease or injury that caused it probably occurred many years prior to death.

The endocranial surface of the frontal bone of one cranium (3030), centred approximately 32mm posterior to the right orbital roof, has an area 20–25mm in diameter comprising a cluster of five small erosions penetrating the inner table and exposing well-remodelled trabecular bone in the diploe (Fig. 15.5). The erosions are 3–8mm in diameter. Their dimensions in the diploe are, in various cases, greater than or similar to their dimensions in the inner table of the cranial vault. The bone in the midst of these lesions is porous and raised somewhat above the surrounding endocranial surface, indicating deposition of new bone. The new bone deposit shows varying stages of remodelling, with some apparently laid down shortly before death. This area is in turn surrounded by a thin lens of new bone extending approximately 60mm from the focus of the erosive lesions; its morphology suggests slight remodelling. The ectocranial surface is normal.

The morphology of the erosive lesions does not permit clarity over whether they originated in the diploe or represent invasion from the endocranial surface and by implication are a response to soft tissue alterations within the braincase. Both scenarios therefore inform the differential diagnosis.

Arachnoid granulations are anatomical structures that protrude from the dura and when large may cause pressure erosion of the internal cranial table (Grossman and Potts 1974). The location of the erosions in the current case, however, would be atypical of arachnoid granulations (Roberts *et al.* 2009) and this interpretation would not explain the new bone production. A meningioma is a benign neoplasm that arises from the arachnoid cells. It may invade cranial bone through the inner table, producing bone lysis. Presentation, however, as a cluster of small lytic lesions in the anatomical location seen here would be atypical, and there is no evidence for the linkage to aberrant vascular channels characteristic of these lesions (Waldron 1998). In addition to bone lysis, meningiomas often elicit new bone formation but this tends to be of quite different character to that seen here, being spicular in nature and often quite florid in extent (Marques 2019, 664–5).

The combination of erosion and new bone production is most likely indicative of infection. Lytic lesions in the cranial vault may occur in syphilis and other treponemal diseases, with the frontal bone a favoured location, but involvement of the inner table and sparing of the outer table, as in 3030, would be atypical (Hackett 1976; Roberts and Buikstra 2019, 382–3). Tuberculous meningitis may be accompanied by meningeal granuloma formation. In principle these granulomas might potentially cause pressure erosion of overlying cranial bone but the extent to which this actually occurs is unclear (Roberts *et al.* 2009). Spread of tuberculosis to cranial bones may also occur via a haematogenous route. Lesions are often multiple, there is



Figure 15.4 Antero-posterior view of part of the diaphysis of femur 3102. Medial is toward the bottom of the photograph. The approximate limits of the smooth subperiosteal bone deposit are indicated by the arrows (© Historic England, photograph Simon Mays)

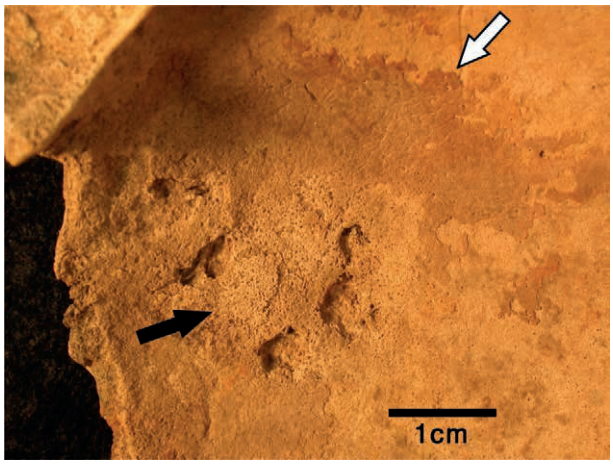


Figure 15.5 Endocranial surface of right side of frontal bone, cranium 3030. Right orbital roof is visible top left. Centred in the midst of the cluster of pits is an area of porous new bone (dark arrow). Surrounding this is a larger thinner lens of poorly remodelled new bone (light arrow), which has flaked away post-mortem in places revealing the normal endocranial surface beneath (© Historic England Archive, photograph Simon Mays)

generally greater erosion internally, and there may be small amounts of perifocal reactive bone formation (Hackett 1976, 73–4; Roberts and Buikstra 2019, 345–7).

The osseous appearance of the lesions appears most consistent with a diagnosis of tuberculosis, most likely spread via a haematogenous route. In an effort to investigate this further, attempts were made to extract and amplify bacterial DNA of *Mycobacterium tuberculosis* sp. A sample was taken from the internal surface of the cranium (3030) by scraping away bone fragments using a sterile scalpel blade. These were pulverised in a sterilised pestle and mortar to yield a uniform bone powder. Eighty-five mg of this powder was taken forward for DNA extraction. Remnant DNA was extracted using a modified version of that originally described by Boom *et al.* (1990), using the chaotropic buffer GUSCN with trapping of any DNA fragments on a

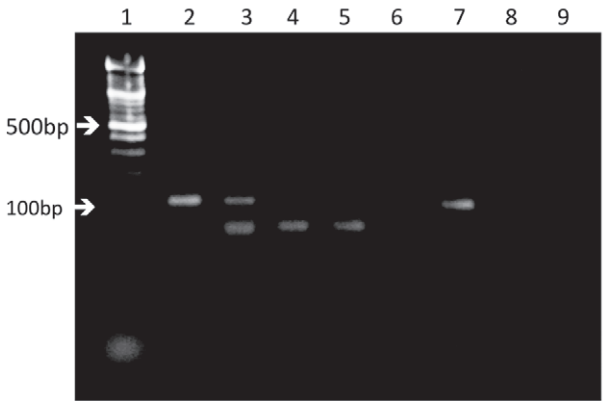


Figure 15.6 Gel electrophoresis of amelogenin product from individual cranium 3030 run out on 3% agarose gel in 1 x TAE buffer. The single product amplified from cranium 3030 is seen in lane 7 on this gel run. DNA size markers (100bp ladder) are present in lane 1 and template (water) blanks are in lanes 8 and 9 (© G. Michael Taylor, photograph G. Michael Taylor)

silica suspension. The details of this modified method have been described recently (Inskip *et al.* 2017). Residues were eluted from the silica slurry in 65µl of high-performance liquid chromatography (HPLC) grade water and stored at -20˚C until assayed.

Screening for evidence of *M. tuberculosis* (MTB) complex DNA used established polymerase chain reaction (PCR) methods to screen for traces of two insertion elements present in all members of the MTB complex. The first method was for IS1081, present in six copies in all complex members and the second for the repetitive element IS6110, present in multiple copies in *M. tuberculosis* strains and usually fewer (1–4 copies) in *M. bovis* and other MTB complex species. The IS1081 method was run using a variety of primers to check for different template sizes, these being 135bp with primers F2/R2, 113bp with primers F2/R3 and 79bp with F3/R3. PCR products were reported using a specific HEX-labelled hybridisation probe (HEX- 5'-ATT GGA CCG CTC ATC GCT GCG TTC GC-3'-BHQ1) (Mays *et al.* 2011). Additionally, for the primer combinations F2/R2 and F2/R3, products were also reported with the intercalating DNA binding dye EVAGreen™. This approach increases sensitivity but to the detriment of specificity. The IS6110 method, using primers IS-1 and IS-2, yields amplicons of 123bp and with primers IS-3 and IS-4 amplicons of 92bp. The primer sequences and PCR conditions for both methods have been reported previously (Taylor *et al.* 2003; Mays *et al.* 2011).

Human DNA

An attempt was made to confirm the sex of individual 3030 using a PCR for the tooth enamel protein amelogenin. The sequences of the primers used in this procedure were (F2) 5'-TGACCAGCTTGGTTCTAWCCC-3' and reverse (R1) 5'-CARATGAGRAAACCAGGGTTCCA-3'. Full details are given in Waldron *et al.* (1999).

PCR amplification

All PCRs were run on a real-time PCR platform (Stratagene MxPro 3005P) together with multiple template blanks to check for cross contamination. The inclusion of positive control tubes was avoided to exclude the possibility of contamination with modern DNA. Amplicon sizes were also checked using agarose gel electrophoresis.

Results: MTB complex screening methods

When used with the DNA binding dye EVAGreen™ the IS1081 method with primers F2/R2 was found to generate a product with a melt temperature of 87˚C, lower than that expected (91–92˚C). Gel electrophoresis subsequently showed the amplicon was approximately 200bp long, greater than the expected 135bp. Similarly the primer combination F2/R3 generated two non-specific products (Ca 100bp and 150bp) rather than the expected single amplicon of 113bp. This indicates some primer cross-reaction with unknown mycobacteria or possibly other bacteria with insertion sequences having homology with IS1081 which were present in the marine environment. All variants of the IS1081 PCR method where the HEX probe was used failed to show any evidence for MTB complex species. Similarly the IS6110 method failed to show any product generation.

Results: amelogenin

The amelogenin PCR generated a single band of about 100bp when applied to the 3030 extract (Fig. 15.6). The expected product sizes for males would be 105bp and 290bp, which reflect products amplified from the Y and X chromosomes respectively. Females generate the single X chromosome product (290bp). In this case, we interpret this finding from cranium 3030 to generation of the Y chromosome amplicon only and this could reflect the presence of fragmented DNA with sizes below that needed to amplify the X-chromosome product. We have seen this outcome previously in older cases (Waldron *et al.* 1999; Dowd 2016). Tentatively, therefore, and within the constraints imposed by fragmented DNA survival, we infer this individual may have been male.

Discussion

The remains represent a minimum of five individuals, probably all male, with the youngest in their late teens or early 20s. The presence of skeletally immature remains is not unexpected; 18 of 88 individuals recovered from excavations on the *Mary Rose* (1545) were adolescent (Stirland 2005), as were four of the 20 individuals recovered from the *Vasa* (1628; During 1997). Indeed, the youngest individual recovered from the *Mary Rose* was ten years old, while a nine-year-old was recovered from the excavation

of the Swedish battleship *Kronan* (1676; Kjellström and Hamilton 2014).

The statures of only two individuals could be calculated and gave results of about 1.70m and 1.76m. These are comparable to a mean calculated from a small sample of ten early 17th-century Londoners of 1.75m (Bekvalac 2018) and the mean figure for the 92 *Mary Rose* sailors of 1.71m (Stirland 2000, 159). These two men are slightly taller than the mean for their 34 Swedish counterparts from the *Vasa* (1.68m) (calculated using the Trotter and Gleser 1952 equations; During 1997).

What is perhaps unusual is the finding of chronic infectious bone disease in one cranium (3030). Infectious disease was not noted among the remains from the *Vasa* (MNI=25) (During 1997) and it was rare among those from the *Mary Rose* (MNI=179). From the latter vessel, only two elements, both ribs, showed periosteal reactions, which suggested chronic chest infections (Stirland 2000, 96–9). Although no definitive determination of the cause of the infection in this cranium (3030) was possible, it may well have been tuberculous (the failure of the biomolecular work to amplify *M. tuberculosis* complex DNA may have resulted from poor survival of the molecule or other reasons and cannot be taken as evidence for absence of infection) and was probably disseminated to the bone from soft tissue lesions. This individual (3030) would probably have been most unwell during his final voyage down the Thames.

Animal bones

by Polydora Baker and Philip L. Armitage

Six animal bones were recovered by hand-collection and through environmental sampling from five grid squares (G9, G10, I9, I11 and J10) and from trench 4 on S2. Three further animal non-bone remains may derive from intrusive organic seabed detritus and are not discussed. Two worked objects, an ivory comb and a tool handle made of cattle bone, are discussed by Schuster (Chapter 11).

The non-worked bones were identified with the aid of the Historic England (P. Baker) and personal (P. Armitage) reference collections and published identification guides. Preservation, angularity (integrity of bone edges) and fragmentation were recorded, with surfaces examined for butchery marks and other taphonomic modifications using a low power binocular microscope. Age at death follows Silver (1969). A single measurement was recorded after Driesch (1976).

The hand-collected finds (recorded by P. Baker) include two bones from *Bos taurus* (cattle/cf. cattle) including a right pelvis (ischium with region posterior to obturator foramen; 3013) and a right humerus distal shaft (3336); the fused caput and proximal shaft of a right femur from a sheep/goat (*Ovis aries/Capra hircus*; 3168) and two rib fragments from unidentified medium (sheep/goat/pig, *Sus domestica* size) or large (cattle/equid, *Equus* sp. size) mammals. The latter include the proximal or distal end of an ossified costal cartilage (3136) and the proximal articulation of a caudal rib (3291). Specimen (3539) from an environmental sample has been very tentatively identified as a piece of the shaft from a sheep metatarsal (recorded by P. Armitage). None of the bones are more than 50% complete, probably reflecting butchery and post-depositional breakage. Preservation ranges from moderate to good, but most show changes, no doubt owing to damage and burial during submersion. Some of the specimens have broken and abraded surfaces and edges as well as fine scratch marks, probably due to movement on the seabed. Most bones are discoloured over large parts of the surface and the caudal rib is almost completely black, possibly owing to iron/manganese staining (Armitage 2013). The sheep femur has patches of encrusted material.

The cattle pelvis has fine striations on the cross-section between ischium blade and acetabulum and was (probably) sawn to reduce the hindquarter into portions, while the cf. cattle humerus has fine cut marks on the distal shaft, perhaps resulting from disarticulation, and a green-stick fracture, indicating it may have been broken for marrow extraction. No age at death information was available for either specimen. The pelvis is similar in size to that of a modern female Kerry cow reference skeleton (HE2277, around 450kg) and the humerus is slightly more robust than that of Kerry/Gascon reference cows (HE2277, 2711; SD approximately 51.5mm). The sheep/goat femur is from an adult animal (over 2.5–3 years) similar in size to a Cotswold ewe (HE1352). The bone is broken mid-shaft and longitudinally probably owing to post-depositional breakage rather than butchery. The medium-large mammal rib and ossified costal cartilage are fragmentary but do not show secure evidence of butchery. The caudal rib fragment is of large mammal size but also compares in size and morphology to those of a modern (female) pig breed (HE3867, Large White x Blue).

Discussion

The animal bones from the *London* may have derived from food waste or provisions carried on board the ship, though this is not definitive as some may have washed in. Both cattle bones display evidence of butchery indicating that these were food remains. Fresh and preserved meat provisions were carried aboard medieval and post-medieval ships, including (probably) the *London* and contemporary vessels (e.g. Armitage 2002, 2013; Coy *et al.* 2005; Migaud 2011).

For example, cattle pelves along with scapulae were among the most common bones (after vertebrae and ribs) found in casks on the *Mary Rose*, while longbone shafts were rare. Brined meat may have retained blade fragments of scapulae and pelves and butchered rib and vertebra sections (Coy *et al.* 2005, 273); ribs of cattle and pigs have been found

on various shipwrecks including, for example, the *Earl of Abergavenny* (1805) and in the smallest of assemblages such as those from the *Gloucester* and from the *Stirling Castle* (Armitage 2002; 2013; Gautrey 2014; Dagless *et al.* 2020).

In contrast, the marrow-filled longbones, which could potentially rot, would have been boned out prior to preserving the meat (Coy *et al.* 2005, 573). In this respect the presence of a cattle humerus could indicate transport of live animals, as could the sheep/goat femur. Armitage (2002; 2013 and references within) noted that sheep carcasses were unsuited to salting and that mutton would have been procured from animals carried to supply fresh meat, in particular for the captain and other high status crew. The presence of a possible sheep metatarsal fragment (part of the foot) could further support the notion that whole (and possibly live) animals were transported on board. The bones provide some albeit limited information about the types of livestock used for preserved meat or procured for live carriage and are consistent with contemporary, post-medieval livestock sizes, perhaps reflective of late and post-medieval 'improvements' and breed diversification, as well as selection of large carcasses for ship supplies (e.g. Thomas *et al.* 2013; Fraser 2019).

Pollen

by Michael J. Grant

Samples recovered from the *London* underwent pollen assessment to identify the level of pollen preservation and to identify archaeological potential. Pollen analysis has been undertaken successfully on a number of wreck sites (e.g. Scaife 2005; Greig 2005; Robinson and Aaby 1994; Diot 1994; Muller 2004; Wilson 1975). The pollen assessment was conducted on 17 sediment samples collected from the seabed, from the interior of the hull, and samples associated with archaeological finds including residues in powder boxes and in a clay pipe, adhering to the gun carriage, and a single sample of oakum (not conserved) from a wicker basket (not recovered) found adjacent to the gun carriage.

The majority of the sediment samples showed a pollen assemblage derived from a regional pollen source, both aerially and fluvially transported, which has been incorporated into the seabed deposits and sediments adhering to the gun carriage. By contrast the sample of oakum from the basket is dominated by *Cannabis sativa* (hemp) pollen. This suggests that the basket held hemp in the form of rope/caulking that would have been used aboard the vessel.

Some spatial variations were observed between the pollen samples, most notably between samples derived from interior structures compared to samples from the seabed beyond the hull, providing glimpses of a pollen signal that might be associated with the ship pre or immediately post sinking. Insufficient pollen was obtained from the archaeological material to warrant further analysis.

The pollen assemblage associated with organic material recovered from trench 3 is clearly of terrestrial origin and is likely to be derived from a peat deposit that has been eroded within the Thames Estuary and subsequently transported to this location. Sample 6(1) is the only sample studied where the pollen assemblage can be clearly related to activities associated with the ship before it sank, with no incorporation/contamination of pollen derived from a contemporary regional source area or derived from pollen of unknown age already present in estuarine deposits.

Environmental samples

by Sarah F. Wyles

Seven samples (50–56) were selected for the assessment of the preserved environmental remains and were processed for the recovery of molluscs and plant remains. The samples of between 20 and 1000ml were taken from a number of locations from trenches 3 and 4 on S2. Waterlogged stem fragments were present in all seven processed samples, with waterlogged plant remains in low numbers in five of them.

These included sedge (*Carex* sp.) seeds and common reed (*Phragmites australis*) from the peat fragment (sample 50). A few seeds of bramble (*Rubus* sp.) were noted in sample 53 from outside the gunport and in sample 54 from the gundeck. Low numbers of seeds of watercress (*Rorippa* sp.) were recorded in sample 51 from the top of the clayey silt on the exterior of the hull and in sample 52 from the clay silt at 1m depth in trench 4. No waterlogged plant remains were observed in sample 55 taken from inside the chest containing the powder boxes or from the fill of clay pipe (3677; sample 56). A few charcoal fragments were also recovered from samples 54 and 51.

Molluscs were recovered in low to moderate quantities from four of the seven samples and in high numbers from sample 52. No shells were recorded from the peat fragment (sample 50) or from the clay pipe (3677; sample 56). The shells were predominantly of mussel (*Mytilus edulis*) and tellin/furrow shell type (*Scrobicularia/Tellina* type). There were a number of shells of cockle (*Cardium* sp.), top shells (*Gibbula* type), *Peringia ulvae*, *Rissoides* and acorn barnacles (*Balanus balanoides*). There were also a number of sea urchin (Echinoidea) spines.

A number of foraminifera, including those of *Quinqueloculina* and *Elphidium* type, and ostracods were recorded in six of the seven samples (except 50).

Sedges and watercress are indicative of damp grassland and wet environments, while common reed is often found in the upper edges of estuaries and on other wetlands which are occasionally inundated by brackish or salt water. Brambles are common on waste/rough ground and these seeds may possibly have been brought in on material such as the gunwadding, as they were recorded in samples from the gundeck and from outside the gunport. They may, however, be unrelated to activities and environments linked



Figure 15.7 A queen conch shell (3330; © Historic England, photograph Angela Middleton)

to the ship's use or sinking and may have derived from other sources, such as being transported by water from the surrounding land at a later date.

Mussels favour open rocky shores or rocks in sheltered harbours and estuaries, whereas *Scrobicularia* and *Tellina* can inhabit thick mud and muddy sand in estuarine and intertidal conditions. Barnacles can exploit rocky lower shore environments and sea urchins are found in the lower shore. Top shells can be recovered from the middle shore or below, while cockles can be found in sandy mud on the middle shore or below. Rissoidae can favour shallow marine environments. *Peringia ulvae* is 'a species restricted to brackish or salt water in estuaries, intertidal mudflats and saltmarshes, commonest within the upper half of the intertidal zone sometimes associated with marine molluscs like cockles and *Scrobicularia*' (Kerney 1999, 33). The assemblages seem therefore to be indicative generally of material being washed in from estuarine and shallow marine environments.

Queen conch shell

by Greg Campbell

A queen conch shell (3330) (*Lobatus gigas*, until recently *Strombus gigas*; Landau *et al.* 2008) was recovered from the surface of S2. The recovered shell measures 138mm high by 62mm wide (excluding spines) (Fig. 15.7). The base of the column is only slightly eroded, so the present shell height is a good approximation of the original shell height. The lip of the aperture, however, and approximately one-quarter of the final whorl (the body whorl) have been lost, leaving a roughly semi-circular sharp-cornered edge. In addition the usually prominent and substantial spines have been reduced to relatively short stubs; the outer ends have been polished to a smooth matte finish and the internal hollows of the spines contain a blue clay. Although the spines erode while the animal is alive, owing to wave-rolling, the loss



Figure 15.8 The London *conch (3330) compared to an adult queen conch from the author's collection (© Historic England, © Greg Campbell)*

of both aperture and spines is most probably the result of wave-erosion of the dead empty shell.

An oval grey-brown stain within the surviving body-whorl, extending into the internal hollow marking the interior of the base of the last (largest) spine, marks the lowest point within the shell when it rests on a flat surface. This stain is probably the trace of a small pool of standing water inside the shell, indicative of the shell lying washed up empty on a beach for some time. The outer surface and inside of the body-whorl bears several small colonies of bryozoans (sea-mats, tiny encrusting marine animals which survive only underwater); the conch therefore spent some time as a dead empty shell underwater.

Queen conches are native to the Caribbean, where they have been a foodstuff since early prehistory, but they are world famous as large decorative shells. While big for a shell, the *London* specimen is small for a conch (Fig. 15.8). This specimen was probably a juvenile, as it has not developed the truly ornamental adult form, with the broad rose-coloured frilly edged lip, and is rather small to have been harvested for food (Brownell and Stevely 1981).

It is most likely that, rather than contamination (lost accidentally from another vessel over the wreck site), the conch is from the *London*. The simplest explanation for the presence of this queen conch (wave-eroded, beach-stranded and too small to have been collected for ornament or food) on the wreck is that it was collected from a Caribbean beach by one of the crew as a memento of an earlier trip.

Biological specimens

by Philip L. Armitage

Environmental sampling recovered a single specimen tentatively identified as a sheep bone and a tool handle of cattle bone (see Baker and Armitage above and Chapter 11, Schuster). Other probably intrusive non-bone remains have been excluded.

Chapter 16
Textile and Fibre Analyses

Margarita Gleba with a contribution by Des Pawson

Complete structural analysis was undertaken on eight objects, including six pieces of textile and the wicks from two candles. Fibre analysis was performed on 53 samples from 33 objects including various pieces of rope, thread used for linstock repair, stitching threads from leather shoes, shoelaces, a gunwad (3479) and oakum (see Table 16.1). In several cases different structural elements of the artefact were sampled (e.g. weft and warp sampled separately in textiles; rope, worming and serving sampled separately in cordage). In some cases samples were taken before and after conservation. This analysis highlights how the *London* finds fit in the broader context of 17th-century trends in fibrous materials, the technologies of their production and consumption patterns.

Analytical procedures

Structural analysis

Structural analysis using autoptic observation, hand lens and digital DinoLite microscope (20x, 50x, 230x magnification) included determination of structural parameters such as weave and thread count per centimetre (which is indicative of textile quality), thread twist, diameter and angle, presence of edges and any other characteristic elements, such as sewing etc. (see Emery 2009).

Fibre identification and analysis

A scanning electron microscope (SEM) was used for fibre identification.[1] The samples from pre-conserved objects were air-dried before analysis (Table 16.2). The samples were not coated.

Results

Structural analysis

Technical textile data are summarised in Table 16.1. Textiles from the *London* include three shoelaces still attached to leather shoes (3390, 3731; Figs 16.1 and 16.3, and 3761; Fig. 16.2), two textiles adhering to the insoles of leather shoes (3118H and 3118O; Figs 16.4 and 16.5) and a textile tied with a rope (3704; Fig. 16.6) (see Table 16.1).

Textile shoelaces

All three shoelaces were found in association with and still passing through the holes in the uppers of the leather shoes. They are brown in colour but originally may have been dyed. Dye analysis (Vanden Berghe and Coudray 2019; see also Chapter 9, Mould) identified the presence of tannins in the samples from all three shoelaces and indigotin in one of the two yarns from 3731, indicative of dyeing with either woad (*Isatis tinctoria*) or indigo (*Indigofera* or *Poligonum* sp.). The presence of gallic acid, a tannin, in both samples of 3731 suggests that it may have been added intentionally, possibly to achieve a black colour in combination with the indigoid dye. The presence of ellagic acid and its derivatives in all shoelace samples could indicate that the tannins were used either as dye to obtain brown shades or resulted from contamination from shoe leather or wood from the ship's hull (Vanden Berghe and Coudray 2019).

Two of the shoelaces (3761 and 3390) are woven in fine warp-dominant weave, although while one lace (3390) is a simple tabby (Fig. 16.1), the other (3761) is a half-basket weave (2/1 tabby) with paired warp (Fig. 16.2). They also differ in their yarn, with one lace (3761) having z-twisted (thrown) yarn, while the other (3390) has yarn

1. Fibre identification was undertaken using a Hitachi TM3000 TableTop SEM at the McDonald Institute for Archaeological Research, University of Cambridge. The following instrumental settings were used: analytical condition mode at 15.00kV accelerating voltage, compositional imaging and working distance of 4–10mm. The diameter of fibres was measured using SEM utility tool at 400x or 1000x magnification.

Table 16.1 Technical textile data summary of textiles from the London

Object no.	Weave	Size (cm)	Warp count	Weft count	Warp twist	Weft twist	Warp diameter	Weft diameter	Warp angle	Weft angle
3761	2/1 tabby or half-basket	2x29	26 (x2)	13–14	z	z-i	0.2–0.3	0.3–0.4	medium-loose	loose
3390	Warp-dominant tabby	3x16	40–44	26	i	i	0.2–0.3	0.3–0.4	na	na
3731	Braid	1x?	na	na	S2z-i	na	Plied 0.8–0.9 (single 0.4–0.6)	na	na	na
3118H	Balanced tabby	4x2	8	8	z	z	0.5–0.8	0.5–0.8	medium	medium
3118O	Balanced tabby	3x1	7	7	z	z	0.5–0.8	0.5–0.8	medium	medium
3704	2/2 tabby or basket weave	Largest fragment 6x2	4 (x2)	2 (x2)	z	z	1.2–1.8	1.4–1.5	medium	medium

Key: thread counts are in threads per cm; thread twist: z = clockwise, i = no discernible twist; diameters measured in mm; warp angle: medium = 10–30°, loose = below 10°. All measurements are approximate since the objects probably deformed after a long period in sea water



Figure 16.1 Textile shoelace (3390) in a leather shoe (© Historic England Archive, photograph James O. Davies)



Figure 16.2 Textile shoelace (3761) in a leather shoe (© Historic England Archive, photograph James O. Davies), with detail of shoelaces (right) (© Historic England, photographs Margarita Gleba)

Table 16.2 Summary of fibre analysis of the fibrous finds from the London

MG sample no.	Object no.	Find/sample description	Function	Material	Fibre description
46	3390	Textile shoelace warp	textile	silk	fine straight fibres with triangular section
47	3390	Textile shoelace weft	textile	silk	fine straight fibres with triangular section
21	3731	Textile shoelace	textile	silk	fine straight fibres with triangular section
48	3761	Textile shoelace warp	textile	silk	fine straight fibres with triangular section
49	3761	Textile shoelace weft	textile	silk	fine straight fibres with triangular section
33	3761	Textile shoelace	textile	silk	fine straight fibres with triangular section
6	3118H	Textile on leather shoe (after conservation)	textile	plant bast	very degraded, not well processed, Z-splits
7	3118H	Textile on leather shoe (before conservation)	textile	plant bast	very degraded, not well processed, Z-splits
8	3118H	Textile on leather shoe (before conservation)	textile	plant bast	very degraded, not well processed
53	3118O	Textile from leather shoe	textile	plant bast	bundles, tracheids, epidermis, not well processed
10	3704	Textile and rope	textile	plant bast	bundles, tracheids, stomata, not well processed
11	3704	Textile and rope	textile	plant bast	bundles, stomata, not well processed
41	3704	Textile and rope	textile	plant bast	bundles, tracheids, stomata, not well processed
54	3113	Candle wick	thread	plant?	not sufficiently preserved
4	3118C	Leather shoe	thread	plant	bundles, not well processed, z-splits
3	3118F	Leather shoe (stitching)	thread	plant	bundles, not well processed
2	3118H	Leather shoe (stitching)	thread	plant	bundles, not well processed
1	3118I	Leather shoe	thread	plant	bundles, not well processed
52	3118O	Leather shoe	thread	plant bast	bundles, nodes, not well processed, but fibres more separated
5	3046	Leather boot, bucket or valve	thread	plant	bundles, not well processed
26	3524	Powder cartridge bottle cap	thread	plant bast	bundles, not well processed
29	3188 A&B	Linstock with remains of fibre binding repair (upper section)	thread	plant bast	very degraded, nodes
30	3188 A&B	Linstock with remains of fibre binding repair (lower section)	thread	plant bast	bundles, tracheids, not well processed
50	3188	Linstock with remains of fibre binding (after conservation)	thread	plant bast	bundles, tracheids, not well processed
9	3127	Double pulley block with rope	rope	plant bast	bundles, not well processed
32	3163	Breeching rope Z3 laid – rope	rope	plant bast	bundles, not well processed
31	3163	Breeching rope Z3 laid – worming	rope	plant bast	bundles, not well processed
25	3172	Rope Z3 laid	rope	plant bast	bundles, not well processed
27	3173	Rope with sennit serving – rope	rope	plant bast	bundles, not well processed
28	3173	Rope with sennit serving – serving	rope	plant bast	bundles, not well processed
14	3206	Tampion/Flexible rammer	rope	plant bast	bundles, not well processed
38	3208	Rope with sennit serving and worming – rope	rope	plant bast	bundles, nodes, not well processed
40	3208	Rope with sennit serving and worming – serving	rope	plant bast	bundles, nodes, not well processed
39	3208	Rope with sennit serving and worming – worming	rope	plant bast	bundles, nodes, not well processed
34	3209	Rope with sennit serving and worming – rope	rope	plant bast	bundles, not well processed
35	3209	Rope with sennit serving and worming – serving	rope	plant bast	bundles, not well processed
36	3209	Rope with sennit serving and worming – worming	rope	plant bast	bundles, nodes, not well processed
22	3211	Rope Z3 laid	rope	plant bast	bundles, not well processed
44	3296	Linstock	rope	plant bast	bundles, not well processed
15	3303	Iron tube with rope	rope	plant bast	finer bundles, but not well processed
19	3324	Flexible rammer Z5 laid	rope	plant bast	bundles, not well processed
23	3484	Concreted rope with organic fibres discernible at both ends	rope	plant bast	bundles, tracheids, not well processed
24	3488	Concreted rope with s-twisted yarns discernible at one end and fibres at the other	rope	plant bast	bundles, tracheids, not well processed
13	3560	Rope in iron	rope	plant bast	bundles, tracheids, not well processed
18	3568	Concreted rope with s-twisted yarns discernible at one end and fibres at the other	rope	plant bast	bundles, tracheids, not well processed
20	3632	Wooden carved block with rope inside and separate small rope fragment, *c.* 1 cm in diameter	rope	plant bast	very degraded
37	3632	Wooden carved block with rope inside and separate small rope fragment, *c.* 1 cm in diameter	rope	plant bast	bundles, not well processed
12	3704	Rope, several strands, 1cm in diameter; possible knot	rope	plant bast	bundles, not well processed
42	3704	Textile and rope	rope	plant bast	bundles, nodes, not well processed
16	3758	Cable	rope	plant bast	bundles, not well processed
43		Slow match (found in box, not associated with artefact)	slow match	plant bast	bundles, nodes, not well processed
17	3479	Gunwad (before conservation)	gunwad	plant bast	bundles, not well processed
51	3479	Gunwad (after conservation	gunwad	plant bast	bundles, tracheids, stomata, not well processed
45	Sample 6	Oakum	oakum	plant bast	bundles, epidermis, not well processed



Figure 16.3 Textile shoelace (3731) in a leather shoe (© Historic England, photograph Angela Middleton)



Figure 16.4 Insole with adhering textile (3118H; © Historic England Archive, photograph James O. Davies)



3118H



3118O

Figure 16.5 Textile (3118H and 3118O) from a leather shoe (© Historic England, photographs Margarita Gleba)



Figure 16.6 Textile (3704) tied with a rope (© Historic England, photographs Margarita Gleba)

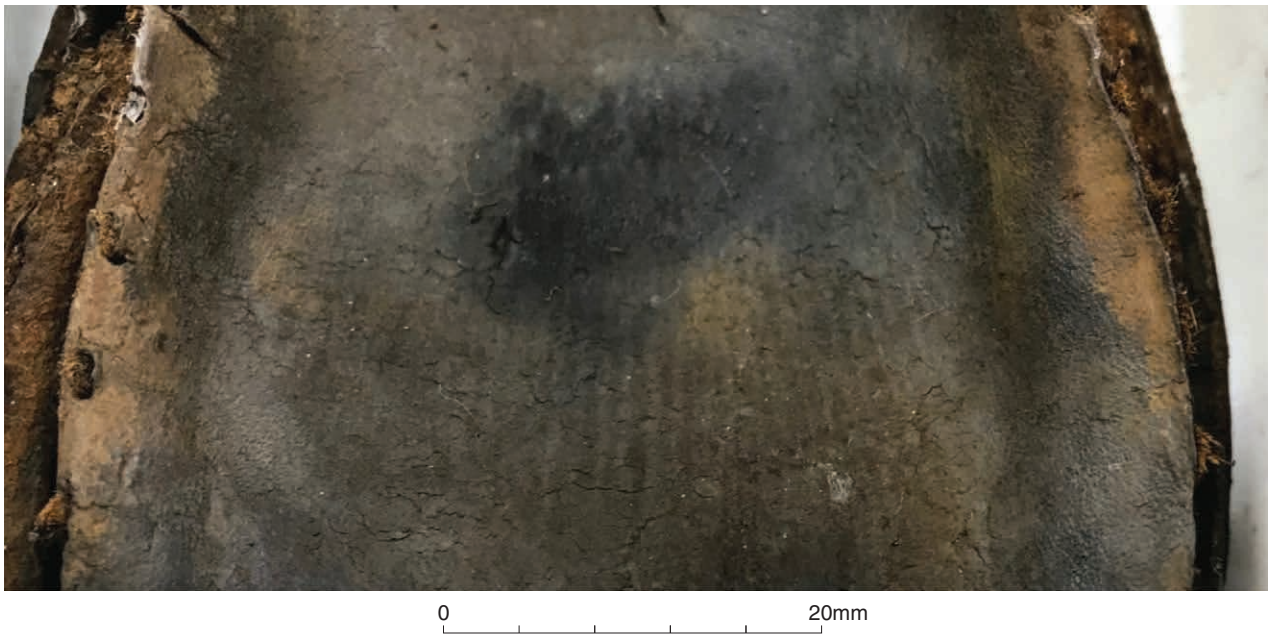


Figure 16.7 Possible textile imprint on a leather shoe (3761; © Historic England, photograph Margarita Gleba)



Figure 16.8 Stitching thread in a leather shoe (3118H; © Historic England, photographs Margarita Gleba)

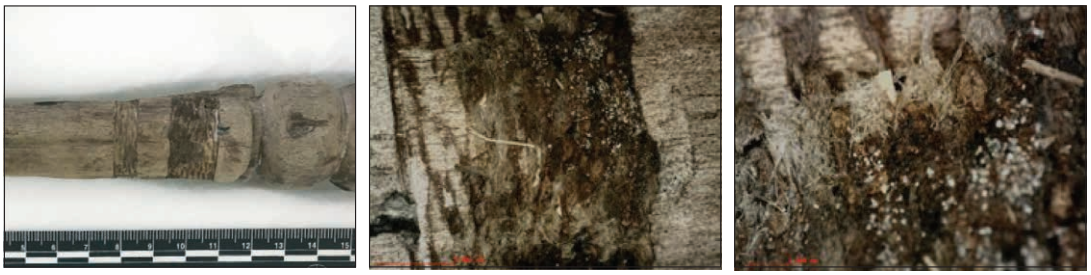


Figure 16.9 Thread used to repair a broken linstock (3188; © Historic England, photographs Margarita Gleba)

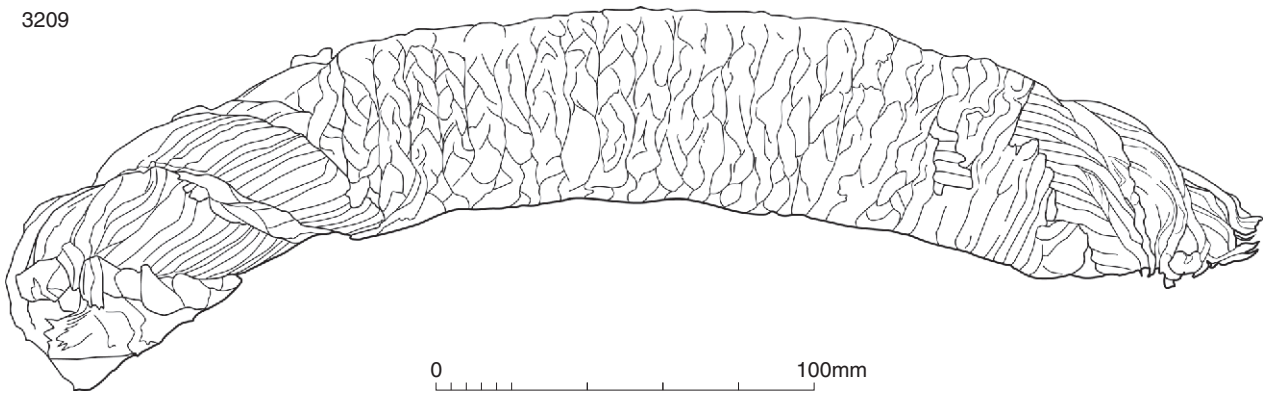


Figure 16.10 Rope fragment with serving and worming (3209; © Historic England, drawing Aleksandra Osinska)

Table 16.3 Silk fibre diameter measurements from shoelaces

Object no.	Sample description	Number of fibres measured	Mean diameter (in µm)	Diameter range (in µm)
3761	before conservation	16	12.62	9.6–15
	warp	14	14.21	10.2–17.4
	weft	15	12.47	8.2–16.8
3390	warp	21	13.01	8.7–16.2
	weft	16	13.69	8.8–16.8
3731	thread	25	11.56	7.7–16.7

without discernible twist, accounting for its more lustrous appearance. Both preserve simple selvedges, allowing the estimate of their width (2cm and 3cm respectively). In both, the ends and some parts of the selvedges are extremely frayed, suggesting extensive use. The latter is also suggested by almost permanent creases in one lace (3390), which created vertical lines in the warp direction where threads have become compressed. It is possible however that burial, compression and site evolution processes might have caused the fraying and creasing. The third shoelace (3731) is braided or plaited from three-thread bundles, each consisting of four(?) S2z-plied threads (Fig. 16.3).

Textiles from leather shoes

Two textiles were found still adhering to the insoles of shoes (3118H and 3118O) (Figs 16.4 and 16.5), although the latter is no longer *in situ*. They are both balanced tabbies of similar quality (8/8 and 7/7 threads per warp/weft respectively) made of rather coarsely processed yarn of medium z-twist. Both appear very flattened.

Textile tied with rope

The final textile in the assemblage (3704) is a very coarse basket weave or 2/2 tabby, which was found tied in an S-direction overhand knot with a piece of 3 strand, Z-laid rope (Fig. 16.6). The threads are very coarse, of medium z-twist. After conservation it became apparent that one of the fragments appears to be folded in a tube, which may have a diameter similar to the associated rope, but measurements are not possible as the fragment is flat and very brittle.

Textile imprint on a leather shoe

Fine parallel lines can still be observed on the inside of a leather shoe (3761), which number 7–8 lines/cm (Fig. 16.7). These may be imprints of a textile, possibly a knitted sock, since knitting produces a structure consisting of parallel lines.

Stitching and repair medium

Functional stitching in shoes (3118C, 3118F, 3118H, 3118I and 3118O) and a fragment of bucket (3046) was done using coarse, possibly S-plied thread, which in most cases survives as tufts of fibre in the holes only, not permitting complete structural analysis (Fig. 16.8).

A linstock in two parts (3188) appears to have been repaired using an S2(3?) z-yarn (Fig. 16.9).

Rope

Samples from 18 rope fragments were analysed. The rope fragments are all of z-laid (hawser) type, but varying in diameter. Two fragments preserve serving and worming (3208 and 3209; Fig. 16.10); one example has sennit serving but no worming (3173), while another rope has worming but no serving (3163). Most ropes are three-strand but at least two of the thinner fragments are five-strand (3127[2] and 3324) . One cable (3758) was recovered in 2016.

Fibre identification and analysis

Technical data on all analysed samples are summarised in Table 16.2.

Textiles

The three shoelaces (3761, 3390 and 3731) are made of silk. The fibres are continuous fine and smooth filaments with a drop-shaped or rounded triangle cross-section (Fig. 16.11). The diameters of the fibres are consistent in all samples, ranging between about 8 and 17 microns (µm), with averages of 12–14µm (Table 16.3). Rast-Eicher (2016, 283) provides a silk diameter range of 10–12µm.

The two textiles from the shoes (3118H and 3118O) and the textile associated with the rope (3704) are made from poorly processed plant bast fibre (Fig. 16.12). Hurds (wood stem parts) are present in all these fragments and are visible to the naked eye (see Fig. 16.5), with epidermal tissue preserving stomata clearly visible in the SEM (Fig. 16.12). Similarity with rope samples suggests the fibre may be hemp (*Cannabis sativa*) but further multi-analytical investigation is needed to confirm this identification.

Candle wicks

Microscopic observation of protruding wick threads from one candle (3126) indicated that the fibres in the wick are well processed and separated (Fig. 16.13). SEM analysis of

2. This item has the same number as the double block with which it was associated, possibly part of a strop from the block.

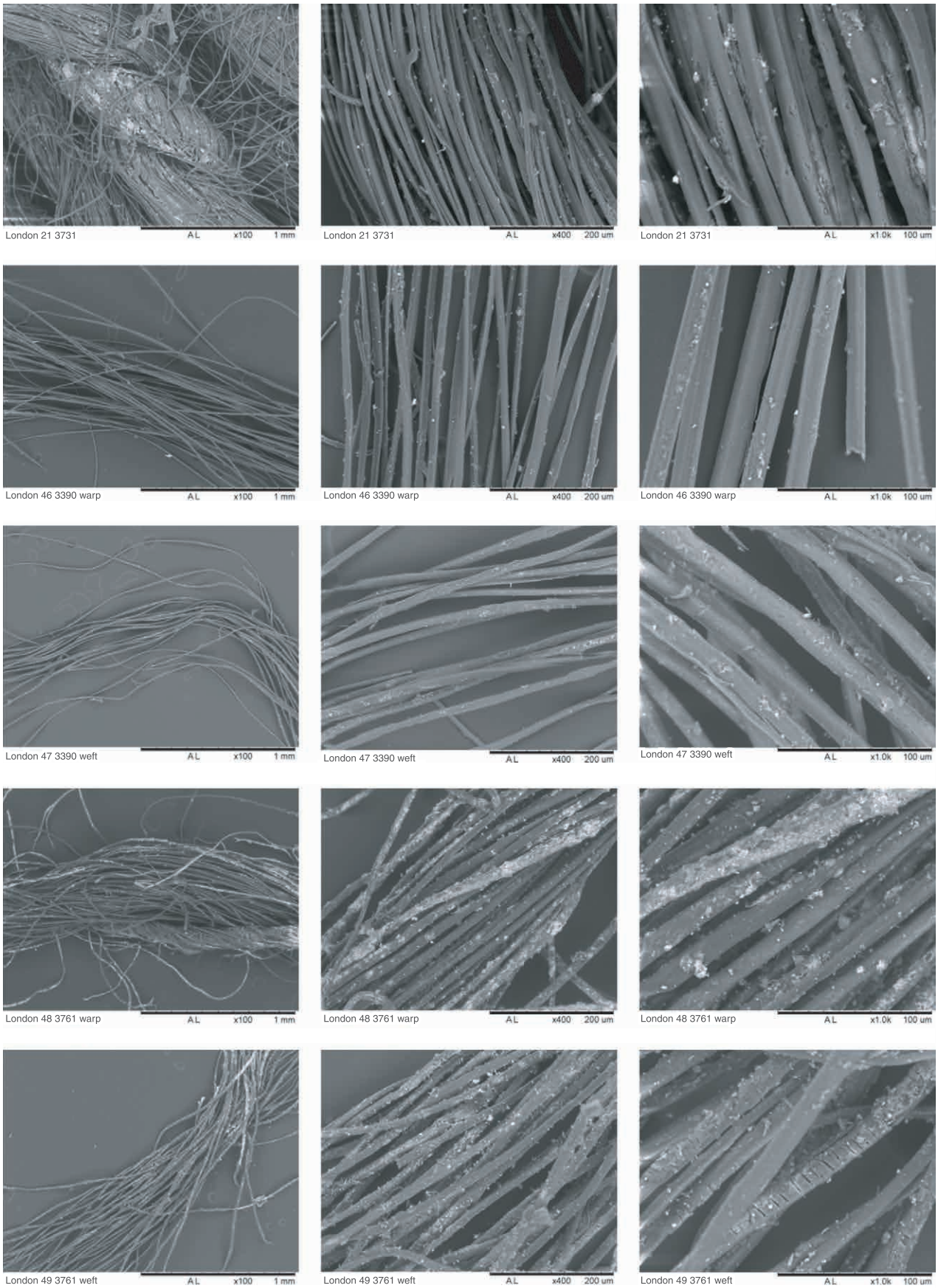


Figure 16.11 SEMicrographs of silk fibres in shoelaces (3731, 3390 and 3761; © Historic England, Margarita Gleba)

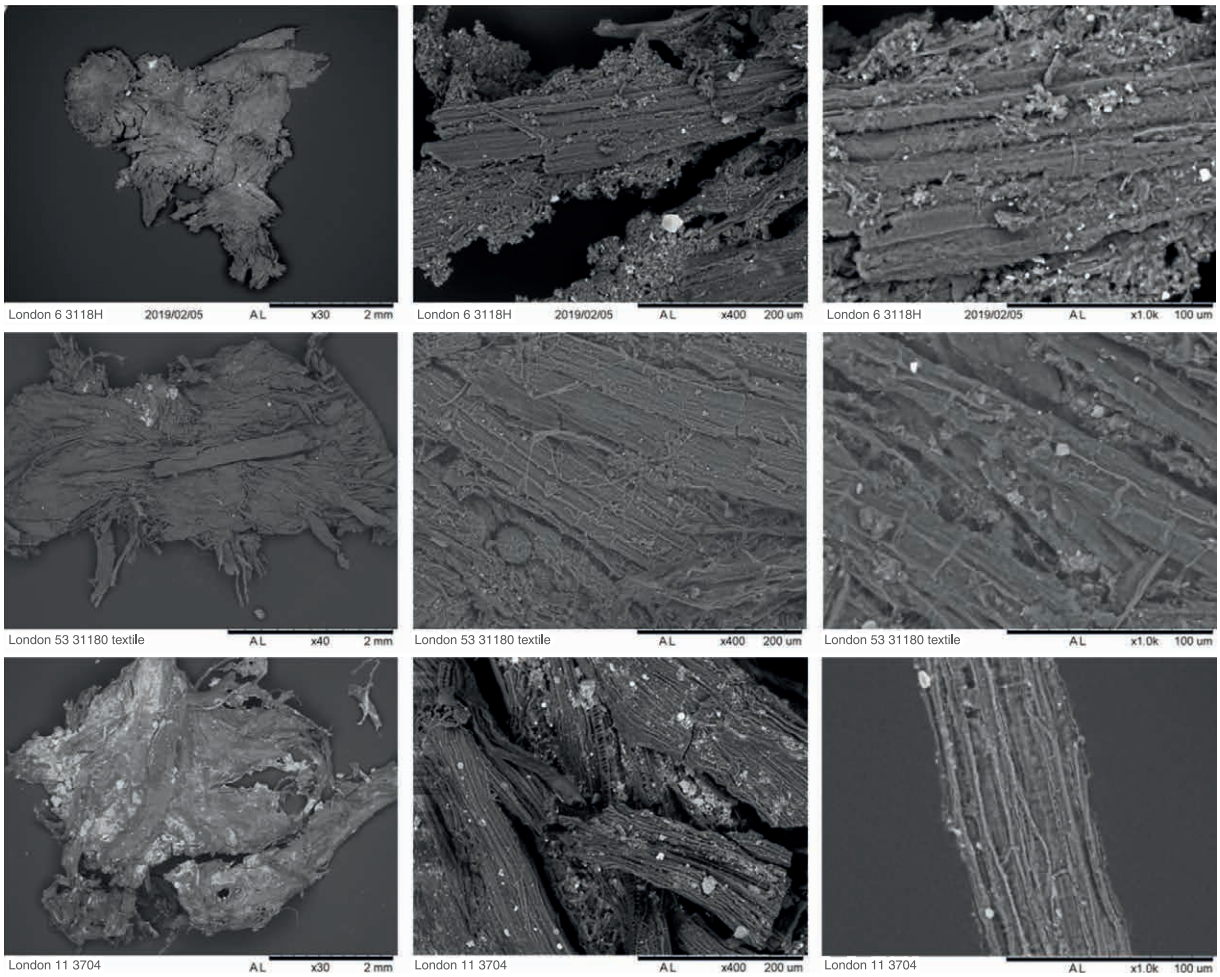


Figure 16.12 SEMicrographs of plant bast fibres in textiles (3118H, 3118O and 3704; © Historic England, Margarita Gleba)



Figure 16.13 Candle (3126) with an intact wick (© Historic England Archive, photograph Steven Baker)

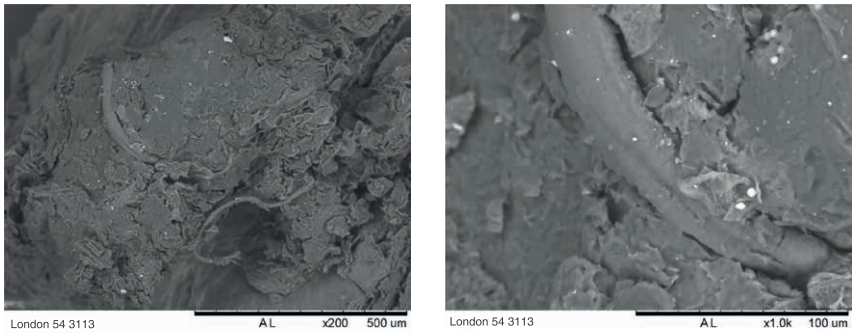


Figure 16.14 SEMicrographs of plant bast fibres in candle wick (3126; © Historic England, Margarita Gleba)

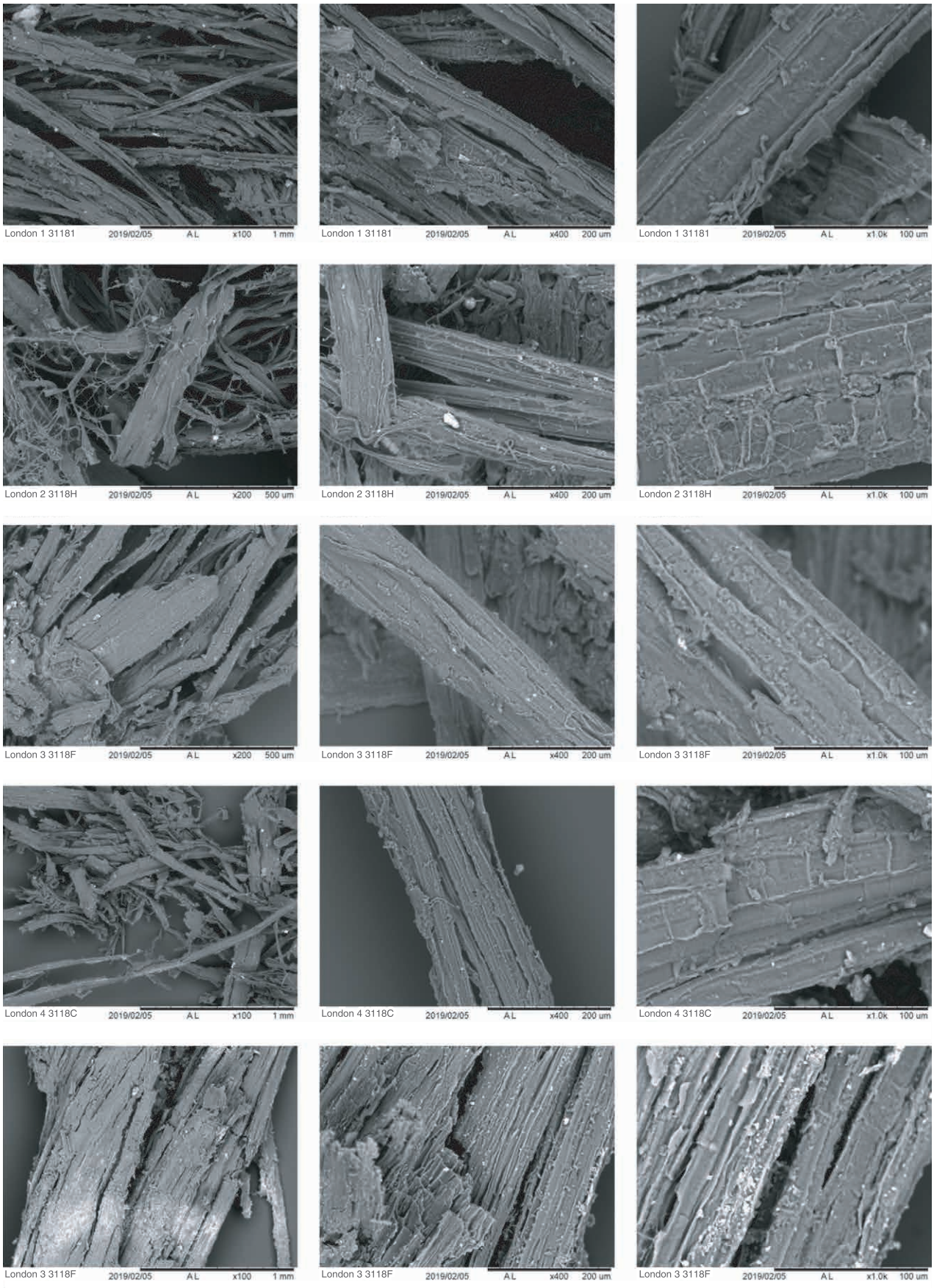


Figure 16.15 SEMicrographs of plant bast fibres in shoe stitching medium (© Historic England, Margarita Gleba)

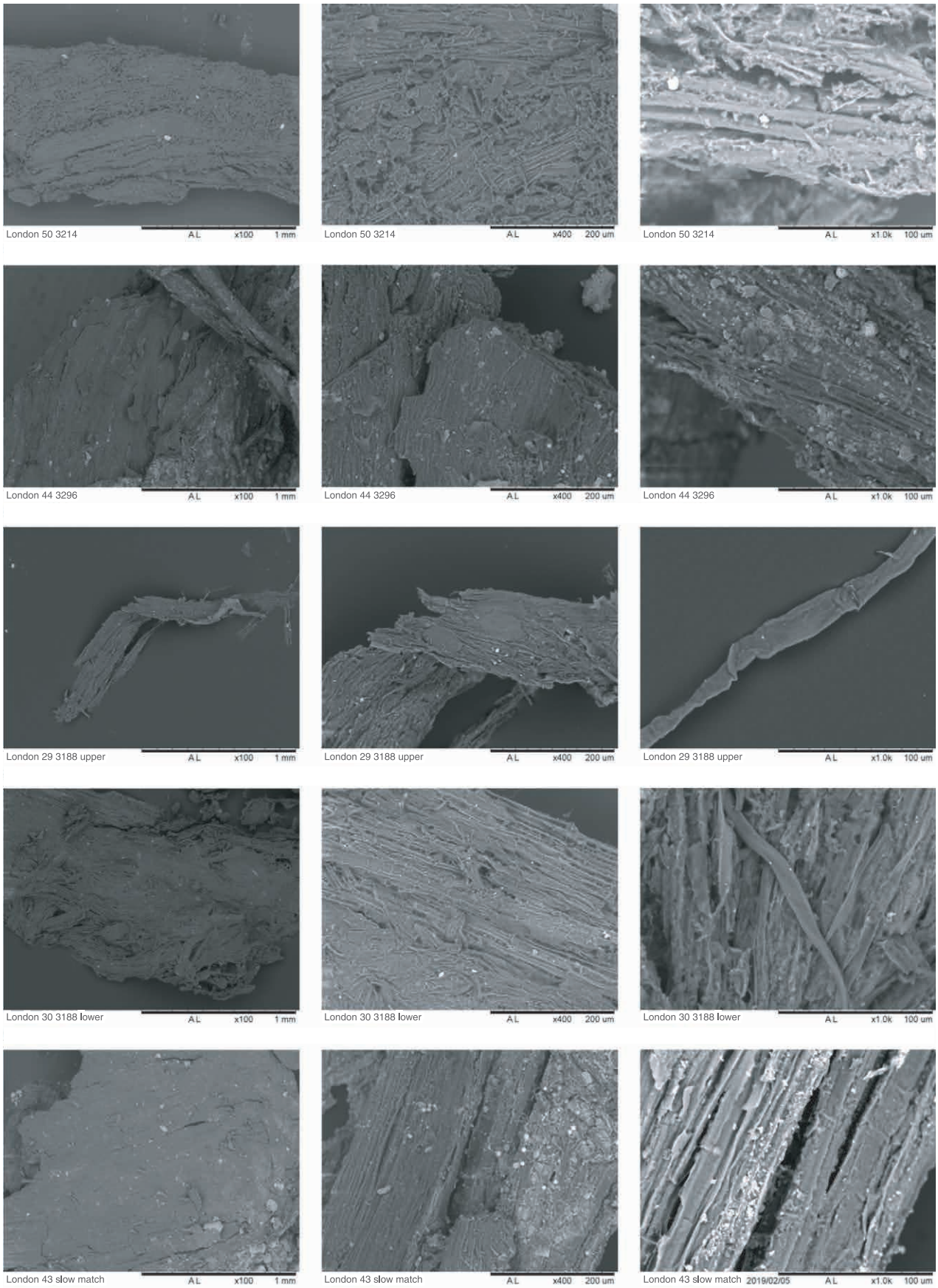


Figure 16.16 SEMicrographs of plant bast fibres in shoe stitching/repair medium (© Historic England, Margarita Gleba)

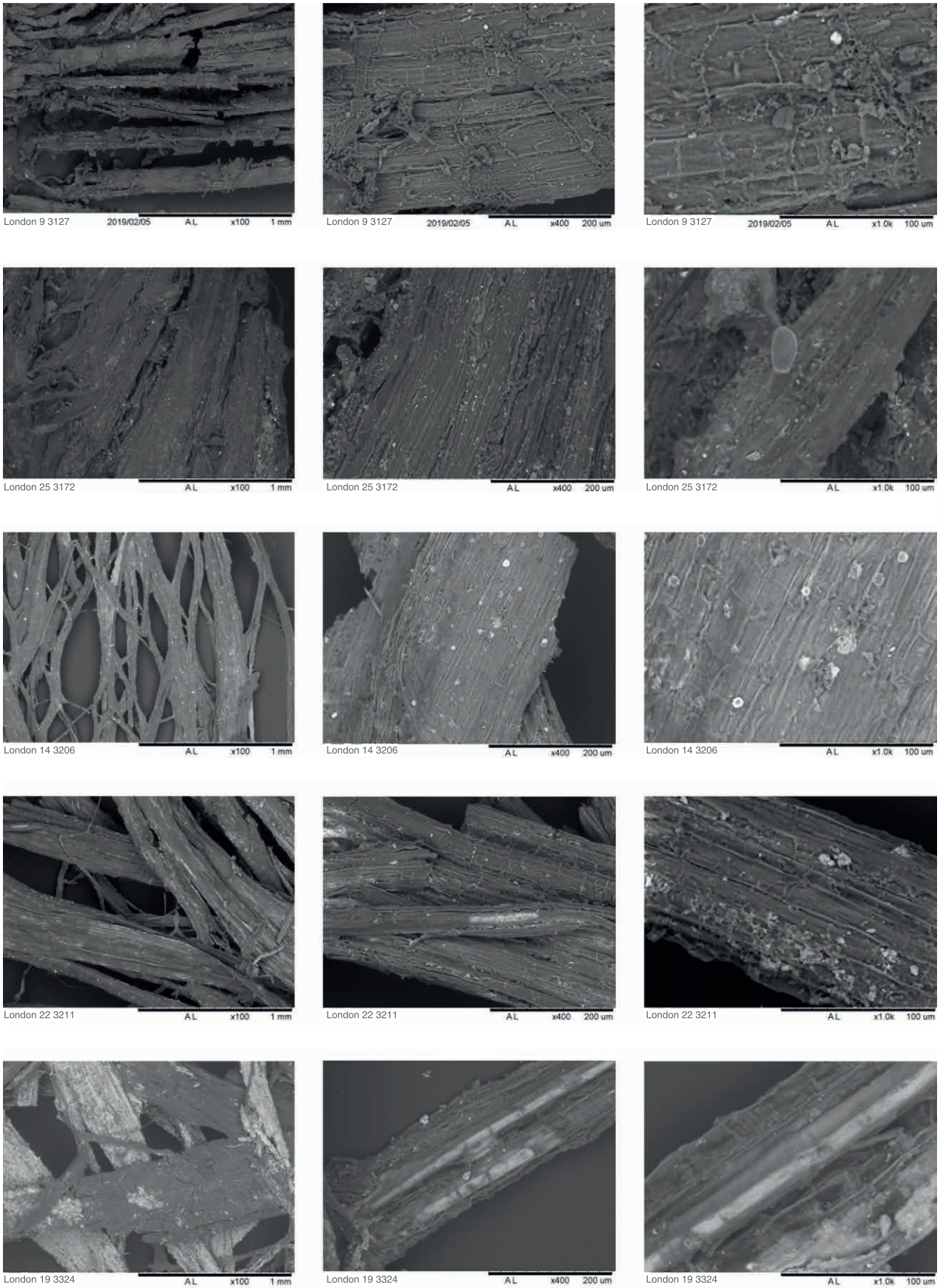


Figure 16.17 SEMicrographs of plant bast fibres in ropes (© Historic England, Margarita Gleba)

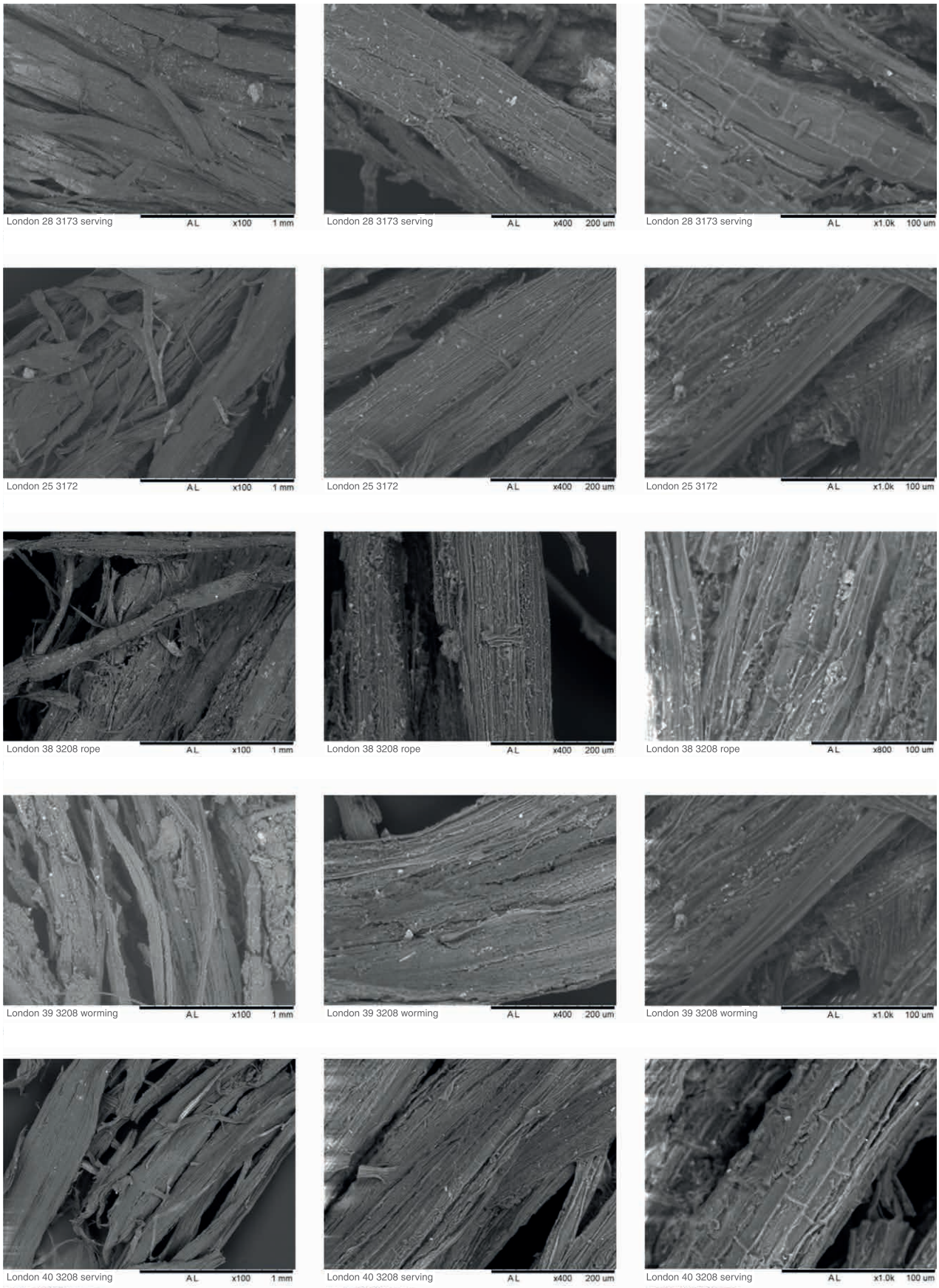


Figure 16.18 SEMicrographs of plant bast fibres in ropes (© Historic England, Margarita Gleba)

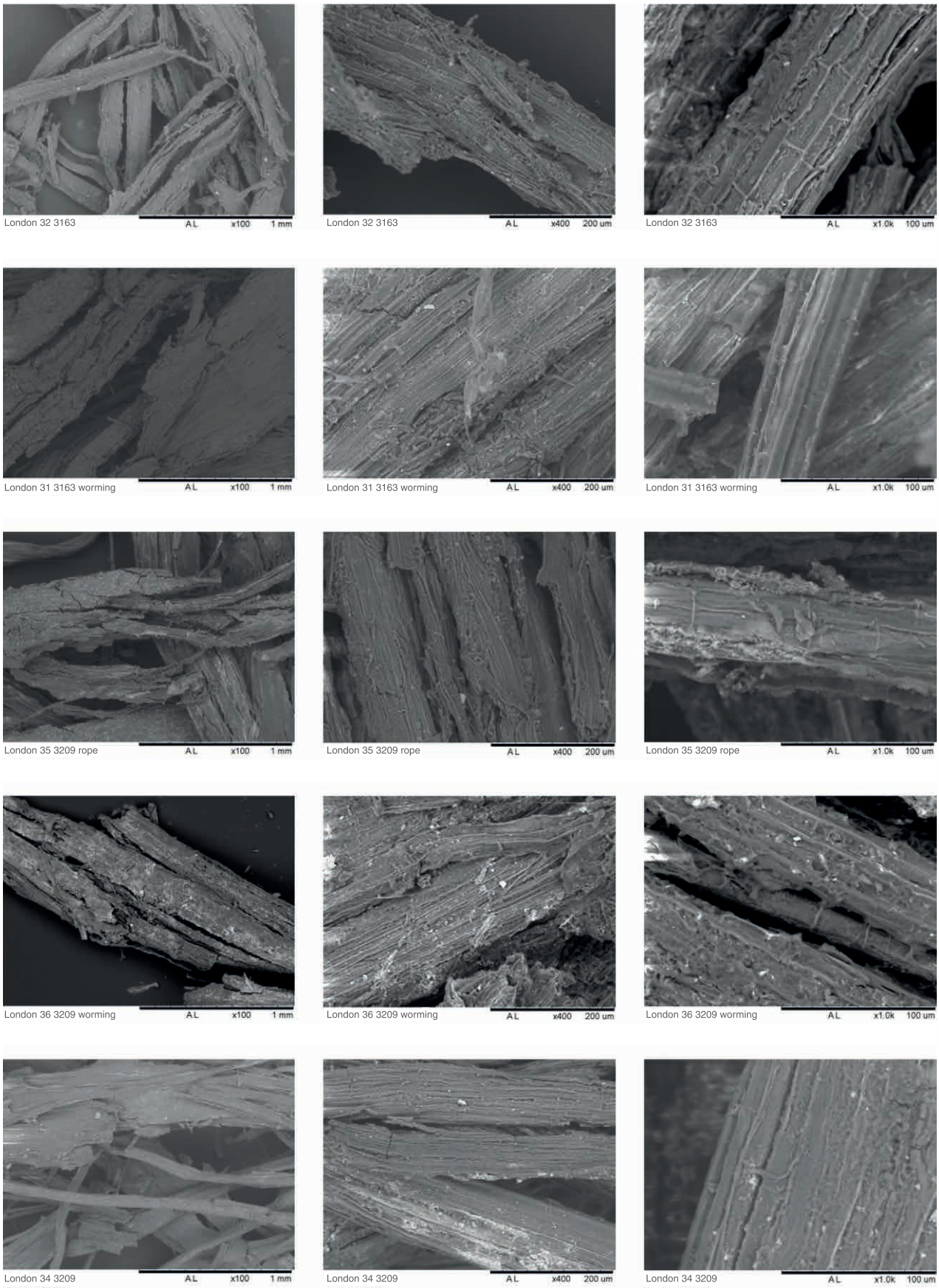


Figure 16.19 SEMicrographs of plant bast fibres in ropes (© Historic England, Margarita Gleba)

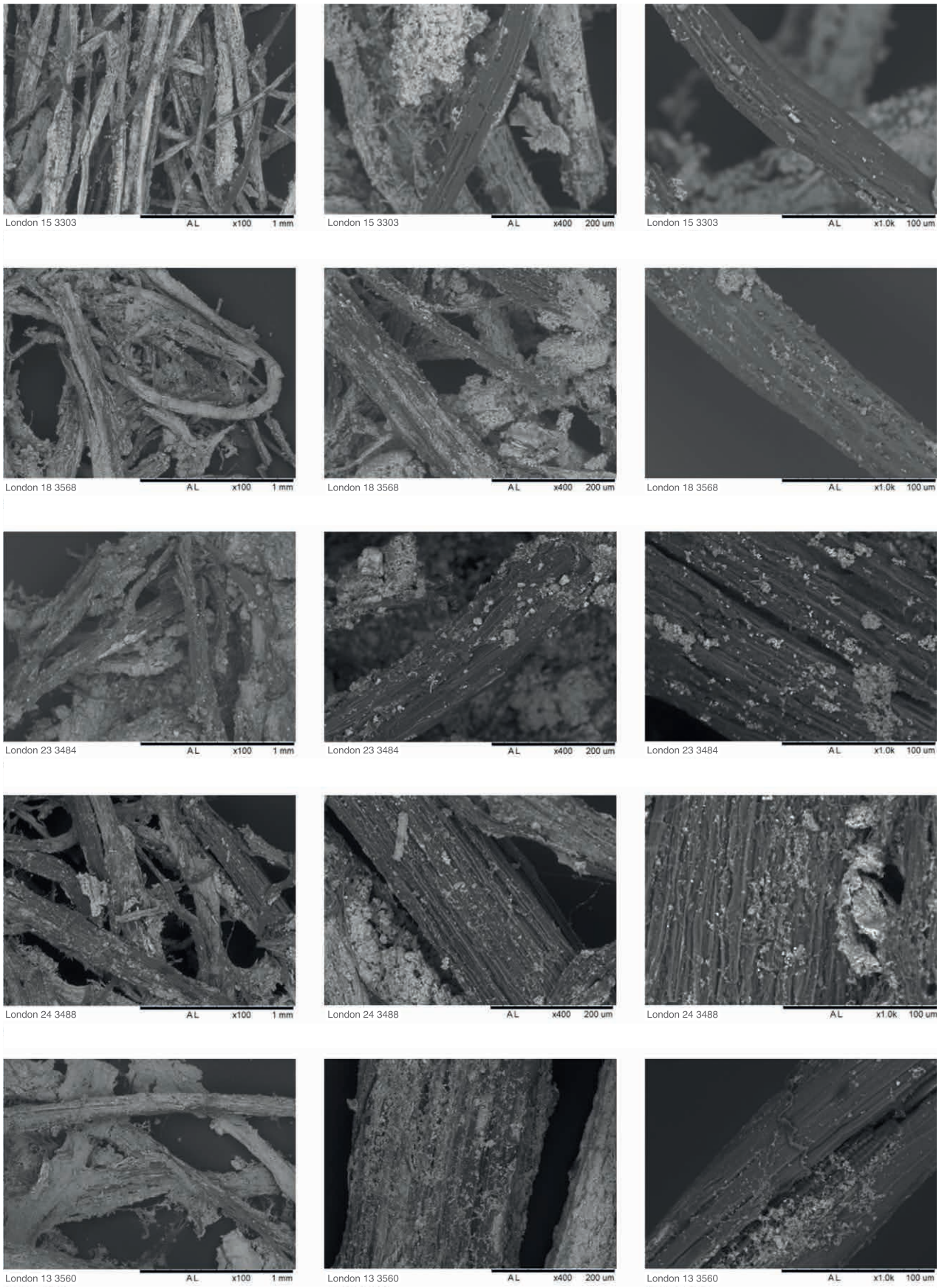


Figure 16.20 SEMicrographs of plant bast fibres in ropes (© Historic England, Margarita Gleba)

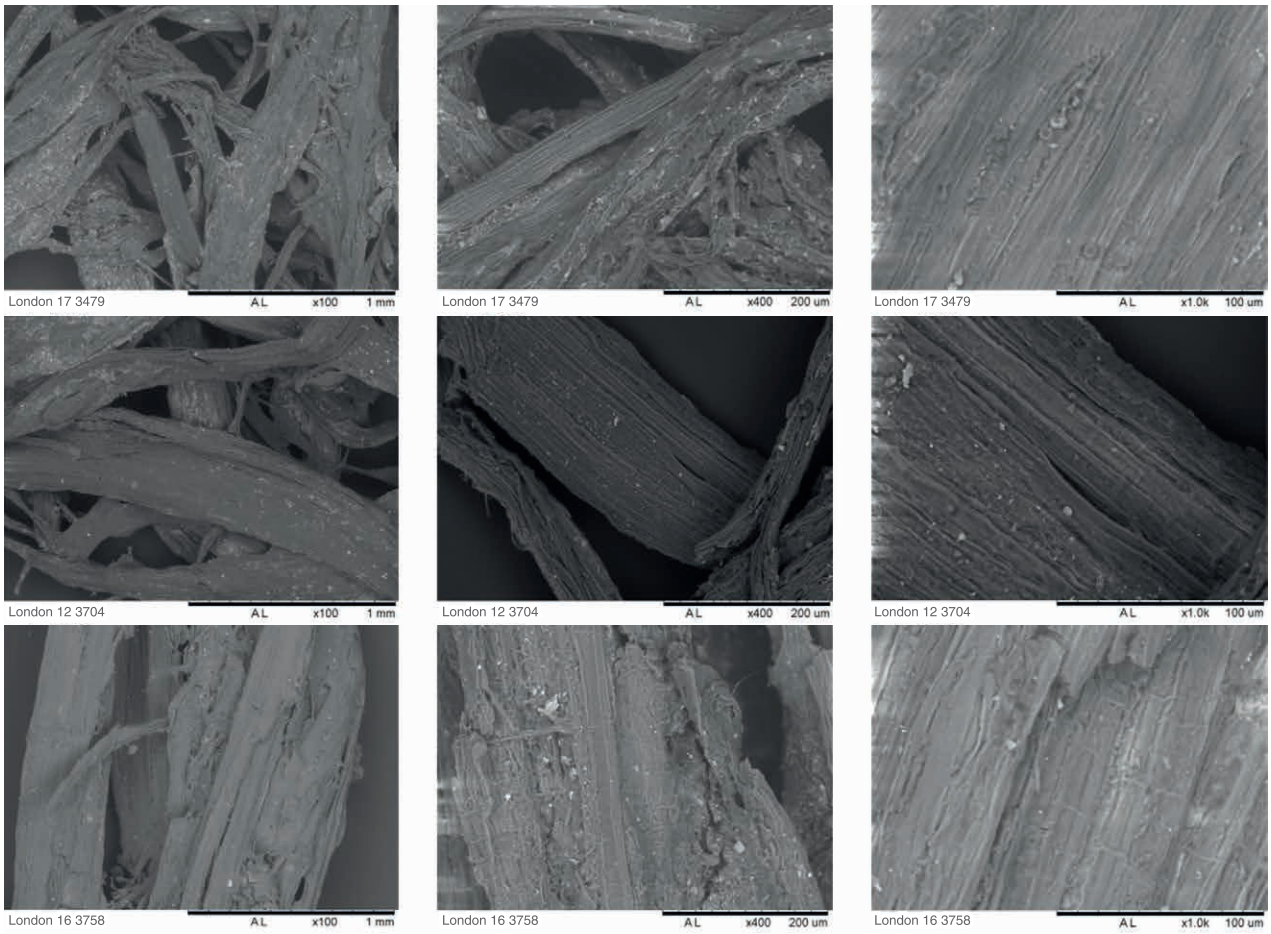


Figure 16.21 SEMicrographs of plant bast fibres in ropes (© Historic England, Margarita Gleba)

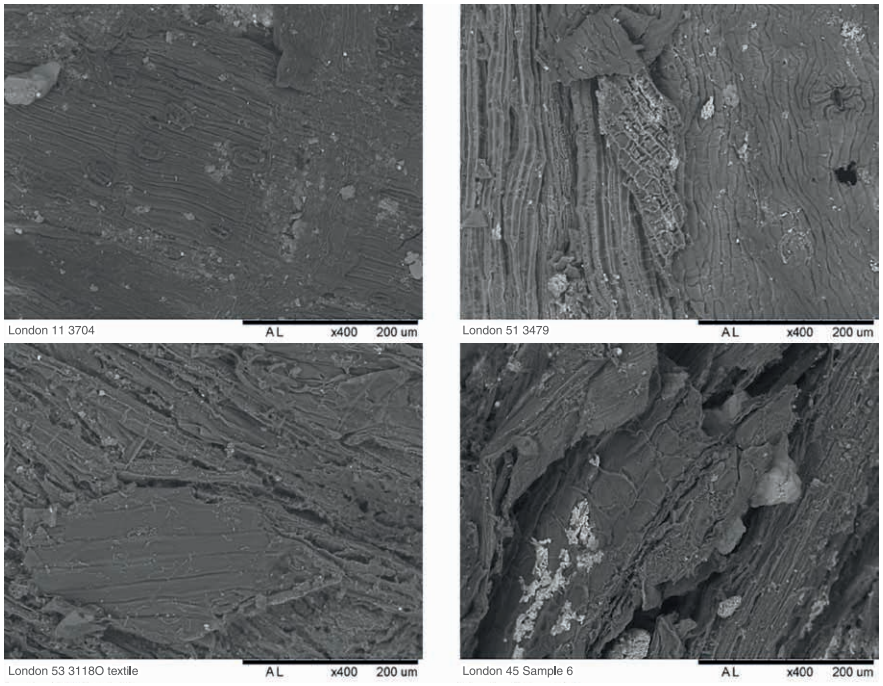


Figure 16.22 SEMicrographs of epidermal tissue in various plant bast fibre samples (© Historic England, Margarita Gleba)

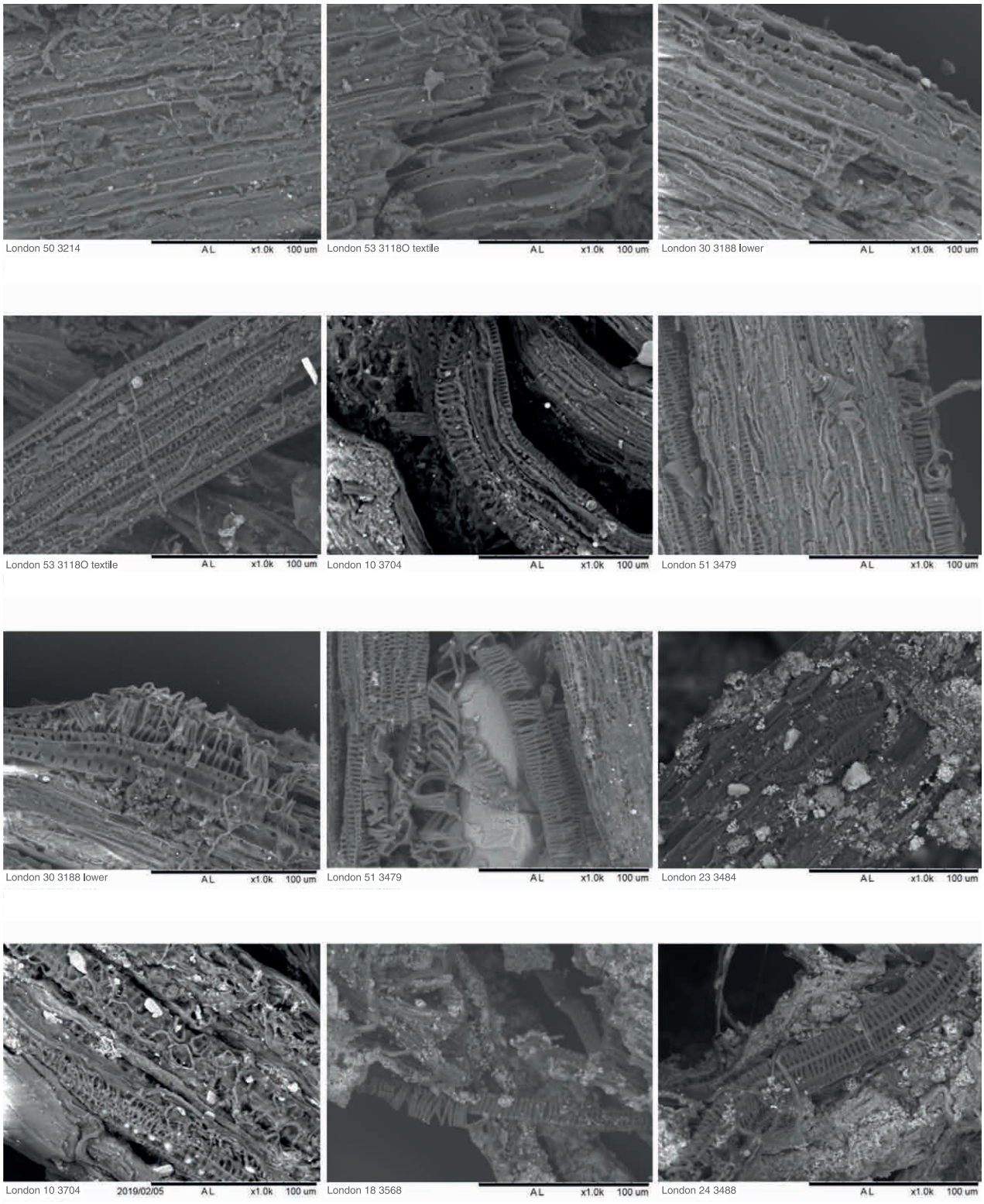


Figure 16.23 SEMicrographs of pitted vessels (top row) and tracheids in various plant bast fibre samples (© Historic England, Margarita Gleba)

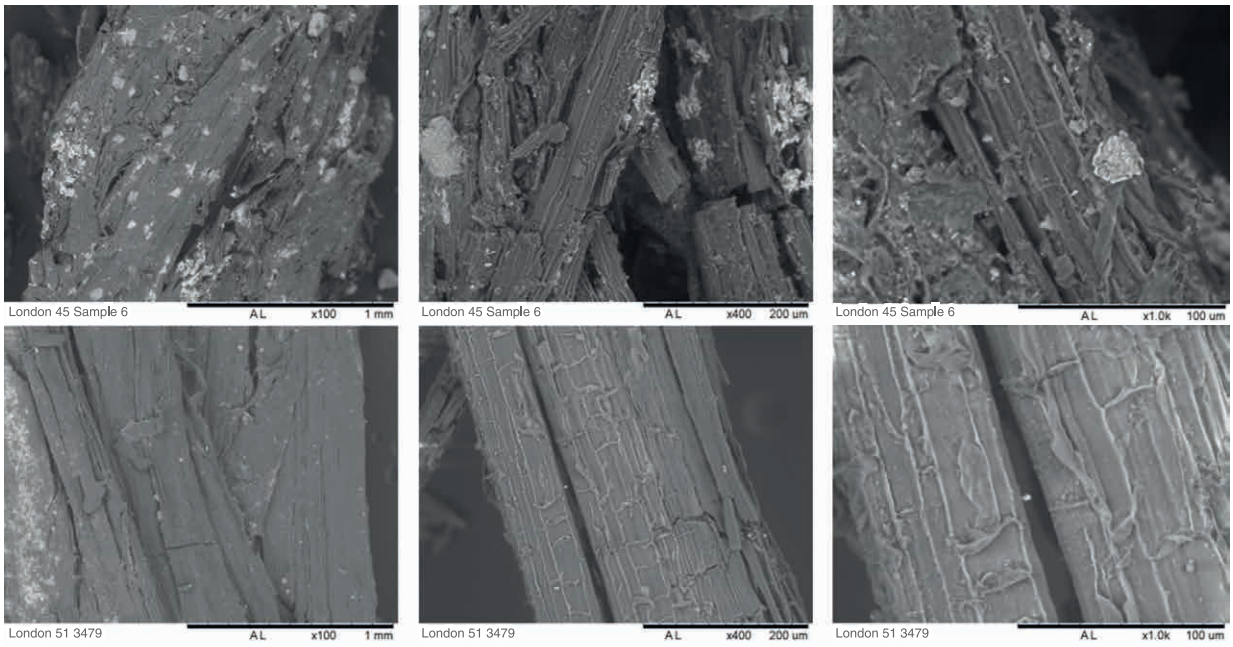


Figure 16.24 SEMicrographs of plant bast fibres in oakum (Sample 6) and gunwad (3479; © Historic England, Margarita Gleba)

the candle identified remains of two fibres, which appear to be of plant bast origin, but these were not sufficiently well preserved for species identification (Fig. 16.14).

Stitching and repair medium

The examined material used as the stitching medium for the leather shoes (3118C, 3118F, 3118H, 3118I and 3118O) and a leather bucket (3046) consists of coarsely processed plant bast fibres. Microscopically the fibres are round bundles and are still covered in connective tissue, which obscures their surface and diagnostic characteristics (Fig. 16.15). They were probably not well heckled, a stage in the plant bast fibre processing where retted plant stalks are combed to separate the fibres (see Discussion, below), although they appear to be better separated than material used for ropes and other related objects (see below).

Fibre diameters range between 14.2µm and 33.8µm. Nodes are discernible in all samples, although owing to the flattening of the fibres they are not very pronounced. Occasional z-splitting of the fibres is possibly indicative of the z-microfibrillar orientation, which is typical for hemp (*Cannabis sativa*) (as opposed to s-oriented flax; on modified Hertzog test to determine the microfibrillar orientation see Bergfjord and Holst 2010, 1193; Haugan and Holst 2013; Suomela *et al.* 2018). The same characteristics were observed for the samples from a powder box cap (3524) and a linstock repair thread (3188) (Fig. 16.16). In the latter case 'cottonised hemp' was observed: when hemp fibres separate they are often flat and, especially when degraded, start twisting and looking like cotton.

Rope

The material used for rope construction consists of very coarsely processed plant bast fibres, with non-fibrous material ('hurds') present throughout. Microscopically the fibres are not well separated and appear in ribbon-like or round bundles, which obscure their surface and diagnostic characteristics (Figs 16.17–16.21). In the case of ropes recovered from iron tubes, e.g. 3303, the diagnostic features are also obscured by iron concretions on the fibre surface (Fig. 16.20).

The fibres were probably not heckled or only coarsely so. The fibres are mostly collapsed, so cross-sections are not very informative, but the nodes or dislocations are discernible in most samples (Fig. 16.17). The non-fibrous material consists of both epidermal and parenchymal plant tissues, including helical tracheids and pitted vessels in several cases (Fig. 16.22–16.23). The few fibres from which diameter measurements could be taken range from 10–40µm. All samples examined in the SEM appear to be made of the same material, bast fibre of hemp (*Cannabis sativa*).

Oakum and gunwad

Oakum from a wicker basket (Sample 6) and the gunwad (3479; Fig. 16.24) have characteristics similar to the rope material and appear to be very coarsely processed hemp (*Cannabis sativa*). The abundant presence of cannabis pollen in oakum from Sample 6 further supports the identification (Grant 2016, where it is numbered as Sample 12).

Discussion

Textiles – shoelaces

The three surviving shoelaces (3390, 3761 and 3731) are all made of silk, a luxury material associated historically with the elites. The 17th century was one of the most excessive



Figure 16.25 Rubens and Isabella Brant in the Honeysuckle Bower *(1609/10) by Peter Paul Rubens (1577–1640) (© Staatsgemäldesammlungen, Alte Pinakothek, Munich)*

in costume history and has been termed 'the century of ribbons, bows, and lace' (Ordoñez and Welters 1998, 89). Both men's and women's clothing of this period was extravagant and every accessory from gloves to bonnets to shoes was decorated with ribbons in many forms (Fig. 16.25). Silk, the raw material used to make these ribbons, became 'an essential luxury' (Rothstein 1990, 3). According to Peck (2000, 225):

> *In 1559 silk fabrics constituted 3.3% of imports and 5.1% in 1622. Raw silk was 1.1% of imports in 1559 and 7.5% in 1622. During the 17th century as a whole, silk imports constituted from 23% to 29% of the value of all imports. By the late 17th century, silk, either raw, or as silk thread worked especially by the weavers in Spitalfields, London, was the most valuable of all raw material imports to England.*

Although the large-scale silk industry at Spitalfields in London dates from the settlement of large numbers of French Huguenots following the revocation of the Edict of Nantes by Louis XIV in 1685, foreign silk-weavers had settled in England long before. The earliest silk-weaving operations in England were established in the middle of the 15th century, producing ribbons, fringes and other decorative items. James I sought to develop a skilled labour force in the industry and even encouraged the farming of the silk worm in England. Sericulture never established owing to the unfavourable climate, however, and the raw material had to be imported from abroad. English manufacturers used prime thrown silk imported from Italy to make silk ribbons and wider fabrics (Kerridge 1985, 126).

Silk ribbons in tabby weave first appear in English archaeological deposits in the 10th–11th centuries, but do not reappear until the late 14th century (Crowfoot *et al.* 2006, 141). The technical differences indicate that while the earlier finds were imported the latter ones were probably produced locally from imported raw material. These ribbons are similar to the *London* examples in that they are all warp-faced and have thread counts between 28/12 and 50/18 threads/cm but differ in their width (not exceeding 13mm) and the thread is plied rather than single (Crowfoot *et al.* 2006, 141, table 14). Silk ribbons and laces were also recovered from the *Mary Rose* (1545). They were warp-dominant tabbies with only slightly twisted yarn and thread counts of over 40–50 threads/cm in the warp and more than 25 threads/cm in the weft (Forster *et al.* 2005, 30–31). Plaited silk braids have been found in the 13th and 14th-century deposits of London (Crowfoot *et al.* 2006, 140–1).



Figure 16.26 Candle (3113; © Historic England Archive, photograph James O. Davies)

The silk laces from the *London* thus appear to be typical accessories of the period elite (as confirmed by the types of shoes they were found with; Chapter 9, Mould), in use at least since the late 14th century. We can surmise that they belonged to one of the higher-ranking crew members of the *London*.

Textiles from the shoes

The two textiles found adhering to the insoles of the leather shoes (3118H and 3118O) are made of plant bast fibre that was not very well processed. They could be fragments of either lining for the shoe uppers or insock (a textile lining placed on top of the insole; Q. Mould pers. comm.). Such items, however, tend to be made from wool like, for example, the items recovered from the *Mary Rose* (Forster *et al*. 2005, 88).

The material and the rather coarse quality of the cloth in both textiles recovered from the *London* shoes (7/7 and 8/8 threads/cm and poorly processed fibre) leaves open the possibility that these may be fragments of sacking or even sail that may have lodged inside the shoes (Q. Mould pers. comm.).

The few extant sail fragments from other shipwrecks have a similar quality. The sails from the *Mary Rose* (1545), for example, have 10–12/8–10 threads/cm (author's analysis). The sailcloth of the Swedish ship *Vasa* (1628) was made from z-twisted hemp which included 'tufts of tow' and had 10–12 warps/cm and 7 wefts/cm (Westheden Olausson 1998, 309). A small fragment of possible sail from the 17th-century Swash Channel wreck the *Fame*, identified as a Dutch merchant vessel, had 10–12/10–12 coarsely processed z-twisted hemp threads/cm (author's analysis). Sail fragments from *Queen Anne's Revenge* (1718) range from tabby cloth with 10/10 threads/cm to half-basket weave with 14 paired warps and 7–9 wefts/cm (McCaskill 2009, 20–22). The sail of the Swedish-registered merchantman *Jeanne-Élisabeth* wrecked in France in 1755 was woven in coarse hemp z/z tabby, with 12 warps/cm and 6 wefts/cm (Bartoš and Sanders 2011, 70).

The possible textile impression on the leather shoe 3761 could be from a knitted sock. Textile impressions have also been noted on two shoes from the *Mary Rose* (Forster *et al*. 2005, 87).

Textile with rope

The construction of the textile fragment is not sufficiently well preserved to understand its function. Its association with a rope at first glance suggests that it may be part of a sail but the cloth is generally coarser than all other extant sail cloth fragments (see previous section) and is woven in basket weave. Another possibility is that it constituted some type of chafing gear or serving.

Candle wicks

A candle is a cylinder of solid fuel formed around an axial wick. The candles from the *London* (3113 and 3126) appear to have been made by rolling wax sheets around a wick. The successive layers of the sheets are clearly visible in the candle profiles. FTIR analysis conducted on the candles confirmed that the candles had been rolled rather than dipped, as the wax layers, of between <1mm and 2mm thickness, are very distinct (Fig. 16.26). This analysis identified the wax as beeswax (Fig. 16.27). The candles still contain wicks impregnated with wax. Flax was the standard material used for wicks. One of the fragments of one candle (3126) has a wick protruding at least 1cm which is composed of at least four (possibly more) z-twisted threads (see Fig. 16.13). The threads were probably twisted but the direction of the twist could not be ascertained without damaging the candles.

Candles made of beeswax were a luxury commodity in the 17th century, the norm being tallow candles or rushlights made by dipping a wick made of the stripped and dried pith of a rush (*Juncus effusus*) or reed into hot waste animal fat. Beeswax was significantly more expensive than tallow because the raw material was less abundant and beeswax candles were extremely labour intensive to produce. They also produced the cleanest light, however, without smell and lasted longer. Given their expense, it is probable that the two beeswax candles from the *London* belonged to an officer.

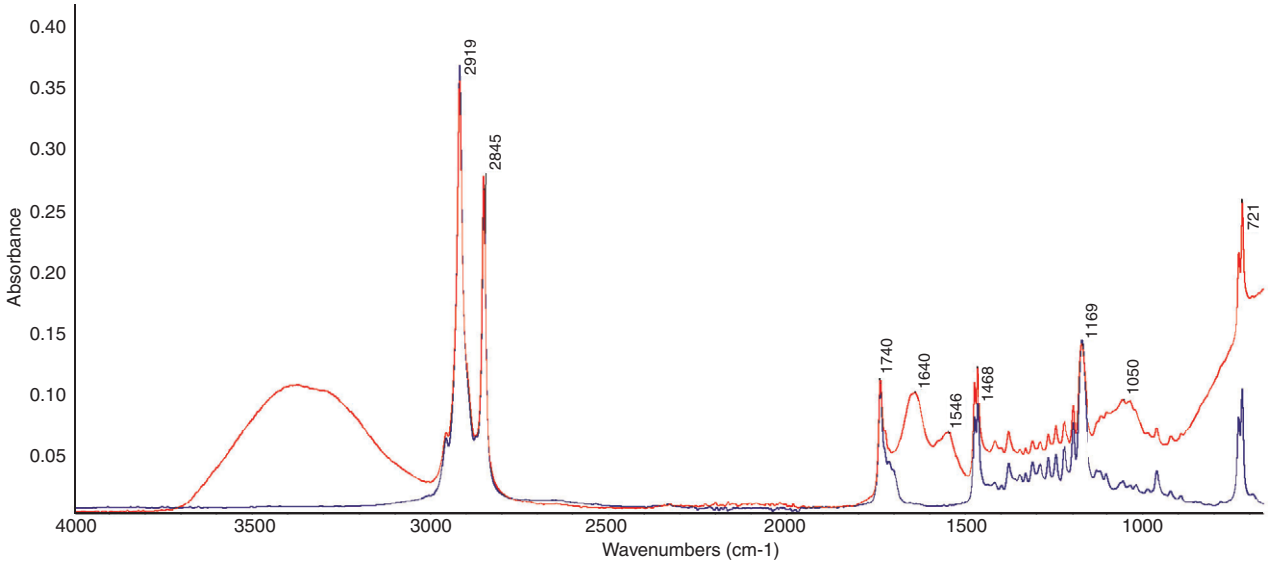


Figure 16.27 FTIR spectra of the beeswax candle (3126; red) and a comparison spectra of beeswax (purple) (62200 Kremer Pigment) (© Historic England, Angela Middleton)

The oldest surviving beeswax candles north of the Alps were found at the Alamannic cemetery of Oberflacht, Seitingen-Oberflacht, Kreis Tuttlingen, Germany and are dated to the 6th or the beginning of the 7th century (Paulsen 1992a). Like the examples from the *London* they appear to have multiple strand wicks. No other examples of candles could be traced, which elevates the significance of these examples.

Stitching/repair medium

The remains of the sewing thread in the leather shoes and the leather bucket are all made of plant bast fibre. Plant fibres became the norm for shoemaking from the medieval period onwards (Walton-Rogers 2003, 2361). Shoes from the City of London from the late 14th century had plied waxed flax threads (Grew and De Neergaard 2001, 48).

Plant bast fibres in the sewing threads on leatherwork from 16–22 Coppergate and from the Bedern Foundry in York, spanning the period from the 12th to 18th centuries, were identified as either flax (*Linum usitatissimum*) or hemp (*Cannabis sativa*). In all cases 'the fibres are in intact bundles, which means they have not been fully processed by heckling'. Where discernible, the thread is z-twisted and S-plied (Walton Rogers 2003, 3259–60). Small lengths of stitching thread preserved in the shoes from the *Mary Rose* were not analysed but it is suggested they may have been made of waxed linen (Forster *et al.* 2005, 88).

The lack of processing resulted in a strong and relatively stiff thread, which was needed for the leatherwork, while waxing contributed to waterproofing of the openings. FTIR analysis confirmed the residues to be tar/pitch (see Fig. 9.29). Handmade shoes are still stitched with pitched or waxed hemp thread today.

Cordage, slow match and oakum

All cordage on board the *London* appears to have been made of plant bast fibre, almost certainly hemp (*Cannabis sativa*), although the existence of a mixture of other bast fibres cannot be discounted on the grounds that only very small samples from each object were analysed and many samples were too degraded for a definite identification. Mixing of various plant bast fibres with very similar characteristics (hemp, flax, nettle) in ropes and oakum would have been the standard practice during this period (D. Pawson and D. Sanders pers. comm.).

The fibres in all ropes, in the possible slow match, the gunwad and the oakum from the *London* still adhere in bundles, with much of the epidermal and connective plant tissues and hurds (woody stem parts) still present. This suggests that the fibres were not well or not completely processed and heckling was either not carried out or carried out only partially.

The use of hemp for the cordage on board the *London* is not unusual. There was a shift towards hemp cordage in northern Europe at the turn of the 14th century (Sanders 2010, 18). A 14th-century medieval cog in Tallinn, Estonia contained predominantly hempen ropes, with a smaller number made of lime bast (Rammo 2017). The *Mary Rose* (1545) also carried hempen cordage (Scaife 2005, 626), as did the Swedish *Vasa* which capsized on her maiden voyage in 1628 (Magnus and Seeberg 2024) and the French vessel *La Belle* that ran aground in the Gulf of Mexico in 1686 (McCaskill 2009). The ropes from the 17th-century Swash Channel wreck (the Fame) have been tentatively identified as hemp as well (D. Pawson and D. Sanders pers. comm.). *Queen Anne's Revenge*, which ran aground in Beaufort Inlet, North Carolina, in 1718, had cannon wads and other ropes

primarily made of hemp (Chen and Lusardi 2001). Samuel Pepys' diaries (Latham 1996a, 217) also refer to hemp as the principal material for the cordage.

The slow match, which would have been inserted into a linstock and used to light the cannon, was usually made of three main strands of fibrous hemp including a considerable amount of porous cortex that probably facilitated the absorption of saltpetre/nitrate in which it would have been soaked.

Oakum was a preparation of tarred fibre, painstakingly unravelled from ropes and cordage, used for caulking or packing the joints of timbers in wooden vessels. Oakum found in a basket (Sample 6) from the *London* contained large quantities of hemp pollen, suggesting that oakum is made of hemp (Grant 2016). According to Grant (2016) an abundance of hemp pollen onboard wreck sites is well documented, being associated with the use of its fibres for making rope, cordage and sailcloth. For example, hemp pollen was also abundant in the samples from the *Mary Rose*, as was nettle pollen (Scaife 2005).

Conclusion

The present analysis represents one of the few (if not the first – D. Pawson and D. Sanders pers. comm.) systematic scientific investigations of fibrous material recovered from a shipwreck. While ropes are found frequently on shipwreck sites, little or no scientific fibre analyses are usually conducted (e.g. Sanders (2019) and Magnus and Seeberg (2023) do not provide information on fibre identification of ropes recovered from *Mary Rose* and *Vasa*). Other fibrous objects (shoelaces, shoe linings, candle wicks) have few analysed and published comparanda and add important information regarding the realities of the daily life on the *London* and more generally in 17th-century England.

Retrieval of silk shoelaces still connected with shoes, which would have been items of relative luxury, highlights the absence of other textiles, in particular any items made of wool. As silk is the most fragile of the fibrous materials when waterlogged it is unlikely that the absence of wool is due to preservation conditions. Indeed numerous wool clothing items were recovered from the *Mary Rose*, which is a very similar environment. More probably this is a result of the areas of the ship that have been excavated to date, which is primarily the area around a gun carriage (A. Middleton pers. comm.).

While plant bast fibres would have been used around the ship for cordage, sails, stitching/repair medium etc., wool (and silk) would have been used primarily for the crew's clothing. Survival would be expected either in association with human remains or if items had been protected through storage in a container (e.g. a chest), as in the case of the *Mary Rose*. The few human remains recovered to date from the *London* are very disarticulated and dispersed, so clothing is unlikely to survive. The shoelaces have survived because they were connected with multiple shoes (group 3118) that were all tightly packed in one area, resulting in a lot of compression and physical protection (A. Middleton pers. comm.).

Cordage and fibre

by Des Pawson

The recovery of cordage from the *London* and other recently excavated wrecks of the period is highly significant as recovery of such material from wrecks historically has been quite rare. These finds can be compared with details in early seamanship dictionaries that were introduced in the 17th century, compiled by Mainwaring (1623; Mainwaring *et al*. 1993; Manwaring and Perrin 1922), Smith (1627; Goell 1970) and Boteler (1634; Perrin 1929), as well as a series of pamphlets (1657; Hayward and Kendall 1967), which give sizes of rigging for ships of this era.

The collection of cordage recovered from the *London* in the 2014–15 seasons included 25 samples[3] but covers a modest range of material. It all consists of Z-laid rope, with only one piece of cable-laid material, which probably reflects the area of the wreck from which the material was recovered. Of particular interest are the ropes served with sennit[4] and the fact that one piece (3173) had not been wormed. Rather than dockyard-made, these are most likely to have been made on board by some of the crew using yarns drawn from part-worn rope, which could be an example of a short cut taken when the work was carried out, as once the rope had been served the absence of worming would be difficult to detect.

Alternatively it may have been a deliberate, considered choice, for an as yet unexplained reason. The lack of parcelling (tarred canvas wrapped around the rope prior to serving) suggests, and may confirm, that this practice is a later 18th-century development, as parcelling of cordage is not mentioned in the 17th- century seamanship dictionaries (Manwaring and Perrin 1922). The repair of the linstock (3188) with cordage and the reuse of worn rope provides an insight into the maintenance of such items and a degree of economy and self-reliance.

Eight items of cordage or related materials were recovered in 2016.[5] The hemp cordage appears to range mostly in the 32–64mm diameter, all Z-laid rope, with only one piece of cable-laid cordage. Most of the material viewed is rope of three-strand, Z-laid construction, the strands themselves being S-laid from Z-twisted yarns.

Although the rope is approximately 350 years old it is very close in appearance to rope in use today, with a similar

3. 3120, 3121, 3127, 3139, 3163, 3172, 3173, 3180, 3188, 3200, 3206, 3207, 3208, 3209, 3210, 3211, 3238, 3249, 3257, 3292, 3294, 3294, 3303, 3358 and 3374.
4. Samples 3173, 3208 and 3209.
5. 3479, 3484, 3488, 3560, 3568, 3632, 3704 and 3758.

angle of lay (37° degrees) for rope to British Standards. However, owing to the condition of the rope, wear patterns could not be identified. Two or possibly three items are of particular interest, including the only piece of cable (3758) recovered from the site, the lace on the shoe (3761) and a piece of textile tied with a length of cordage (3704).

The piece of cable (3758) is in reasonable condition. It is S-laid, from three strands of Z-laid rope. The cable measures 43cm (17") in circumference, approximately 136mm in diameter. Both the cable, and the rope from which it was made, have a lay of approximately 37 degrees.

The shoe (3761) has a fibre lace still *in situ*, which is three yarns loosely S-laid and appears still to retain the S-direction overhand knot left in it from the shoe being fastened. Although it is possible that this line could have been made up from yarns drawn from an old piece of rope, in the case of the shoelaces recovered from the *London* all have been identified as silk (see Gleba above). The length of cordage (3704) tied around a patch of fabric is a piece of three-strand, Z-laid rope of approximately 8mm diameter, tied in an S-direction overhand knot.

In the past much cordage found on wrecks has tended to be ignored, due to the difficulty in bringing it to the surface and subsequently analysing and preserving it (see Hocker (2023)). Because of the lack of available material, the cordage from the cordage from the *London* is highly significant and will provide a greater understanding of the technology and working of ships and the skills of those who sailed them. The fact that there have recently been assemblages of cordage from other ships of this period, the Swash Channel wreck, the *Stirling Castle* and more recently the *Invincible*, all helps to build a clearer picture of cordage and how it was made and used at this time.

Chapter 17
Discussion

Michael Walsh

The impact of the *London's* loss

It is impossible to say with any certainty whether the loss of the *London* affected the outcome of the war but perhaps the impact of the loss should not be overstated; as with both the First and Third Anglo-Dutch Wars, fighting in the second war continued for more than two years (until 31 July 1667) after the loss. Moreover, a slightly larger replacement, the 80-gun *Loyal London* (increased to 92-guns one month later), was launched on 10 June 1666, just over 15 months after the accident.

It is possible that the loss of the *London* had an impact on battles immediately following the incident, especially the Battle of Lowestoft in which the *London*'s captain, Vice-Admiral Lawson, was mortally wounded. The battle was fought on 3 June 1665, only two months after the *London*'s sinking, between two fleets each comprising more than one hundred vessels. Although this battle was won by the English, despite the absence of the *London*, the victory was not pressed home as most of the Dutch fleet were able to escape. Had the fleet not been allowed to escape it would undoubtedly have brought the war to an early conclusion but would the presence of the *London* have made any difference?

The bulk of the Dutch fleet escaped because the fastest English ships were not given the order to pursue but instead followed the example of the *Royal Charles* and slackened their sails to slow the ships, thereby enabling the Dutch escape. Quite why the order was not given is unclear; when the fastest English frigates were released belatedly in pursuit the following morning they captured a further six Dutch ships.

Various reasons have been proposed to explain this failure, including fears for the safety of James, Duke of York, or the possibility that James, having narrowly escaped death in the Battle of Lowestoft (three men standing next to him had been killed by cannon fire and he had been spattered with their remains (Latham 1996b, 157–8), had completely lost his nerve.[1] Neither of these explanations, however, explain adequately why the fastest ships were not sent in pursuit earlier, as James would not have been involved.

Whatever the reason, it seems highly unlikely that the presence of the *London* would have made any difference as it was certainly not one of the fastest ships in the fleet. So it would seem that its loss had minimal, if any, impact even in the weeks and months after its loss. Indeed the Dutch sued for peace in the aftermath of this defeat but the English, buoyed by their success, rejected their terms (Davenport 2004, 120).

The impact of the loss of the *London* on the outcome of the war was outweighed by other factors, most notably financial constraints, that certainly had a far greater impact. By early 1667 England's financial position had become so desperate that it no longer had sufficient funds to maintain the fleet's seaworthiness or to pay crew wages, so it was decided in February that the heavy ships should remain laid up at Chatham (Wilson 2012, 139). The unintended consequence of this decision was that it emboldened the Dutch to embark on the raid on the Medway which undoubtedly brought the war to a speedy conclusion.

Financial constraints

As stated above, by 1667, as peace negotiations were in progress, the English fleet had been reduced to save money and the remaining large ships had been laid up. The negotiations at Breda had been in progress since March but Charles had been prevaricating in the hope of assistance from the French. Pepys reported in his diary on 3 June 1667 that the Dutch attitude was that the English ambassadors had come to beg for peace. The same day, reporting Dutch naval activity, Pepys stated '… we have not a ship at sea to do them any harm with …' (Latham1996c, 73).

1. Pepys (23 June 1665; https://www.pepysdiary.com/diary/1665/06/23/ accessed 16 September 2025) appears to suggest that Lawson was in part to blame: 'How poorly Sir John Lawson performed, notwithstanding all that was said of him; and how his ship turned out of the way, while Sir J. Lawson himself was upon the deck, to the endangering of the whole fleete'. This might reflect Pepys' personal feelings, as he admitted when he reported Lawson's death, 'I cannot, without dissembling, say that I am sorry for it, for he was a man never kind to me at all' (25 June 1665; https://www.pepysdiary.com/diary/1665/06/25/ accessed 16 September 2025).

The audacious Dutch raid on the Medway in June 1667, unthinkable with a fully operational English fleet, was a humiliating blow that forced Charles II to sign an unfavourable peace treaty on 31 July, a month after the raid. The attack had offended Charles even though he had not been negotiating in good faith. The condition of the English fleet had tipped the odds in favour of a successful Dutch raid as a direct result of noticing weaknesses in English defences resulting from the English placing the bulk of their fleet in reserve. The Dutch were also motivated by revenge for the destruction of West Terschelling during the English attack in August 1666, which became known as Holmes' Bonfire.

The English were disorganised as it had taken the Dutch fleet almost five days to reach Chatham; the Dutch fleet was first sighted in the outer Thames Estuary on 6 June but the English only began to react on 10 June. In addition the English had relied on coastal defences (Davies 2008, 21) that, in the Medway, were not up to the task. There was just one active fort (Garrison Point) at Sheerness, which the Dutch captured on 10 June (Latham 1996c, 77)); Pepys (13 June 1667) described the impact of the shooting from Upnor Castle on the Dutch fleet as 'no more … than of a fly' (Latham 1996c, 81). Pepys had visited Upnor Castle before the outbreak of the Second Anglo-Dutch War (on 4 August 1662) where he found considerable room for improvement '… a fine prospect, but of very small force; so to the yard, and there mustered the whole ordinary, where great disorder by multitude of servants and old decrepid men, which must be remedied'.[2] There were also a handful of batteries and a boom across the river to protect the main anchorage, which the Dutch fleet broke through on 12 June. They then navigated around the 30 or so block ships that had been sunk hastily by the English, which gave the Dutch easy access to the remainder of the helpless English fleet (Konstam 2011, 36).

The Dutch captured two ships including the English flagship the *Royal Charles* and the English lost 13 other ships including three of their finest (*Loyal London*, *Royal James* and *Royal Oak*; Latham 1996c, 81) that had been sunk to prevent capture but were then set on fire by the Dutch. So four of their eight 75+ gunships were lost, and three of the four largest 'big ships'; only the *Royal Sovereign* survived as it was in Portsmouth at the time of the raid.

This raid resulted in a quick end to the war and a favourable peace for the Dutch. The *Royal Charles* was supposed to have been moved; Pepys recorded on 13 June '[the ship] which Pett should have carried up higher by our several orders, and deserves, therefore, to be hanged for not doing it' (Latham 1996c, 79). The raid has been described as 'one of the worst naval defeats England has ever sustained' (Vere 1955, 145). A new building programme had restored the English Navy to its former strength by 1670 (Fox 2012, 60).

Financial constraints also affected English morale, as many sailors and soldiers had not been paid for months or even years; sailors were paid primarily with 'tickets', or debt certificates, which were only redeemed after long delays when cash was available (Rommelse 2006, 42). Pepys (14 June 1667) recounts (possibly apocryphal) reports of Englishmen heard aboard the Dutch ships that raided the Medway saying, 'we did heretofore fight for tickets; now we fight for dollars!'. Related to the same incident he records a plea from several seamen that 'if I [Pepys] would get their tickets paid, they would go and do all they could against the Dutch; but otherwise they would not venture being killed', while seamen's wives blamed the raid on lack of pay: 'this comes of your not paying our husbands' (Latham 1996c, 81).

Although the costs of executing this war must have contributed to the state's parlous financial position they were stretched before the war began as, after the First Anglo-Dutch War, England had embarked on the Anglo-Spanish War. The extravagant expenditure of the king and his court was also a severe drain on resources.

In addition, as cited above, two other major calamities that not only incurred major expense but also impinged on the ability of the city to generate wealth befell the City of London at this time: the Great Plague in the summer of 1665 and the Great Fire in September 1666. London was the only major urban centre in England at that time, as the population was dominated by the rural poor, so this would have greatly diminished the state's ability to raise finances. Following the Great Fire the Navy Board began to discharge sailors as they were no longer able to pay their wages, with the result that they no longer had the manpower available to crew a major fleet (Fox 2018, 299).

The loss of a great ship and its subsequent replacement placed a tremendous burden on the public purse. For example, the *Sovereign of the Seas*, built in 1634, had cost so much to build that Charles I imposed a 'ship tax' to pay for it, which had contributed to his downfall (Konstam 2011, 11).

Ships called '*London*'

This *London* was the second of several successive ships of the same name; '*London*' has been one of the most common names of British naval warships, although we are currently living through one of the longest periods without a ship called '*London*' (J.D. Davies pers. comm.). The first *London* was a 40-gun East Indiaman purchased in 1636 and listed until 1653. The second *London* (the subject of this volume) was the first of two of similar name lost during the Second Anglo-Dutch War.

In the immediate aftermath of the destruction of the *London* a replacement ship was ordered one month later (in April 1665), financed by the aldermen and livery companies of the City. To show his gratitude to them Charles decreed that it should bear the prefix 'Loyal'. There is another reason why Charles assigned this name; the City of London had previously supported the opposition in the Civil Wars but

2. https://www.pepysdiary.com/diary/1662/08/04/ (accessed 16 September 2025).

had now affirmed their loyalty (J.D. Davies pers. comm.). The same naval commissioner who had built the *London*, John Taylor, also built the more heavily armed, second-rate *Loyal London* at Deptford. It was launched on 10 June 1666 (Winfield 2009, 31) but it too was not destined to survive the end of this war as, a year after launch (almost to the day, 14 June), it was burned to the waterline by the Dutch after it had been scuttled as one of the blockships in the Medway.

Some of the timbers from the *Loyal London* were salvaged on 15 July and were reused to build a new ship, which was launched at Deptford in 1670, the 96-gun first-rate *London* (Davies 2008, 47; Konstam 2011, 15). Charles dropped the prefix 'Loyal' after the City, impoverished by the Great Plague, the Great Fire and the war, refused to share the cost of the rebuild; to what extent the loss, after barely a year, of the ship they had funded had played in this decision is unknown. This ship was rebuilt at Chatham in 1706 as a 100-gun first-rate and again in 1721 and was finally broken up in 1747.

Naming a ship '*London*' might seem something of a jinx, especially to the sailing community who were/are renowned for their superstitious nature. The *London* that sank in the outer Thames lasted only nine years, while its replacement, the *Loyal London*, lasted barely one year.

How unusual was this event?

Of the 39 English ships launched between the mid-1640s and the mid-1660s (the majority, 34 ships or 87%, like *London*, were launched in the 1650s; Table 17.1) and lost prematurely through conflict or by accident, more than one third (14 or 36%) were lost less than 15 years after their launch. More than half (20 ships or 52%) were lost within 20 years of launch (Table 17.2). One might think that this is understandable given the almost perpetual state of war in which England found itself at this time, but only 14 (36%) of the 39 ships in this sample were destroyed through enemy action (Table 17.3).

Eight ships (21%), including the *London*, survived fewer than ten years. Of these, only two, or seven of the 20 ships that lasted up to 20 years, were lost through enemy action. Three ships, including *London's* replacement the *Loyal London*, survived barely one year after launch. This was not a uniquely 17th-century problem; the 60-gun fourth-rate *Plymouth* built in 1705, for example, sank in the same year.

Of greatest interest in this context are the ships that were destroyed by fire or by explosion (three of each or 8%) by accident in circumstances unrelated to enemy action. So the manner in which the *London* was lost, by an accidental ignition of the gunpowder magazine, was not particularly uncommon at this time. The *Fairfax*, for example, was launched in April 1650 but lasted only until spring 1653, when loose gunpowder ignited accidentally, burning it to the waterline at Chatham; it had to be sunk

Table 17.1 Ships launched in the 1640s, 1650s and 1660s

Launched	Number	%
1640s	4	10
1650s	34	87
1660s	1	3
Total	**39**	**100**

Table 17.2 The lifespan of ships launched in 1640s, 1650s and 1660s

Lifespan	Number	%
<10 yo	8	21
11–20 yo	12	31
21–30 yo	4	10
31–40 yo	9	23
41–50 yo	5	13
51–60 yo	1	3
Total	**39**	**100**

Table 17.3 Causes of the ships' loss

Cause	Number	%
Burned by accident	3	8
Condemned	1	3
Enemy action	14	36
Exploded	3	8
Foundered	1	3
Sank	1	3
Scuttled	1	3
Wrecked	15	38
Total	**39**	**100**

to put out the fire. A new ship was ordered to be built from the remains (Winfield 2009, 44, 52). Reports at the time suggested that the accident had occurred when some of the crew were trying to steal rope from the powder room at night (Testimony of Major N. Bourne to the Admiralty Committee, 23 March 1653).[3] Major Bourne and Captain Lawson (the later Vice-Admiral) testified to the Admiralty Commissioners:

> *a thievish contrivement which occasioned the setting on fire some loose powder that was scattered in the powder room by the fall of a candle … the principal officer of trust was absent … and the gunner's mate and yeoman of the powder room, who were on board, we conceive will appear most deeply chargeable … no watch was kept on board; no boatswain or gunner belonging to her, nor any other care taken to prevent this untimely loss.* (Testimony of Bourne and Lawson to the Admiralty Commissioners, 24 March–3 April 1653)

Besides the *London*, two other ships exploded in this era in unusual circumstances. The *Sussex* had an even shorter lifespan, having been launched early in 1653 and destroyed by accident on 9 December in the same year (Winfield 2009, 102), when loose gunpowder was accidentally ignited while lying at Plymouth, with the loss of around

3. *Calendar of State Papers Domestic, Commonwealth*, xxxiv, 69, available at https://www.heritagegateway.org.uk/Gateway/Results_Single.aspx?uid=1033778&resourceID=19191 (accessed 22 September 2025).

50 crew. The *Bridgewater* was launched in December 1653 but was blown up by accident at Sheerness on 2 December 1673 (Winfield 2009, 49). Sadly no further details of these incidents are available.

Two other ships are recorded as being destroyed by fire: the *Dunbar* was launched in May 1656 and while laid up was burned by accident at Chatham on 16 May 1682. The *Pelican* was launched in 1650 but burned by accident at Portsmouth on 13 February 1656. Even the majestic *Sovereign of the Seas* (renamed the *Royal Sovereign*) succumbed to the same fate while being prepared for a rebuild at Chatham on 29 January 1696 (Winfield 2009, 12).

On 9 December 1660 Pepys records the sinking of another ship in a freak accident, 14 years after launch, '… this morning from Woolwich, that the Assurance … was by a gust of wind sunk down to the bottom. Twenty men drowned' (Latham 1996a, 101). Little more than a week later, however, the Assurance was salvaged '… is got up, without much damage to her body …' (Pepys, 17 December 1660)[4] and went on to have a lengthy service; it was sold in 1698.

There are surprisingly common factors in the accidental destruction of many of these vessels including the occurrence in a naval dockyard, the absence of senior officers and apparently poor discipline among the remaining crew. There were no officers above the rank of warrant officer aboard the *London* (it was awaiting the arrival of the Vice-Admiral), the principal officer aboard the *Fairfax* in Chatham dock was absent, the *Dunbar* was laid up also at Chatham presumably with a skeleton crew, the *Sussex* was at Plymouth and the *Pelican* was at Portsmouth. Incidentally, both the *London* and the *Fairfax* were under the command of John Lawson.

Before the war Pepys had been aware of, and concerned about, this problem; he occasionally made surprise visits to ships, including the *London*, to assess their security. On 4 August 1662 he:[5]

> *… went to the guardships and mustered them, finding them but badly manned; thence to the* Sovereign*, which we found kept in good order and very clean, which pleased us well, but few of the officers on board. Thence to the* Charles*, and were troubled to see her kept so neglectedly by the boatswain Clements…*

Then on 12 July 1663, he found:[6]

> *The guard-ships were very ready to hail us, being no doubt commanded thereto by their Captain, who remembers how I surprised them the last time I was here. However, I found him ashore, but the ship in pretty good order, and the arms well fixed, charged, and primed. Thence to the* Soveraign *[sic], where I found no officers aboard, no arms fixed, nor any powder to prime their few guns, which were charged, without bullet though. So to the* London*, where neither officers nor any body awake; I boarded her, and might have done what I would, and at last could find but three little boys.*
>
> *And so spent the whole night in visiting all the ships, in which I found, for the most part, neither an officer aboard, nor any men so much as awake, which I was grieved to find, specially so soon after a great Larum, as Commissioner Pett brought us word that he [had] provided against, and put all in a posture of defence but a week ago, all which I am resolved to represent to the Duke.*

Contrary to popular belief, naval discipline at this time was considerably less harsh than that used in the army or aboard merchant ships. Punishments for these acts seem rare, with only one case found; the cook and the boatswain of the hulk *Europa* were hanged in 1676 for deliberately burning their ship (Davies 2008, 158–60).

As stated previously various theories have been proposed to explain the cause of the explosion that sank the *London* but the most likely causes would seem to be accident, negligence (Fox 2012, 58), a mistake by a crew member unfamiliar with the layout of their new ship or the misappropriation and concealment of gunpowder by sailors who had not been paid (R. Endsor pers. comm.).

Trollope's hypothesis (Keys 2015) that the explosion was caused by the filling with gunpowder of potentially dusty 'high risk' old cartridges that then ignited the main store, in which he cites the *Fairfax* incident, is undermined somewhat by the verdict of the enquiry held at the time into that incident, which suggested that it was the result of poor discipline with crew members attempting to steal rope.

It could be argued that, in the interests of continuing the state's ability to conduct warfare upon the seas, it was in the interests of the public enquiry to find a cause other than the combustion of old cartridges (i.e. a cover up). There seems little evidence to support Trollope's assertion that the *London* disaster finally forced the government to ban the reuse of old cartridges and that subsequently the incidence of vessel self-destruction reduced dramatically (Keys 2015).

It seems more plausible that the explosion on the *London* and similar incidents resulted in two outcomes:

- a tightening of naval discipline, particularly in the management of skeleton crews; and
- a greater appreciation of the combustibility and volatility of gunpowder, with improved handling to avoid the loss of these extremely valuable, not to mention difficult and costly to replace, weapons of war.

4. https://www.pepysdiary.com/diary/1660/12/17/ (accessed 16 September 2025).
5. https://www.pepysdiary.com/diary/1662/08/04/ (accessed 16 September 2025).
6. https://www.pepysdiary.com/diary/1663/07/12/ (accessed 16 September 2025).

Interestingly, no enquiry or courts martial were held following the loss of the *London*, which is surprising given the circumstances of the loss and the importance of the ship. This may be explained by the date of loss, only three days into the start of the Second Anglo-Dutch War. Evidence from the *London* excavations may have some bearing in this instance. The excavation recovered numerous fragments of clay pipes, many of which displayed evidence of having been smoked which, on a ship laden with 13 tons of gunpowder, would give a modern health and safety officer serious concerns (to put it mildly). It therefore seems probable that the explosion of the *London* was an unfortunate accident; the result of poor discipline in the absence of senior officers.

Naval reforms

In the immediate aftermath of the Medway raid (not to mention the *London* tragedy), although the Navy Board came under heavy political scrutiny, somewhat surprisingly there do not appear to have been many, if any, significant changes to the Navy. Although there were many naval reforms in the 17th century, which are generally attributed to Pepys' hard work and organisation (*contra* Davies 2008, 281), they were not implemented until 1676–7 (i.e. after the Anglo-Dutch Wars) when Pepys was Secretary to the Admiralty.

In 1677 Pepys created the first examinations for aspirant lieutenants which, along with the insistence that naval commanders had more experience of the sea, was a key factor in creating a professional officer corps. He also set new standards for ships' surgeons, pursers and chaplains and new regulations governing midshipmen and volunteers, men and guns. Pepys also tried to tackle the problem of sailors' pay, and even persuaded Parliament to finance 30 new ships.

One of Pepys' major reforms had been to crews' rations, following complaints after the Third Anglo-Dutch War. Pepys found unacceptable standards of supplies and shipbuilding owing to cheating and theft, so agreed new standards with suppliers and created a central victualling structure; sailors' daily rations were then increased to one gallon of beer, 500g of biscuit, 100g of salt beef or fish, butter and cheese.[7]

A special commission, proposed by Pepys to cover the work of both Admiralty and Navy Boards, was set up in 1686 to restore efficiency to the Navy, which it achieved early. These reforms began to change the Navy from a corrupt and inefficient service into a professional fighting force by improving discipline, training and conditions in the Navy.

Some of the marks on the finds, such as the touchmark on the spoon that indicated that the owner was single, offered a tantalising hint as to the identity of some members of the crew. Other than Lawson and several unnamed members of his family, however, the names of serving crew members are not known owing to the lack of relevant paperwork, such as paybooks, before 1673. This resulted from the fire that destroyed the Navy Office and no doubt extant records in that year. In addition 1673 was the year in which Pepys became Secretary to the Admiralty, so record-keeping became more rigorous.

In an effort to throw some light on the crew, records at the National Archives were consulted, as they hold a number of wills of seamen who served aboard the *London* (see for example PROB-11-308-506, PROB-11-311-511-512 and PROB-11-319-294). These range in date from 1658 to 1663, thus covering both the period in which the ship was in service to the Commonwealth and then to the Crown. Sadly there is little corresponding information regarding individuals and therefore little that might provide further insights into crew members or their lives aboard the ship. It is to be assumed, for example, that these are the wills of lower-ranking officers, though we cannot be sure. In the majority of instances these wills list simply the beneficiaries of their remaining wages (often after debts have been paid) and to which of their surviving colleagues their onboard possessions (clothes and bedding) should be passed.

More generally, by the end of the Third Anglo Dutch War the English fleet was comparable in size to the newly formed French fleet but smaller than the Dutch fleet so a major building programme was initiated – the 1677 Programme. A strong well-equipped Navy was therefore the legacy of the three Anglo-Dutch Wars (Konstam 2011, 18).

7. https://www.rmg.co.uk/stories/topics/samuel-pepys-navy#:~:text=What%20changes%20did%20Pepys%20introduce,mouldy%20bread%20and%20diseased%20meat (accessed 16 September 2025).

Chapter 18
Conclusions

Michael Walsh

As outlined above the *London* had been built during the English Civil War, a time of great political upheaval. The Navy had sided with Parliament against the Crown and the Commonwealth needed a strong Navy to ensure its own survival. The study of the wreck and its finds provides a unique insight into a ship built for the Commonwealth Navy under Cromwell (Fox 2012, 60).

The rediscovery of this wreck has presented a unique opportunity to study a rare 17th-century warship, the only surviving remains of Cromwell's four large ship's building programme of 1642–60, and a ship that sank while preparing for war on the eve of battle. The study of the wreck has presented not inconsiderable and challenging logistical issues, situated as it is on the edge of a very busy shipping channel, the main channel into the Port of London.

In the early days of the excavation it was not possible to station a dive support vessel or even a fixed buoy over the site which, understandably, slowed operations considerably and prevented the use of the most efficient excavation techniques such as air lifts. The knowledge gained by the licensee team during numerous dives on the site proved invaluable at this time; the decision had been taken early on to undertake diving operations using HSE SCUBA so that the licensee team could participate fully in the excavations. Even when the logistical issues had largely been overcome, with the granting by the PLA of a permit to station a DSV permanently over the site during fieldworks, conditions on site proved extremely challenging, with up to 0.5m underwater visibility at the best of times.

The excavations

Despite this the excavations produced some outstanding results from this deeply buried artefact-rich site; the state of preservation of the site, and the artefacts contained within, is remarkable. The Historic England conservation team, led by Angela Middleton, has done an incredible job on the conservation of the recovered artefacts, as evidenced by the wonderful photographs taken by her colleagues that illustrate this volume. Similarly York Archaeological Trust worked wonders on the conservation of the very rare complete gun carriage.

The small number of ship's parts recovered is quite surprising but can be explained by the fact that the ship structure was left largely undisturbed; indeed, some trenches had to be abandoned owing to the density of ship structures encountered, which is perfectly understandable given the nature of the ship's demise. So only detached items such as the deadeyes and the blocks were recovered.

One of the largest categories of artefact recovered was, unsurprisingly for a warship about to go into battle, weapon-related. The most impressive of these finds was, of course, the complete gun carriage, which is extremely rare if not unique. Also of significance was the discovery of a chest filled with personal weapons including several sets of bandoliers, comprising the remains of the leather belts and straps, the powder and priming boxes and the remains of leather shot pouches that would have hung from the belts.

Cannon-loading, manoeuvring and firing equipment included the remains of flexible rammers and sponges, wadding, shot, hand crow levers, linstocks and a solitary priming iron. As Schuster has pointed out, some of these weapons, such as the Dutch cannon and the Dutch calipers, were about to be trained on their makers. The high proportion of burr shot in the lead bullet assemblage raises some interesting questions regarding who was responsible for these adaptions? Was this state-sanctioned or individual choice?

The ship's equipment included navigational items such as dividers and sounding weights, repair equipment including lead patches and tools, cook house tiles and bricks, storage items such as wooden cask staves, glass bottles and jug fragments, leather buckets, a syringe, candles, leather-bound books which may have been ship's logs (or could equally have been personal journals) and animal bones.

Personal items included numerous leather shoes, clay pipes and stoppers, two piles of coins, a personal sundial, a fragment of a probable mirror, spoons, an ivory comb,

a probable chamber pot, pins and buttons and human remains. The recovery of two pipe stoppers is symbolic of the entire recovered assemblage; one was made from wood that does not survive ordinarily in other environments and both are from sound archaeological contexts, which is particularly important, not only because they are rare but also because these are two of the earliest securely dated examples.

This assemblage is quite revealing; it well illustrates the absence of uniformity in the variety of equipment that was used on just one naval vessel in the years before Pepys' standardisation measures had been adopted, amply demonstrating why such measures were long overdue. The use of a variety of guns with a variety of calibres, for example, seems predestined to result in accidents, particularly in the heat of battle.

Moreover, the modifications to the gun carriage, which had been adapted with the addition of extra pieces of wood for a longer, narrower gun than the one for which it had been built, speak volumes regarding the nation's readiness for war. While adaptions to such a significant piece of weaponry might be understandable, the repairs to more minor and relatively cheap pieces of equipment tell another story; the reuse of yarns drawn from part-worn rope to make the sennit, for example, in combination with the repair to the broken linstock (3188) points to a degree of economy and self-reliance on board the vessel, probably reflecting the parlous state of the nation's finances?

The limited areas of the *London* that have been investigated to date have produced a varied assemblage that throws some light on activities on board the ship at the time that the devastating accident occurred. Why, for example, were the gun-loading implements for the entire ship assembled around just one gun station, fortuitously the one that was excavated for this project? We know that naval discipline at this time was less than ideal but could this equipment, loaded onto the ship two weeks previously, really not yet have been stowed? If so, this would have been a serious lapse and points to poor discipline and a lack of leadership on board. If discipline aboard really was this lax, this must add credence to the suggestion that the explosion that destroyed the ship was an accident.

In support of this hypothesis Lawson later reported to the Navy Board that two weeks before the explosion he had found a large quantity of wood and empty casks lying around the ship and had ordered the purser to have them removed. Mr. Dam, the purser, had testified that there were 21,000 billets of wood, 80 dozen candles and some empty water casks, iron hoops and bags on board when the ship blew up (Blanchard 2017, 180–1) so as incredible as this seems it is a possibility. On the other hand the ship had been preparing for war for two weeks and the Vice-Admiral's arrival was imminent, so it seems more likely that the equipment had been brought out of storage for distribution around the ship in preparation for battle, which aligns with the evidence from the partially loaded guns. As we know, these preparations were curtailed prematurely by the explosion that ripped the ship apart. Perhaps these preparations were the cause of the accident?

There are other anomalies in the recovered assemblage; it is known, for example, that there were no senior officers on board the ship at the time of the explosion (the most senior ranks present were warrant officers) and yet there are items such as the remains of the mirror (3105 and 3031), the fashionable shoes (3118) and the concretions of coins (3078 and 3382), which the specialists suggest were high status items that must have belonged to senior officers or their kin. The evidence from the shoes is particularly confusing, in particular group 3118, in which there was an absence of women's shoes, included numerous shoes of similar design that were either new or barely used at the time of loss.

It has been suggested that this group might have been some form of deck shoe but the date of the wreck pre-dates the introduction of naval standardisation procedures so they are unlikely to have been Navy issue. Moreover, certain features, such as the use of buckle fastenings, the height of fashion at the time, silk laces and decorative elements on the soles, clearly indicate that the shoes belonged to higher status members of the crew but, as we know, there were none present at the time of the sinking. Perhaps the most likely explanation is that these and the other high status items represent personal belongings of senior members of the crew that had been stowed on the ship in advance of the arrival of their owners. This is supported by the presence of fragments of sacking found in association with the shoes.

Similarly the book covers, particularly the one with gold decorated fillets (3718), are indicative of books of some, if not the best, quality, the size of which points to personal journals or log books rather than a recreational use. These, as well as the ivory comb, are again higher status items probably stowed on board in advance of their owners' arrival.

The smoking-related artefacts are particularly interesting; the fact that so many of the recovered pipes display evidence of having been smoked might provide a significant clue to the cause of the accident. It is well recorded that the ship had been laden with around 13 tonnes of corned powder in preparation for going to war and we know that there were regulations restricting the use of smoking tobacco on board wooden ships, and in particular on fighting ships, owing to the inherent danger. The evidence from the archaeological investigations, particularly the discovery of smoked pipes in the vicinity of the only excavated gun station, clearly imply that these rules were not strictly applied and that copious smoking on board must remain the most likely explanation for the accidental ignition of the gunpowder magazine.

Lessons learned

The comparison of geophysical survey data collected over the site over several years has illustrated that only the top 300–400mm of sediment covering the site is unstable but the

overall deposit is fairly stable. This must be caveated, however, as the data have not been collected at different times of the year or at different tidal states, so knowledge of any variation is limited. The movement that has been identified from the recovered data is obviously sufficient to uncover elements of the site, which then leaves ship's structure and other wooden elements of the wreck exposed to marine-boring crustacea such as gribble, leaves more fragile artefacts exposed and vulnerable to the harsh seabed environment and uncovers artefacts which are then liable to be washed away and lost. Experiments should be undertaken in an effort to stabilise this top stratum of mobile seabed sediment to prevent the loss and degradation of artefacts from this valuable site.

It is unfortunate that we have not yet determined which section of the ship remains buried. It is clear that a section of the hull, from low down in the hold up to the main gundeck, survives but we have not yet found anything that enables us to determine whether it is a port or starboard section of the ship. The failure of the diver-tracking system also hindered our ability to accurately position-fix the various elements of the site.

In addition the challenging site conditions and limited site time available hindered the production of a drawn site plan during the diving operations reported here. A site plan has been drawn, however, by the licensee, Steve Ellis, and we are extremely grateful for his assistance and for his permission to use his plan.

Greater understanding of the section of the ship that survives, combined with a fully drafted site plan, might have enabled more targeted excavation to answer more specific research questions. For example, although there was plenty of evidence for weapons of war, hardly surprising given the context, and some evidence of life aboard was recovered, especially shoes and clay pipes, it was fairly randomly distributed and did not enlighten us much further regarding life aboard a 17th-century warship on the eve of battle. Perhaps the extraordinary circumstances in which the ship was lost could never reveal much about 'ordinary' life aboard a 17th-century warship.

Despite the challenging conditions the project has, however, been a great success; this volume illustrates well how collaboration between disparate groups including the licensee team, Historic England, commercial archaeologists, Southend Museums Service and a range of volunteers can produce amazing results and further our knowledge of this appalling incident and this fascinating period in this nation's history.

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The *London* was an English second-rate ship-of-the-line built at Chatham in 1656 during the Interregnum. At the time of the Restoration in 1660 the ship formed part of the fleet that brought the future King Charles II back from exile in the Netherlands.

It was while preparing for the Second Anglo-Dutch War, that the *London* sank in the Thames Estuary in 1665, and was blown apart by an explosion, probably of its gunpowder magazine. As mentioned in Samuel Pepys' diary entry of 8 March 1665, only 24 personnel survived. The site was rediscovered in 1962 and was designated in 2008 under the Protection of Wrecks Act 1973, and was added to the Heritage at Risk register in 2009, owing to the risk of exposure and environmental decay of archaeological material.

Since March 2014 a programme of archaeological excavation, geophysical survey and artefact analysis has been undertaken by Cotswold Archaeology and its specialist sub-contractors on the site of the wreck, which has recovered a remarkable array of artefacts, shedding light on life aboard as well as many technical details about the ship itself.

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