(The account of the discovery in the Thames estuary of a 16th-century armed merchant ship, now known as the Gresham ship, and of the recovery and conservation of the remnants of its hull, its cannon, cargo and other associated artefacts is to be published in 2014 by the NAS as a two-volume monograph, the fourth and fifth in its monograph series.

This version of Chapter 3 of Volume 2 deals the conservation of the more than 100 artefacts raised with the wreck. It is an initial pre-publication draft of the chapter which is still subject to peer review.)
Chapter 3: Conservation Studies
by Dean Sully and Kelly Domoney

The Finds Study Programme
The Finds Study Programme for the Gresham Ship Project was designed to carry out and disseminate technical, analytical and methodological research into the hull, cargo and associated remains of the site investigated in the Princes Channel, Thames Estuary, by Wessex Archaeology in 2003 and 2004 (Firth, 2006; Auer and Firth, 2007; see also Volume I of this monograph). A significant element of the Finds Study Programme has been the interventive conservation of that finds assemblage. Maritime archaeological materials are vulnerable to unpredictable change following excavation and consequently their post-excavation study and long-term survival relies on such interventive conservation procedures (Cronyn, 1990).

Following excavation and recovery, the finds assemblage was initially stored with Wessex Archaeology (Fig. 3.1). When University College London began its research programme in April 2008, the assemblage was relocated to temporary storage at Fort Cumberland with English Heritage (EH), where work was carried out as part of the Gresham Ship Project Conservation Internship from October 2008 to April 2009 (Fig. 3.1). Many of the objects were then moved to the laboratories at the Institute of Archaeology in University College London (UCL), forming a focus for course work related to the MSc Conservation for Archaeology and Museums programme (Domoney, 2009). Following conservation stabilization, the finds archive will be transferred to the care of the Southend Museums Service (see Appendix for finds list). A selection of those finds will ultimately be displayed in a purpose-built gallery focusing on Thames wrecks in a brand new museum building overlooking the estuary where the Gresham Ship was recovered. Although this will be some years in the future, a temporary exhibition that featured some of the Gresham Ship’s artefacts has already been presented in the Central Museum at Southend from June to October 2012.

Figure 3.1 Temporary storage of Gresham Ship finds assemblage: on the left at Wessex Archaeology in 2006; on the right with English Heritage in 2008 at Fort Cumberland, Casement 23 (photos Gresham Ship Project).
Table 3.1 List of UCL student projects associated with the Gresham Ship Project

<table>
<thead>
<tr>
<th>Gresham Ship Assemblage of Artefacts</th>
<th>Archive Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Four guns</td>
<td>Fort Nelson, Royal Armouries</td>
</tr>
<tr>
<td>Large ship timbers, iron anchor, gun carriage, ship ballast, iron bars</td>
<td>National Diving Centre, Stoney Cove</td>
</tr>
<tr>
<td>101 Small finds</td>
<td>Southend Museums</td>
</tr>
</tbody>
</table>

Table 3.2 Location of Gresham Ship finds (See Appendix for complete list of objects)

provided a practical and theoretical understanding of the conservation of marine objects. Confidence was gained through practical experience of preventative measures (for example, wet storage, care while performing interventive treatments) and decision-making about investigative cleaning methods (for example, mechanical or chemical?), desalination processes, drying and stabilization techniques.

The Finds Assemblage

The finds assemblage revealed in the process of excavation and investigative conservation consisted of four iron guns, 42 iron bars and 101 small finds including three lead and five tin ingots, six leather objects, six small wooden finds, eight metal object fragments, copper and tin alloy small finds (salt holders, spoons, a bowl, a jug), plus bricks, stone ballast, rope, glass and ceramic fragments (Table 3.2). The partial and vestigial nature of the assemblage (a common feature of rescue archaeology) limits the potential of the subsequent research. However, there were in addition some 25 ferrous concretions recovered from the wreck site, some or all of which may have accumulated around and then obscured significant finds; the role of the objects initially hidden within the concretions was therefore of particular importance in this Finds Study Programme, offering an opportunity to add significantly to our understanding of the ship and its crew (Auer and Firth, 2007, 14). With this in mind, rather than considering the assemblage as a diminished representation of a complete shipwreck, our approach has been to look at the finds assemblage as a series of snapshots connecting us with events in the past of the ship, as links in a chain that connect the present with the past.

The documentation and conservation of the four guns has been undertaken at the Royal Armouries at Fort Nelson, Portsmouth reported in Chapter 4 of Volume I of this monograph, pages 77–80. The remainder of the assemblage – including the concretions, artefacts and the
metal cargo – form the focus of the Finds Study Programme. Details of the metal cargo are discussed in Chapter 4, while the remainder of this chapter focuses on investigative conservation of the concretion assemblage and the conservation of the small finds.

Temporary Storage

Upon recovery marine archaeological objects are exposed to a change in environmental conditions, which can cause rapid deterioration if not controlled (Robinson, 1998; Watkinson and Neal, 1998). The favourable conditions of low oxygen availability, low light and low temperature that may have given rise to the long term survival of archaeological materials are likely to give way to drier conditions of increased oxygen, light and temperatures (Pearson, 1987a; Oxley, 1998, Yeager, 2005). The transition from excavation to post-excision storage needs to be carefully managed to limit adverse changes in the recovered archaeological material. Post-excavation storage conditions should not adversely affect subsequent examination and conservation treatments and should be relatively inexpensive and easy to maintain (Jones, 2003, 350). Following their recovery in 2004 by Wessex Archaeology and prior to conservation treatment, finds were held in temporary wet storage, bagged and labelled in eight plastic crates immersed in tap water in a large scaffold tank. Even where marine finds are kept wet following excavation, the increased availability of oxygen, combined with available water and the presence of chlorides, leads to secondary corrosion in the corrosion products of metal objects (Smith, 1991, 762). For organic objects, the risks of biological deterioration are increased with increased availability of light, heat and oxygen (Cronyn, 1990, 271). A beneficial side effect of immersed storage in fresh water is the potential for the diffusion of chlorides from the corrosion products into the water. This has extended the desalination period for all finds stored immersed in tap water since excavation. The conductivity of the tap water was monitored and storage water periodically refreshed. Alkaline inhibitive or oxidizing solutions are often used with ferrous metal objects to prevent secondary corrosion, but this is not appropriate for assemblages of mixed materials (Watkinson and Al-Zahra, 2008). The use of low temperatures and the exclusion of light is preferred to the use of biocides, when managing temporary storage of waterlogged organic materials (Kirsten, et al., 2012).

Conservation and maritime objects

Archaeological conservation aims to ensure that artefacts are able to function within the requirements of the archaeological process. Initially this may involve the provision of advice during project start up and initiation (English Heritage, 2006). Such advice is essential to anticipate the scale of potential conservation work and develop cost-effective strategies prior to excavation taking place, but is often absent in rescue archaeological projects. During field work conservation intervention may be required to assist with the delicate excavation of vulnerable objects: this is particularly complex when excavating marine sites. Consequently conservation intervention frequently starts with the temporary storage of assemblages prior to the research and long term potential of excavated material being assessed. Investigative conservation, as part of excavation and post-excision assessment, provides essential data for the interpretation of the archaeological resource (Cronyn, 1990). This, combined with intervention conservation treatments, aims to render the conserved object assemblage suitable for handling, study and eventual storage and display in standard museum and archive conditions, by improving its physical strength and resistance to damage from environmental factors (Cameron, et al., 2006). This has been the focus of conservation work within the Finds Study Programme.

The physical stability of the object assemblage and the retention of contained information that can be revealed through archaeological investigation remains the primary focus of the archaeological conservation process. Interestingly however, greater importance is given to the cultural significance of objects (Muñoz Viñas, 2005). The process is therefore seen to result in the selection of cultural values in the conserved object; as a consequence, certain values will be retained, maintained or enhanced, whilst others will be diminished, altered or removed. The cultural significance of the conservation object is now understood to provide the focus of a conservation process that is revealed by investigative procedures (Avrami, et al., 2000; Pye, 2001).

Conservators operating within a values-based conservation process are, therefore, unable to focus simply on the physical materiality of the objects in their care (Clavir, 2009, 145; Sully, 2013). Accordingly, the aim of conservation is to enhance the preferred cultural values of material heritage, while maximizing the potential of people in the future to access their own preferred values (Muñoz Viñas, 2009, 56).

Within the conservation process, it is recognized that there may be many ‘truths’ that can be revealed in the ‘true nature’ of a conserved object (Sully, 2013). Conservation intervention can be seen to crystallize certain interpretations of these truths in the physical fabric of the object, whilst removing evidence of others (Muñoz Viñas, 2005). The conserved object is necessarily an edited version of all the interactions that link the current state of the object with its past states. It presents a selection of certain truths, materialized as a conserved object, in a clear narrative distilled from the mass of individual stories that complicate an understanding of the past. Its complexity is reduced in order to render the object as a specifically constructed representation of itself. Hence the conserved object reveals only one authored version of the past, rather than having any claim to reality other than that revealed in the process of conservation (Sully, 2013).

Caple describes conservator’s decision-making process as compromise between the three goals of conservation: revelation, investigation and preservation (2000). The goal of ‘revelation’ may sometimes conflict with the goal
of ‘investigation’, for example, one may seek to remove concretions from a heavily corroded iron artefact in order to discover information about it, but this prevents the conservator from presenting the artefact as found, as a corroded iron artefact. Likewise the conservator may wish to present the object as a corroded iron artefact, but that may not allow a stable object to be produced or allow sufficient investigative procedures to reveal contained information about the object. Archaeological objects from maritime shipwrecks provide a stark example of how the conservator’s decisions affect objects. Waterlogged organic objects excavated from a maritime archaeological site, for example, are often significantly altered in form from the original manufactured object and are vulnerable to rapid deterioration in physical condition once excavated and as part of the archaeological process. A conservation response is therefore required to stabilize these objects between the excavation environment and post-excision environments. These actions are always limited by available time and resources. However, maritime archaeological artefacts will require active conservation intervention in order to be useful within an archaeological process.

**Authentic objects**

Artefacts from shipwrecks have complicated life histories from their production, ownership, exchange, use, adaptation, loss, burial, excavation and post-excision processing. In conserving these objects a conservator is faced with decisions about which elements of these biographical events to preferentially preserve in the physical fabric of the conserved object. If we consider the two extremes of a spectrum of change in the nature of the object, the conservator might seek to present the conserved object as a representation of its original manufactured form or alternatively as an archaeological artefact as found within the shipwreck. These possibilities may be limited by the physical condition of the object, but are also a reflection of the expectations of the conservation process within the specific circumstances of the conservation moment. To preserve an object in its original form, as an act of restoration, would mean reversing the changes that have occurred since the object was manufactured. This would involve the removal of evidence of the object’s use, the impact of the sinking of the vessel, the time spent submerged and any effect of the archaeological recovery process. This would require drying the object, removing the effects any changes that have occurred to the object over time (such as later additions, change of form, deformations) and removing all marine deposits within the object (such as soluble concretions), around the object (such as insoluble concretions) and the physical associations between objects linked together by changes caused by the burial environment. By removing the evidence of the shipwreck, a significant portion of the artefact’s history is removed from its physical fabric. This change dramatically alters the way the object is understood and deemed significant. As an alternative, the aim for conservation could be to conserve ‘as found’, as a representation of a shipwrecked artefact. This would suggest that the object should be kept wet, with any marine deposits retained. This might appear attractive in restricting the expense of conservation interventions; however, long term storage and display of waterlogged artefacts is technically difficult and, in the majority of cases, objects are only considered to function within an archaeological archive once dried and stabilized (Ganiaris and Starling, 1996; Goodman and Barnard, 2005; Björndal, et al., 2007; Institute for Archaeologists, 2009; Museum of London Archaeological Archive, 2013).

Drying the object with its marine deposits unaltered is, in most cases, unlikely to produce an object in a stable condition and may have a disastrous effect on the structural integrity of the artefact. The preservation of a ‘shipwreck artefact’ therefore is more likely to stand for conserving an object using a ‘minimal intervention’ approach to altering the object as found. Likewise, preserving the artefact ‘in its original’ form simply stands for the notion of removing any evidence of notable layers of an artefact’s history from its physical fabric. In reality, there is a gradient of intervention that will seek to balance the production of a ‘plausible’ conservation object from the constraints manifest by the object undergoing treatment and the time and resources available to the conservation process (Sully, 2013).

A conservation process that seeks to redefine the object as a representation of its original form is a selective choice that diminishes the object as palimpsest. The desire to render the object in a form other than it currently appears – to reflect a specific expectation about how the object should look (either at point of manufacture prior to use, prior to burial/disuse, prior to discovery or prior to collection); to conform to a specific intellectual process (such as art history, archaeology or anthropology); to reflect a current perception of a well presented archaeological museum object – needs to be resisted. Any such change needs to be effectively justified within a decision making process that defines a clear aim for the conservation treatment that considers the implications for the current and future object (Sully, 2013).

The desire to retain the potential for the conserved objects to reflect the links between the present and the past as shipwreck objects has been the guiding principle of the conservation of the Gresham Ship finds assemblage. The actual conservation undertaken represents a pragmatic response to this guiding principle. This approach is clearly demonstrated in conserving the concretions, in which conservation is a creative process, the product of which is a series of unique conservation objects. The approach of a sculptor or fossil hunter is required in revealing a plausible object from an amorphous concretion. The resulting form of the object is a product of the choices and skills of the conservator in revealing something of value within the altered layers of the concretion. In the absence of objects, their form
Conserving concretions

A significant component of the excavated finds assemblage were the 25 ferrous concretions containing objects in various states of preservation. The formation of marine concretions around ferrous objects can be seen to hinder the identification of the archaeological object inside and obscure the extent of its corrosion and deterioration. Alternatively, it can be seen to provide the raw material for a conservation process to reveal a unique and plausible shipwreck object. Conservation was therefore undertaken to investigate the significance of the concretions, to reveal primary archaeological information, to reveal plausible objects and to conserve identified finds.

Concretion formation

Concretions form on iron artefacts buried in marine sediment (anoxic conditions) and those exposed to seawater on the seabed (aerobic conditions). As ferrous (Fe\(^{2+}\)) and ferric (Fe\(^{3+}\)) ions diffuse outwards they are replaced by chloride (Cl\(^-\)) ions from the seawater; therefore, there will be a concentration of Cl\(^-\) ions in the iron corrosion of the object (Turgoose, 1983). Iron corrosion products interact with materials in the marine environment in close proximity to the corroding iron object. As iron is non-toxic to marine organisms, iron artefacts are rapidly colonized resulting in a build-up of marine growth (North and Macleod, 1987, 77). Primary marine growth consists of calcium carbonate (CaCO\(_3\)) exoskeletons of calcium-depositing organisms such as corals and tube-worms (Florian, 1987, 12). Marine growth creates a hard, rough surface layer on the iron, intermixed with sediments, debris, other wreck material and marine organisms. This layer can retard the corrosion of iron by providing a low-porous barrier between the metal and seawater. Corrosion at the surface of the iron does still occur inside the concretion; the trapped seawater, subject to depleted oxygen levels, will generate an acidic solution (pH 4.8) (North and Macleod, 1987, 77). The solution slowly dissolves the calcite matrix and replaces it with a black iron sulphide matrix. The acidic solution passes through the corrosion product region into pores and crevices in the CaCO\(_3\) concretion (Scott and Eggert, 2009, 123). The CaCO\(_3\) present is gradually replaced with a hard ‘iron cementing matrix’ of Fe\(^{2+}\) and Fe\(^{3+}\) ions as it slowly dissolves in the acidic solution (North and MacLeod, 1987, 77–8). As a result of these reactions, the inner concretion consists of a replica of marine growth formed from iron corrosion products and an outer shell consisting of precipitated CaCO\(_3\) (Fig. 3.2).

Condition assessment

Upon initial examination of the concretions, no information was available concerning the nature of potential finds contained within; therefore, appropriate conservation materials and methods for processing the assemblage were investigated. A pilot project was initiated to determine the potential of the concretions to reveal archaeological and condition information via X-radiography (Fig. 3.3). From this initial assessment, a sample group of concretions was processed in order to develop suitable treatment methods, prior to conserving the remainder of the assemblage.

Documentation and investigation utilised photography, X-radiography and illustration (Figs 3.4 to 3.10). X-radiography was conducted using an AGO HS 225kV Hi-Stability X-radiograph system with Kodak MX125 and Kodak AK film. X-radiography of the assemblage indicated the concretions contained a variety of artefacts in differing states of preservation; well preserved, completely corroded and partially corroded with core intact. A fourth category of concretion was also identified, in which the contents were of indeterminate form and preservation. This was largely due to the density of the larger concretions, in which features within the X-radiograph image were often difficult to
Conservation Studies

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>Well-preserved metal object</td>
</tr>
<tr>
<td>Type 2</td>
<td>Void of completely corroded iron objects</td>
</tr>
<tr>
<td>Type 3</td>
<td>Partially corroded iron object with intact solid core</td>
</tr>
<tr>
<td>Type 4</td>
<td>Indeterminate form and preservation</td>
</tr>
</tbody>
</table>

Table 3.3 Concretion Types 1-4, describing state of preservation of metal artefacts within concretions

identify (Table 3.3; Plates 1 and 2 (Figs 3.4 to 3.8) and Fig 3.9).

Concretion Treatment

The approach to the concretions initially involved mechanically removing loose deposits of sand and sediment from the outer surface. Where possible X-radiographs were used as a guide to the 3-dimensional form of the contained objects and the depth of concretion (Lang, 2005).

Digital photography of X-radiographs proved to be a useful tool in identifying slight differences in density, reducing the need for further repeat radiographs. Figure 3.9 presents two digital photographic exposures of an X-radiograph of concretion containing partially corroded hook (GSP99). A short exposure in the upper image reveals the overall shape of the concretion. The longer time exposure in the lower image helps to reveal the shape and corroded edge the hook tang (left hand side of image). For Concretion GSP86 X-radiography indicated non-ferrous metal-alloy artefacts to be well-preserved within the concretions, associated with part-mineralized wood and voids of corroded wrought iron bar and nails (Plate 2, Fig. 3.7). The shape and surface details of completely corroded metals were preserved in the surrounding concretion and characterized by dark voids in the X-radiographs. In general, bulbous voluminous areas of dense concretion surrounded the voids. Tracings of X-radiographs on Melinex (polyester sheeting) were found to be useful in recording associated positions of artefacts and voids within concretions. Tracings and X-radiographs were used to guide the excavation procedure (Fig. 3.10).

Several techniques for processing the concretions were evaluated for suitability, which were adapted to the nature of the concretion, the state of preservation and location of any contained objects. Options included stratigraphic excavation and/or fracturing the concretion into large sections to reveal contents, with the aim of retaining extant objects and casting void cavities to reveal the form of lost objects.

The following processing methods were applied to concretions containing objects in different states of preservation.

Type 1 Concretions: concretions containing well-preserved metal objects (Fig. 3.4)

Given the small number of discrete finds present in the Gresham ship assemblage, a key aim of initial processing was to remove the bulk of the concretion in order to identify any objects and materials that were present for subsequent treatment and stabilization for the finds archive (Figs 3.4, 3.5 and 3.6 on Plate 1). Well-preserved metal objects were characterized by presence of metal with limited corrosion and weak bonds between the object and the concretion (North, 1987, 210).

Treatment options to reduce the concretions included the use of circular saws, sandblasting, air abrasive and dental drills (Redknap, 1984, 133; Carpenter, 1990). Strong acids have been used to dissolve concretions from cast iron artefacts, but these can be slow, ineffective and potentially damaging to the corrosion products and metal core (North, 1987, 211). Cryogenic freezing with liquid nitrogen was used successfully to crack and remove the concretions from cannon from the shipwreck Trial (MacLeod, 1987, 54).

Figure 3.9 Two digital photographic exposures of an X-radiograph of Concretion GSP99 containing a partially corroded hook (photos Gresham Ship Project)

Figure 3.10 Tracing of X-radiograph used to determine associated positions of artefacts and voids within concretion GSP86 prior to excavation. See Plate 2, Fig. 3.7
The most effective method employed on concretions which did not appear to contain large voids, ceramics or fragile organic objects was to strike the concretion with a large flat hammer, in order to cleanly break the concretion into a series of large sections to reveal contents. A series of strikes were made perpendicular to the surface of the concretion, which loosened small sections of concretion, which were then removed by hand. The size of the tools used depended on the thickness of the concretion. For small concretions or those with a thickness of 5 cm or less, small hammers or geopicks were found to be adequate for processing. For larger concretions, or those with a thickness of 5 cm or more, large flat hammers and stone chisels proved most effective. Concretions were struck in areas of weakness, such as cracks, or at the intersection of different materials, for example, where stones or shells lay in the concreted CaCO$_3$ surface. This process was difficult to control, especially where dense corrosion encapsulated softer less dense contents, leading to unpredictable fracturing of the concretions. Concretions were kept wet with a water spray during processing to avoid uncontrolled drying (Fig. 3.11). Once the bulk of the concretion had been removed, smaller tools such as vibrotools, dentist picks and small chisels were employed to reduce the mass of the concretion in order to separate objects. Where required, final traces of concretion were removed chemically or mechanically in the laboratory depending on material type and condition.

**Type 2 Concretions: concretions containing voids of completely corroded iron objects (Fig. 3.5)**

The aim of processing concretions containing completely corroded iron objects was to cast the remaining voids in order to preserve the form and surface details of the original object (Muncher, 1988; Mardikian and David, 1996; Arnold and McAllister, 1998). The corroded iron within the voids was usually in the form of a black liquid. X-ray fluorescence analysis of the residue indicated iron sulphide, based on the presence of high iron and sulphur peaks in the X-ray spectrum. The voids were cleaned of residue before a casting material could be applied. To do this concretions were cracked into two or three large fragments by striking with a hammer and chisel at a perpendicular angle along a pre-determined inscribed line. The aim of this method was to crack directly through the void and create segments with clean break edges in order to allow for tight reassembly. The iron sulphide residue was then removed by washing with small brushes, wooden tools and pipe-cleaners in running water. Where necessary, two access points were drilled into the void; one for pouring in the casting agent, the other for allowing air to escape. One hole was drilled in concretions with voids that extended through to the surface. The interior surfaces of the voids were partially dried by rinsing in acetone to enable the casting agent to cure effectively. Moisture remaining in the concretion acted as a natural release agent once the casts were fully cured. Concretion segments were reassembled using 3M self-adherent flexible veterinary wrap (Plate 2, Fig. 3.12, upper centre). Visible cracks or gaps were plugged with Plasticine (chalk, mixed oils, colouring), Cling Film (low

*Figure 3.11 Processing concretions at the English Heritage facility in Fort Cumberland (2008/9): (above) inside plastic greenhouse containment area; (centre) inside storage Casement 23 and (below) outside storage Casement 23 (photos Gresham Ship Project)*
Conservation Studies

<table>
<thead>
<tr>
<th>Casting material</th>
<th>Curing time</th>
<th>Viscosity</th>
<th>Working time</th>
<th>Tensile strength</th>
<th>Colour</th>
<th>Curing method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silastic 3483 silicon rubber base and Silastic 83 curing agent</td>
<td>24 hours</td>
<td>17000 mPa.s</td>
<td>90-120 minutes</td>
<td>3.5 MPa after 7 days</td>
<td>White</td>
<td>Condensation reaction</td>
</tr>
<tr>
<td>Tiranti Polyester Resin (with 4% Butanox M-50 Liquid Hardener) (Methyl Ethyl Ketone Peroxide, 33% in Dimethyl Phthalate) mixed with Tiranti Iron Weighting Filler in 60%/40% v/v ratio</td>
<td>20 minutes</td>
<td>180-600 cps</td>
<td>10 mins</td>
<td></td>
<td>Brown</td>
<td>Exothermic reaction</td>
</tr>
<tr>
<td>Araldite 2020 epoxy resin with powder pigments</td>
<td>40–50 minutes</td>
<td>150 mPa.s</td>
<td>30 mins</td>
<td></td>
<td>Brown</td>
<td></td>
</tr>
</tbody>
</table>

Table 3.4 Casting properties of epoxy, polyester resin, and silicone rubber casting materials

density polyethylene) and Plastazote (closed-cell cross linked polyethylene foam).

Casting materials

Three types of casting materials were found to be useful for casting voids of different sizes and complexity (Larsen, 1981). Silicone rubber was useful to replicate complicated forms due to its flexibility on removal. Epoxy resin was effective in casting small intricate voids in a one-piece mould, due to its low viscosity and low shrinkage. Pigmented epoxy casts had a good appearance, but were light in weight and liable to fracture during excavation of the concretion. Polyester resin with iron weighting filler proved useful for large several-part casts; due to its short curing time and low cost (Table 3.4). Iron weighting filler provided additional strength to the cast, preventing damage during excavation and providing an appropriate colour for the resulting cast. However, increased shrinkage occurred during curing and the iron filler presents a potential problem of corrosion post treatment. Due to the strengthening properties and short curing time, polyester resin with iron weighting filler was less likely to be damaged in the process. This was selected as the standard material for casting concretion voids.

Fully cured casts were removed, using gentle hammering, followed by vibrotools in the same manner previously described for concretions containing well-preserved metal objects.

Casting the Void: Concretion GSP25

Concretion GSP25 provides an example of the process of revealing an object cast from a void cavity. The X-radiograph provided clear guidance for the expected location and shape of the concretion cavity (Plate 1, Fig. 3.5, centre). Following initial cleaning and investigation, a chisel and hammer were used to remove superficial encrustation and to crack open the concretion (Plate 2, Fig. 3.12, top image). The crack occurred perpendicular to the void creating two segments with clean break edges, which enable for tight reassembly of the fragments for casting. The void cavity was cleaned and rinsed with acetone. Tiranti General Purpose polyester resin with iron weighting powder (see Table 3.4 for mixing ratio) was poured into the opening cavity in the concretion fragments (Plate 2, Fig. 3.12 upper centre), once the cured, the cast sections were mechanically removed from the concretion using a hammer and chisel (Plate 2, Fig. 3.12 lower centre and bottom). An epoxy resin (Araldite 2020, bisphenol A-epichlorohydrin) was used to join the sections of the cast pieces together to reveal a nail or a spike fastening for deck planks (McCarty, 2005). The cast accurately records the change of form from a square cross-section into a round cross-section. The bottom tip of the nail appears to be broken, the cast had captured this detail well and this suggests the possibility that this tip of the nail could have been hooked (Fig. 3.5 on Plate 1 bottom image).

Type 3 Concretions: concretion containing void of partially corroded iron object with intact solid core (Figs 3.6 and 3.13 on Plates 1 and 3)

X-radiography of GSP99 indicated the concretion to contain a hook-shaped cavity, potentially with a solid metal core (Plate 1, Fig. 3.6). In order to determine whether the core was solid or consisted of fragmentary or liquid iron corrosion products, the concretion was broken into four sections in the same manner as previously described for objects with complete voids. The concretion was found to contain a solid wrought iron core surrounded by liquid iron corrosion. The void was cleaned, sections reassembled and cast in three stages with Tiranti General Purpose polyester resin with iron weighting powder. The three-part cast was necessary as the central core was liable to block the flow of the casting resin. Hook and surrounding cast were desalinated and air dried followed by reconstruction with Paraloid B-72 (polymethyl acrylate copolymer) from a tube.
(approximately 85% concentration). The visible iron core appears to have been stabilized by the consolidating effects of the polyester resin cast. The object as a whole is solid and stable.

**Concretions GSP203**

The technical difficulty of revealing the contents of concretions can be seen in the treatment of concretion GSP 203. Before treatment, the object consisted of a large crust of CaCO₃ and iron corrosion products that obscured the form of the object(s) or any voids as shown in Fig. 3.14 (Plate 3). An X-radioograph appeared to show a narrow void running through the centre of the object, the ends contain denser material and there may therefore have been metal remaining in these areas.

The concretion was fractured using a large hammer perpendicular to its surface, revealing a cylindrical iron object running through the centre of the bulk of the concretion. Although there was a significant amount of iron remaining, there were also voids suggesting that this surviving iron would not be strong enough to survive any attempts to remove it from the concretion without some form of consolidation. The interior surfaces of the voids were dried with acetone prior to filling with Tiranti General Purpose polyester resin with iron weighting powder. This consolidated the remaining iron, creating a combination of a cast and part of the original object. As the casting was revealed, it became clear that only the core was made up of resin; the surface was very friable and liable to loss. The surface of the fragments was wrapped with a temporary facing protected with Paraloid B 72 (ethyl methacrylate copolymer) in acetone. Due to the extremely fragile nature of the iron surface, some of this was lost during processing; however, the majority was retained and consolidated. This provides support for the fragments during desalination immersion in de-ionized water with 1% v/v triethanolamine as a corrosion inhibitor. The fragments of the complete bolt are shown in Fig. 3.15.

The length of this bolt as shown in Fig. 3.15 is approximately 310 mm with the head around 55 mm across. The diameter appears to slightly taper towards the bottom which is expected of bolts to make them easier to insert, it ranges from 20 mm at the bottom to 27 mm just below the head. This is probably a clinch bolt, the end of this bolt was left projecting about a half a diameter above the timbers to be fastened and then a ring was placed on top. The head of the bolt was then hammered in order to spread out the head of the bolt further and tighten it over the ring thereby securing the timbers in place (McCarthy, 2005, 69–71).

**Type 4 Concretions: concretion containing unidentified objects (Plate 2, Fig. 3.8; Plate 4, 3.16)**

X-radiographs of the majority of the Gresham Ship concretions did not reveal readily identifiable features or objects. Concretion GSP202 was chosen as a test case to assess processing options which could then be applied to similar concretions (Plate 4, Fig. 3.16). The concretion was gently cracked open using a flat hammer and stone chisels. This was carefully undertaken to avoid uncontrolled fragmentation of the outer concretion (and therefore destroy any internal voids) or damage any contained objects.

During initial processing, the concretion was found to contain the form of an iron cannon powder chamber (GSP202.1 – Plate 4, Fig 3.17). At this point, the remainder of the concretion was excavated stratigraphically, using light hammering in order to fragment the hard iron sulphide and calcium carbonate concretion matrix. During excavation a hammerhead with partially mineralized wooden shaft (GSP202.2) and a fragment of rope (GSP202.3) were discovered and positions recorded on the Melinex plan.

Preliminary research indicated the powder chamber (dimensions 450 x 250 x 250 mm) to be similar in style to iron examples excavated from two Spanish Armada shipwrecks: *El Gran Grifón* and *La Trinidad Valencera* off Fair Isle, Scotland and Kinnagoe Bay, Northern Ireland dating to 1588 (Martin and Parker, 1988, 222 nos 16 and 21).

Not all concretions were as straightforward as concretion GSP202. In many cases, the contents of the concretions were difficult to interpret with evidence of lost metal elements represented by a combination of different cavities and wood from which specific features could not be identified. Concretion GSP20, for example, revealed discrete finds, such as a silver spoon, ceramic fragments, wrought iron chain fragments and cast voids, but other fragile elements were more difficult to preserve. Such features were photographed and where possible a mould was created with either silicone rubber and/or cast with polyester resin.

After excavation recovered artefacts were conserved by material type (see below). The remainder of the removed concretion was processed into gravel-sized pieces of approximately 10 mm in diameter using a flat hammer, in case small objects, such as coins, were present. The rubble was discarded, with a few samples retained as examples of the results of concretion processing.

**Removal of chlorides**

The most destructive feature of submersion of iron objects in seawater is the presence of chloride salts, which concentrate within objects and their corrosion products (Reguera, et al., 2007). Removal of chlorides is crucial in mitigating the long-term adverse effects of the corrosion process. Upon excavation from their concretion, iron objects (for example, the powder chamber GSP202.1 and chain links GSP90.1) were immediately immersed in a sealed tap water environment to retard further deterioration, prior to desalination treatments being initiated.

A variety of desalination techniques have been developed for use on marine iron artefacts (North and Owens, 1981; Rees-Jones, 1972; Smith, 1991; Gonzalez, et al., 2007, Wang, et al. 2008). Methods vary in intensity, cost, level of efficiency, equipment and
resources. The most commonly used techniques are water diffusion, alkaline sulphite reduction and electrolysis. Electrolysis is the preferred choice of many conservators when the equipment, expertise and resources are available (Hamilton, 2010). It provides an efficient and effective method of removing chlorides, loosening concretions and reducing iron corrosion products to the denser magnetite (North, 1987, 216). A less efficient, but more straightforward method of chloride removal is water diffusion, with the object being soaked in successive baths of tap water with an added corrosion inhibitor. Washing in 2% w/v sodium hydroxide (NaOH) in a container at least five times the volume of the object is recommended by North (1987, 221), measured using a chloride ion selective electrode (Wang, et al. 2008). This is then followed by immersion in distilled water with a corrosion inhibitor, such as sodium nitrate (NaNO₃) at 1000 ppm (North, 1987, 222–3).

The iron objects recovered from concretions were transferred to a 5% w/v solution of sodium sesquicarbonate (Na₂CO₃·NaHCO₃) in tap water, which stabilizes the iron by neutralizing the acidity, preventing oxygen infiltration and forming a passivating film on the surface of the iron. Ferrous metal objects have been desalinated or are undergoing desalination, using this method, monitored through pH measurement to ensure that a level between pH 11–12 is maintained for periods of over one year (North and Macleod, 1987; Carpenter and MacLeod, 1993; Weizhen and Chunhun, 2005, 101). Measurement of pH was with Merck Alkaliti® pH7, 5–14, BDH indicator strips 0–14, Merck Acilit® indicator strips 0–6 and Merck Neutraliti® indicator strips 5.0–10.0. Chlorides were measured with chloride strip test, Merckquant® (Merck) 1.10079 Chloride Test (Cl⁻) and silver nitrate test (Odegaard, et al., 2000).

Other alkaline corrosion inhibitors were used: for example, 1% v/v triethanolamine as a corrosion inhibitor was used with composite materials, such as wood/iron composites (for example on hammer GSP202.2) and polyester resin/iron composites (for example on metal bolt GSP203). Non-ferrous metals, other inorganic and organic objects were desalinated in tap water without the addition of corrosion inhibitors, monitored with conductivity measurements (using an Inolab pH/Cond 750 meter and waterproof meter DiST by Hanna (HI98311)). Water baths were monitored and changed weekly/monthly until no increase in conductivity was measured over one month/three months. A two-stage desalination using tap water followed by de-ionized water was used in a specific cases (for example, non-metal inorganics) and carefully monitored in the case of copper alloy/concretion GSP201.1. De-ionized water immersion can have detrimental effects on some materials, such as tin alloys. Tin alloy will be adversely affected by immersion in solutions below pH 8; therefore de-ionized water and often tap water will need to be buffered prior to use (Hamilton, 2010).

**Summary of Concretions finds**

From the 25 concretions processed, a range of discrete objects and ship-related artefacts were revealed, along with the retention or partial retention of the concretions themselves. Objects or casts of objects that were excavated from a concretion were allocated sequential part numbers, based on the finds number of the concretion (for example, GSP66.1 to 86.7). A selection of the small finds will be discussed further in this chapter. However, details of each object and their conservation treatment can be found as an open access research data base. This provides a complete digital archive of object files containing conservation treatment records and associated analysis and before, during and after treatment images.

Metal and metal/organic composite objects were recovered from twelve concretions (GSP66, 86, 90, 93, 94, 95, 99 200, 201, 202, 203, 209). A combination of casting and object retrieval techniques were required to reveal partially preserved metal objects (for example, GSP66, 99 and 209). Object casts were recovered from concretion voids, as the sole record of the contained metal object for three concretions (GSP25, 83 and 96).
Five concretions (GSP26, 27, 216, 217 and 218) were prepared to present a tangible record of the stages in conservation, manifest as an object. Concretion GSP26 was retained as a partially processed concretion (desalinated and air-dried) (Fig. 3.18). Other concretions such as GSP27, were prepared as a partially processed concretion with cast elements in place, to present the process of concretion casting.

No information about contents was recovered from five concretions (GSP12, 29, 66, 70 and 97). These concretions were processed into small fragments to ensure no object information was present. The process in each case was documented and the concretion fragments were discarded.

Metal small finds (Tableware)

Conservation of tin-alloys

Three tin-alloy objects underwent active conservation; two salt holders (GSP14 and 86.1; Plate 5, Fig. 3.19), originally identified as candlesticks and a spoon (GSP86.7). As few examples of tin objects survive from marine burial environments, these objects were deemed significant for the interpretation of the site (Cronyn, 1990, 211; MacLeod and Wozniak, 1997, 118). All three objects had been selected for an exhibition on the Gresham Ship at University College London in May 2009 and were required to be conserved to display standard. The aim of the conservation process was to identify appropriate and effective conservation procedures to remove iron sulphide and calcium carbonate concretion from tin-alloys.

Analysis

Qualitative X-radiograph fluorescence (XRF) analysis of exposed metal areas indicated each object to be manufactured from tin with varying amounts of alloying metals (Fig. 3.20).

Condition assessment

Visual examination and initial investigative cleaning of a salt holder (GSP86.1, dimensions: 108 x 77 x 33 mm) and spoon (GSP86.7, dimensions: 79 x 30 x 4 mm), both excavated from concretion GSP86, indicated the presence of strongly adhered iron sulphide concretion as well as calcium carbonate marine encrustation. As concretion covered approximately 80% of each surface, it was difficult to determine the condition of the underlying metal. However, exposed sections of the outer surfaces consisted of a fine grey protective patina typical of tin oxide corrosion (Cronyn, 1990, 211; MacLeod and Flecker, 2001). Calcium carbonate marine encrustation on the surface of a second salt holder (GSP14, dimensions 74 x 65 x 25 mm) measured between 2 mm and 7 mm in thickness. Investigative cleaning revealed a paste-like black and grey corrosion layer directly below the encrustation in which original surface features including the moulded design were present. The paste-like nature of the tin corrosion layer therefore affected removal methodology of the harder concretion crust.

![Image](image.png)

**Fig. 3.20a XRF analysis: using hand-held portable InnovX XRF instrument (photo Gresham Ship Project)**

Treatment

The tin-alloy group was identified as a test case to document different approaches to their conservation. Mechanical removal was attempted on both salt holders. However, due to the strong adherence and density of the concretion compared to the underlying metal, this method was abandoned in favour of chemical means to reduce the risk of physical damage to the objects.

An experiment using different concentrations of dilute hydrochloric acid (HCl) in tap water was conducted on salt holder GSP86.1 (Table 3.5).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 1% v/v HCl localised application in cotton wool over 48 hours</td>
<td></td>
</tr>
<tr>
<td>2. 2% v/v HCl localised application in cotton wool over 48 hours</td>
<td></td>
</tr>
<tr>
<td>3. 5% v/v HCl localised application in cotton wool over 48 hours</td>
<td></td>
</tr>
<tr>
<td>4. 2% v/v HCl total immersion bath over 24 hours</td>
<td></td>
</tr>
<tr>
<td>5. 5% v/v HCl total immersion bath over 24 hours</td>
<td></td>
</tr>
</tbody>
</table>

Table 3.5 Chemical cleaning tests carried out on salt holder GSP 86.1

Immersion in 5% v/v HCl in tap water proved to be the most efficient method for removing the iron sulphide as the acid gradually dissolved calcium carbonate inclusions, which in turn loosened the sulphide matrix. This was chosen to remove encrustation adhered to salt holder GSP14.

Following concretion removal, both salt holders were desalinated to remove residual HCl. Desalination consisted of immersion in a running tap water bath for five hours followed by five static tap water baths over a two-week period. Conductivity and pH levels of the baths were regularly monitored. During desalination both objects exhibited active, localized corrosion in the form of white spots occurring on deteriorated sections of metal. White products formed after two days on GSP 14 and after seven days on GSP86.1. The formation of white products is likely to be due to the pH of the water bath,
Figure 3.20b  XRF analysis: pXRF data for surface analysis of salt holder GSP86.1
as tin has the propensity to corrode in pH of less than 8 (Hamilton, 2010). Corrosion products may have formed faster on GSP14 than on GSP86.1, due to the advanced corrosion of the alloy prior to immersion. Each object was dewatered through an acetone bath for 24 hours, prior to air drying.

Chemical treatments proved extremely effective at producing objects with fine surface detail whilst leaving all corrosion layers intact (Figs 3.19 and 3.21 on Plate 5 and Fig. 3.23a). The pilot treatment emphasised the importance of maintaining high pH of immersion solutions for tin-alloy objects, even in areas with hard tap water.
Conservation Studies

Post-treatment analysis

After treatment, examination of one of the salt holders (GSP14) under optical microscopy indicated the presence of a green wax-like substance inside the cavity and in areas around the rim (Fig. 3.23 – White and Page, 1992). This has particular relevance given the initial identification of these objects as candlesticks. The substance was sampled and its composition analysed using Fourier transform infrared spectroscopy (FTIR; Fig. 3.22). The resulting spectrum was compared to reference samples of beeswax and beef tallow, common materials used in candle manufacture in the 16th century. No comparative bond-peaks were present. Further comparative FTIR analysis with lead and tin carbonate samples from the Infrared and Raman Users Group online spectral library (www.IRUG.org) resulted in similar peaks in the 700, 1100, 1450 and 1750 wavenumbers (cm-1) regions. Results suggest that the substance consists of a tin or lead corrosion product or residual marine encrustation.

A straight forward desalination and air drying treatment was carried out for the group of lead ingots (GSP16, 84, 85) and tin ingots (GSP33, 81, 91, 213). Lead and tin alloy metals are vulnerable to acidic conditions and are more stable when dried and protected from volatile organic compounds (Pearson, 1987a, 113; Barker, 2003, 48). Therefore, this group of objects was desalinated in changes of tap water and once conductivity levels had stabilized at levels that matched the initial tap water readings, they were dried quickly to limit the amount of time spent immersed in water.

Spoons

Mechanical cleaning was chosen to remove iron sulphide concretion from the surface of a spoon that was revealed within concretion 86 (GSP86.7, dimensions 108 x 77 x 33 mm). Scalpel cleaning was effective in removing thin layers of concretion (1 mm in thickness), but was liable to result in scratch marks. Vibrotools were tested in dense areas of concretion. However, the vibrations were considered to be too damaging to the underlying object. Air abrasion without aluminium abrasive powder proved useful in removing dense areas of concretion. However, rapid removal resulted in a matted effect on the metal surface, possibly due to residual aluminium powder in the pressure chamber. Therefore, a combination of these techniques was carefully applied to limit their adverse effects.

Removal of the concreted layer revealed a stem with a square cross-section and a moulded decorative design along two sides ending in a volute scroll at the base of the bowl (Fig. 3.24). In a comparison with thirty-five Tudor and Stuart period pewter spoons excavated at riverside sites in Southwark, only one similar example is recorded and identified as a continental import (Egan, 2005; 112, fig. 102 no. 540). A maker’s mark may have been present at the base of the spoon’s bowl; however, due to heavy corrosion in this area, the remains of a mark are not visible or detectable by X-radiography.

Figure 3.24 Spoon GSP86.7 after conservation (photo Gresham Ship Project)

The processing of concretion GSP20 revealed another spoon (GSP20.1, dimensions 152 x 83 x 14 mm), ceramic fragments, bone fragments, iron pin fragments and void casts (Plate 6, Fig. 3.25).

Mechanical cleaning using scalpels and air abrasive was used to reduce the outer layers of the hard concretion. To reduce the potential surface damage from mechanical removal on the soft silver surface, chemical cleaning was undertaken. A solution of 5% v/v dilute hydrochloric acid in de-ionized water was locally applied to the spoon’s surface, so that the attached ceramic fragment was not affected. This revealed excellent surface detail, including a human figure at the end of the spoon handle, decoration along the handle on front and back and a circle at the top of the spoon bowl (inner surface) which may be a makers mark or hallmark. After cleaning in dilute hydrochloric acid residual chlorides were removed in four baths of running water each for 6 hours. The object was then desalinated in changes of tap water monitored weekly over three weeks using a Hanna EC/TDS Conductivity meter, prior to being air-dried.

Copper alloy jug GSP208

Copper alloy jug GSP208 is a rim fragment, broken across at the base of the neck with curled, sharp edges. This object was not associated with a concretion and when found exhibited a brown and green metal surface (Fig. 3.26) (MacLeod, 1982, Scott, 2002). XRF analysis suggests that the object is composed of brass (copper (Cu) 64–75%; zinc (Zn) 8–10%).

An attempted desalination using 5% w/v solution of sodium sesquicarbonate in tap water (Pearson, 1987a, 12) was abandoned after two days, when the bath water turned blue, indicating copper corrosion products were being washed out of the object (North, 1987, 235). In this solution, hydrolysis of the CuCl and Cu2(OH)3Cl occurs with the release of chloride ions. Due to the speed of this reaction, the object was removed from the alkali bath to passive storage in tap water. Desalination continued in 100% tap water for three weeks; conductivity levels were checked weekly using a Hanna EC/TDS Conductivity meter, after which the water replaced. This was repeated until the conductivity level matched that of the initial...
reading. The desalinated object was air dried in atmospheric conditions and regularly monitored for salt crystallization. The object was fully dry after two weeks, indicated by monitoring weight change to a stable level. The object was then packed for inclusion in the archive in a Stewart Box (polyethylene) with Plastazote (polyethylene foam) support and acid free tissue, with silica gel providing a desiccated environment to minimize further corrosion. The object will be assessed for stability prior to archiving, to determine whether any further stabilization is required, such as the addition of benzotriazole (BTA) corrosion inhibitor and protective coating (Paraloid B-44).

The Copper alloy/concretion GSP201.1

The concretion debris surrounding iron gun GSP201 was found to contain the remains of a copper alloy vessel and a ceramic jar. These were separated into discrete lumps of concretion during corrosion removal at Fort Nelson and transported to UCL Institute of Archaeology for conservation. The ceramic jar concretion GSP201.2 can is discussed below. The copper alloy object concretion (GSP201.1) will be described here (Fig. 3.27).

The copper alloy object GSP201.1 was a large circular form (diameter 432 mm) with a relatively intact exterior surface. Portable XRF (pXRF) surface analysis indicated that the alloy was brass (58–70 % copper (Cu); 25–31% zinc (Zn), see Table 3.6. The primary aim of the conservation treatment was to reveal information about the manufacture and use of the object, to prepare the object for long-term deposition in an archive and for potential display in a future exhibition. The fine impression of the associated gun makes it a good candidate for display as a shipwreck object. Its value lies in its story-telling capability; it is visually striking and informative of the overall story of the Gresham ship. Its typological identification and manufacturing information potentially add to the body of evidence supporting the Tudor period date for this vessel.

The impression of the gun’s surface can be seen on the interior concave surface of the concretion, leaving the distorted external side of the copper alloy object exposed (Fig. 3.27 and Plate 7, Fig. 3.29). The object had crumpled along both its horizontal and its vertical axis, resulting in a concave shape interior surface and a convex exterior surface. The surface of copper alloy bowl was covered with copper and iron corrosion products. There was a missing section of rim on one side of the object, which was obscured by the presence of the concretion. One section of the rim was semi-detached and was split at the edge, filled with concretion and/or sediment. The majority of the concretion is thick and solid, adhering firmly to the bowl. The impression of the gun is quite clear (Fig. 3.27) but an area of concretion was soft and liable to loss.

Despite the degree of distortion, the form of the vessel indicates that the base was deep and rounded, suggesting a basin or bowl, rather than a plate. For example, this object exhibits a similar pattern of crumpling to the once rounded bridle boss shown in Egan, 2005, no. 1058. A form similar to the pewter surgeon’s basin from the Mary Rose is a possibility (Jones, 2003, 85). It is less likely to
A riveted circle section of metal can be seen on the central base of the object (diameter of rivet outer circle: 57 mm). After chemical and mechanical cleaning the rivets on the rim and base were seen to be pink in colour, indicating a ‘purer’ copper composition, confirmed with pXRF analysis with a decrease in zinc content for these areas (Plate 6, Fig. 3.28 and Table 3.6).

The copper alloy metal is relatively thin (>5 mm) and likely to have been one piece of metal, set into a circular band of metal, the width of the present rim. The interior bowl edge has been curled over this circle of metal and the interior edge between the rim and the beginning of the wall of the vessel. The rim appears to be split into two sections, with the interior rim appearing to curl over the exterior sheet. Six rivets are evident on one section of rim and appear to continue along the semi-detached rim section, revealing the remains of the grommet in which the rivet would have been set. However, these do not penetrate into the internal face. These rivets do not appear elsewhere on the majority of the rim.

**Conservation Treatment**

One aim of the conservation treatment was to enhance the appearance of the object. This was achieved by revealing some of the brass metal surface below the corrosion product and by removing corrosion around the rivets on the base and rim of the object. To present this as a ‘shipwreck object’, the retention of the concretion is significant and therefore the aim of the treatment was to retain as much of the concretion as possible. It was not intended to remove all of the corrosion products on the surface of the object, as this can provide support for the damaged structure of the vessel, which was particularly true for the more fragile rim sections, which were filled with concretion deposits. The calcareous deposit on the outer surface of the vessel could not easily be removed by mechanical cleaning. Therefore, dilute acid and chelating agent solutions were tested to determine an efficient cleaning method to remove corrosion from the copper alloy surface (Table 3.7).

Mechanical cleaning, aided by chemical poultices (30% w/v citric acid and 10% w/v EDTA disodium salt solution mixed into a 5% w/v Laponite RD in de-ionized water), revealed the bright golden yellow colour of brass metal just beneath the corrosion product (Huda, 2002). To avoid over cleaning the bowl surface, the application of the poultice was limited to 5 minute periods before removal and rinsing. The most efficient technique for removing calcareous deposits was found to be dilute citric acid applied as a poultice (Laponite RD gel) to loosen the deposits, followed by mechanical removal and then rinsing with de-ionized water.

A two-phase desalination treatment was carried out using tap water followed by de-ionized water immersion. This was monitored weekly with standardized conductivity,

### Table 3.6 pXRF composition of the copper alloy and concretion (GSP201.1). The high level of zinc and low lead levels suggest this can be categorized as brass

<table>
<thead>
<tr>
<th>Location</th>
<th>Cu%</th>
<th>Zn%</th>
<th>Pb%</th>
<th>Sn%</th>
<th>Ag%</th>
<th>Fe%</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Exterior Surface</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface</td>
<td>69.2</td>
<td>26.0</td>
<td>0.3</td>
<td>2.6</td>
<td>0.2</td>
<td>1.6</td>
<td>Ni</td>
</tr>
<tr>
<td>Base rivets</td>
<td>70.3</td>
<td>26.3</td>
<td>0.3</td>
<td>2.0</td>
<td>0.2</td>
<td>1.0</td>
<td>Ni</td>
</tr>
<tr>
<td>Semi-Detached rim</td>
<td>66.0</td>
<td>27.5</td>
<td>0.4</td>
<td>2.9</td>
<td>0.2</td>
<td>2.8</td>
<td>Ni, Mn</td>
</tr>
<tr>
<td>Rivet (uncleaned)</td>
<td>53.9</td>
<td>25.0</td>
<td>0.3</td>
<td>3.3</td>
<td>0.4</td>
<td>16.8</td>
<td>Ni, Mn, Zr</td>
</tr>
<tr>
<td>Rivet (cleaned)</td>
<td>66.6</td>
<td>15.0</td>
<td>0.5</td>
<td>1.4</td>
<td>0.3</td>
<td>15.5</td>
<td>Ni, Mn, Zr</td>
</tr>
<tr>
<td><strong>Interior Surface</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concretion</td>
<td>68.6</td>
<td>25.4</td>
<td>0.3</td>
<td>2.1</td>
<td>0.2</td>
<td>3.4</td>
<td>Ni</td>
</tr>
<tr>
<td>Concretion</td>
<td>0.0</td>
<td>1.9</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>97.1</td>
<td>Co, Mn, Zr</td>
</tr>
<tr>
<td>Semi-detached rim (left)</td>
<td>57.8</td>
<td>31.0</td>
<td>2.2</td>
<td>2.6</td>
<td>0.3</td>
<td>5.9</td>
<td>Ni, Mn</td>
</tr>
<tr>
<td>Solid concretion</td>
<td>0.0</td>
<td>6.1</td>
<td>0.2</td>
<td>0.0</td>
<td>0.0</td>
<td>89.8</td>
<td>Co, Mn, Zr</td>
</tr>
</tbody>
</table>

**Figure 3.27 Copper alloy fragment and concretion GSP201.1 with impression of gun GSP201 visible on interior concave surface of concretion (photo Gresham Ship Project)**

This image shows the copper alloy fragment and concretion GSP201.1 with the impression of a gun GSP201 visible on the interior concave surface of the concretion. The object appears to be a cooking vessel, such as a cauldron, as there is no evidence on this object of foot attachments or notches/attachments along the rim for a hanging mechanism (Gardiner and Allen, 2005, 432; Butler, et al., 2009).

A riveted circle section of metal can be seen on the central base of the object (diameter of rivet outer circle: 57 mm). After chemical and mechanical cleaning the rivets on the rim and base were seen to be pink in colour, indicating a ‘purer’ copper composition, confirmed with pXRF analysis with a decrease in zinc content for these areas (Plate 6, Fig. 3.28 and Table 3.6).

The copper alloy metal is relatively thin (>5 mm) and likely to have been one piece of metal, set into a circular band of metal, the width of the present rim. The interior bowl edge has been curled over this circle of metal and the interior edge between the rim and the beginning of the wall of the vessel. The rim appears to be split into two sections, with the interior rim appearing to curl over the exterior sheet. Six rivets are evident on one section of rim and appear to continue along the semi-detached rim section, revealing the remains of the grommet in which the rivet would have been set. However, these do not penetrate into the internal face. These rivets do not appear elsewhere on the majority of the rim.
joined together as shipwreck objects and have now been stabilized in this association as part of the long term archaeological archive. The long term association between the spoon, the ceramic, the copper alloy bowl and the gun present intimate relationships that reflect the wrecking event and the taphonomic processes that led to the survival of these objects in this form. These objects have been transformed by their association with the wrecked ship and their time as part of the marine environment, prior to the processes that lead to their recovery and most recently by their transformation as conserved archaeological objects.

**Organic Small Finds (personal possessions)**

**Small Wooden Finds**

Six small wooden finds had been retained as part of the finds assemblage. These included a pike shaft GSP204 (Fig. 3.30 and Plate 7, Fig. 3.33), barrel stave GSP11 (Fig. 3.32), trenail WA 54135 and three small objects GSP32 (Fig. 3.31), GSP82 and GSP207 (Hildred, 1997).

Each object was assessed to determine the research potential of the material for the Gresham Ship Project. The condition of each object was documented and species of wood identified prior to designing an appropriate conservation treatment to stabilize the wood finds for archive deposition.

**Condition assessment**

Detailed documentation (photography, illustration, dimensions, X-radiography and species identification) was conducted in order to assess the treatment regime needed for each wooden artefact. Drawings noted the transverse, tangential and radial planes in order to assess impregnation rates and potential shrinkage during treatment. All six fragments were in a solid dense condition, although the pike GSP204 exhibited severe marine mollusc attack at one end (Fig. 3.30). Dense calcium linings visible in X-radiography indicated borer tunnels had penetrated one-third of the pike’s length. The pike tip also exhibited iron staining, resulting from the associated iron tip (part of GSP205: see Plate 11, Fig. 3.44). A small wedge fragment GSP32 exhibited heavy iron corrosion staining and associated concretion from an iron pin which, when viewed as thin-sections under transmitted-light microscopy, appeared to have partially mineralized the wood (Fig. 3.31) (Blanchette and Hoffmann, 1994).

**Species identification**

Species identification and cell wall condition was assessed, using thin sections under light transmitted microscopy. This was required in order to assess impregnation rates and molecular weights of polyethylene glycol needed for treatment (Cook and Grattan, 1990). Five samples were identified as oak (*Quercus* spp.) which is known for problems associated with consolidation using polymers with large molecules, cross checking on radial surfaces and wide cracks in tangential surfaces post treatment (pers. comm., Jacqui Watson).

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**Table 3.7 Chemical Cleaning Tests for copper alloy/concretion (GSP201.1)**

<table>
<thead>
<tr>
<th>Chemical Cleaning Test</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Citric Acid 30% w/v</td>
<td>in deionised water (to remove the calcareous deposits)</td>
</tr>
<tr>
<td>Ethylenediaminetetra acetic acid (EDTA) disodium salt 10% w/v</td>
<td>in deionised water (a chelating agent for ferrous metal ions)</td>
</tr>
<tr>
<td>EDTA tetrasodium salt 30% w/v</td>
<td>in deionised water (a chelating agent for calcium)</td>
</tr>
<tr>
<td>Sodium hexametaphosphate (i.e., Calgon™) 30% w/v</td>
<td>in deionised water (a chelating agent for calcium carbonates)</td>
</tr>
<tr>
<td>Laponite RD (synthetic inorganic clay, [magnesium silicate]) 5% w/v</td>
<td>in deionised water (a gel poultice for the application of citric acid 30% v/v in deionised water)</td>
</tr>
</tbody>
</table>

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The decorated objects, tin alloy salt holders (GSP86.1, GSP14) and spoon (GSP86.7), silver spoon (GSP20.1), copper alloy jug (GSP208) and copper alloy bowl (GSP201.1), provide a small but interesting group of finds. These have been documented, described, cleaned and stabilized to present conserved objects in various states. The chemical cleaning of the tin alloy objects and silver spoon aimed to reveal surface detail from beneath the marine deposits formed on the objects. The outer metal surface of the copper alloy bowl was revealed, whilst attempts were made to retain the large iron concretion adhering to the inside. Different technical solutions were applied that combined robust mechanical removal techniques with more subtle uses of chemical cleaning that were adapted to the particular requirement of each treatment. The excavation and conservation process has provided raw material for further research.

The small number of objects in this group does restrict our ability to develop interpretations concerning shipboard society, but they do have the potential to tell interesting stories and become powerful museum exhibits.

The association between the ceramic fragment rim that adheres to the silver spoon (GSP20.1) provides an intriguing object that hints at the use of the spoon in board the ship. We could speculate that the spoon was scooping contents of the ceramic bowl to which it is now firmly attached. We can however be more definitive in that we can say that both the spoon and the ceramic, the copper alloy bowl GSP201.1 and the gun GSP201 were...
The small fragment GSP207, possibly part of a barrel lid, was identified as pine (*Pinus* spp.), a species which responds well to Polyethylene Glycol (PEG) impregnation and freeze-drying due to its simple cell structure (pers. comm., Jacqui Watson).

All fragments underwent desalination in tap water over a period of four months to remove the bulk of soluble marine salts. Objects were stored at 4°C to prevent bacterial degradation. Conductivity levels of bath water were monitored using an InoLab pH/Cond 750 meter. Tap water was changed when levels stabilized and desalination was completed when conductivity levels reached the same as tap water.

**Figure 3.30**  
Pike shaft GSP204 before conservation: above woodborer activity visible in X-radiograph; below holes created by marine woodborers; white areas are calcareous material they left behind (photo Gresham Ship Project)

**Figure 3.31**  
Left GSP32 photomicrograph of ring porous cell arrangement showing intact early wood cells (TS x 40). Cell lumen filled with iron corrosion products (photo Gresham Ship Project)

**Figure 3.32**  
Right barrel fragments before conservation: above oak barrel stave GSP11; below pine barrel lid GSP207 with marine growth (photos Gresham Ship Project)

**Treatment**
Iron staining posed several problems for the pre-treatment and post-treatment stability of the wood. Potential problems include physically blocking the microstructure of wood, making it impermeable to bulking agents; physical degradation caused by oxidation of iron sulphides into sulphuric acid and structural damage caused by crystallization of iron pyrite crystals (Watson, 1985, 213, 217; Jones, 2003, 63). Ferric (Fe$^{3+}$) ions from the burial environment are actively chelated (bound) by cellulose and tannates that build up over time. Under anoxic conditions, iron salts are converted into sulphides (pyrite) by sulphate
Reducing bacteria. Iron sulphide is unstable in the aerobic environment and its oxidation can destroy an object. Sulphuric acid produced inside the object will start to hydrolyse the wood (Watson, 1985, 213; Jones, 2003, 63). Pyrite is also reduced to gypsum by oxidation or bacterial action; the crystallization of gypsum can cause distortion of the cell wall (Watson, 1985, 213, 217). High concentrations of iron salts (iron pyrites) in dried archaeological wood results in structural damage and blooms of sulphate crystals occur on the wood surface (Jones 2003, 63; Hamilton, 1998, 3). Removal or stabilization of iron salts needs to be achieved to mitigate damage (MacLeod, et al., 1994; MacLeod and Richards, 1997). The use of a complexion agents such as EDTA (disodium salt of ethylene-diaminetetraacetic) and DTPA (diethylenetriamine-pentaacetic acid) were considered as a method to reduce residual insoluble iron salts (Fe\(^{3+}\)) to soluble salts (Fe\(^{2+}\)) prior to bulking. Removing iron salts is, however, difficult, as many iron compounds are insoluble in most chelating agents and can be only dissolved by strong mineral acids, which have been found to soften wood cell walls in wood and lead to increased shrinkage in waterlogged leather (Watson, 1985, 213; Jones, 2003, 63, Karsten and Graham, 2011). Therefore, no attempt was made to remove ferrous ions from the waterlogged organic materials, except where this was considered necessary to reveal surface detail from beneath obscuring deposits (for example, leather shoe GSP35) (Hovmand and Jones, 2001; Hovmand, 2002).

Due to the small size of the wooden objects, it was not possible in most cases to carry out destructive condition assessment measurements, such as maximum moisture content (max) (Cook and Grattan, 1990, 245; Panter and Spriggs, 1997, 188). Concentrations and impregnation time were therefore determined by other means, such as visual assessment, X-radiography and optical microscopy, the pin test and comparison with previous conservation research. These suggested variations in the treatment regime from 10–25 v/v % Peg 400 in water and 0–20% w/v Peg 4000.

**Pike shaft GSP204**

GSP204 (dimensions 364 x 40 x 42 mm) was identified as the tip of a pike shaft (Fig. 3.33 on Plate 7 and Figs 3.30 and 3.34). Thin-section microscopy indicated that the wood is ring porous with wide multisereate rays, identified as oak (Quercus spp.; pers. comm., Jacqui Watson and Martin Bridge; Hather, 2000, 46). The pike has been manufactured from the length of the tree, its cross-section corresponding to the transverse section, providing the object with maximum strength. The pike is octagonal in cross-section and the spike-end has been worked in five-planes. There are traces of residual iron at the spike end and a fibrous material is adhered to the spike end and is possibly the remains of caulking or marine growth.

Similar pikes were used commonly in medieval European warfare from the 13th to the 18th centuries after which the widespread use of muskets rendered it obsolete. A Tudor pike would have ranged from between 3 and 6 m in length. On board ship, they could be used for boarding or to repel boarders. The long length of this weapon required a very strong wood, such as well-seasoned oak or ash and the shaft would be tapered towards the end to prevent sagging (Brown, 1997; Hather, 2000).

**Pre-Treatment Condition**

The pike end is complete in shape, the outer surface of which was soft and the core dense. The pike end was much denser than the shaft end, possibly due to mineralization of the wood by iron corrosion and absence of borer activity. White marine coral concretions were present in small areas at the shaft end, associated with large marine borer tunnels (Fig. 3.30). Several small fragments were detached from the shaft end, which was fragile and liable to loss during handling.

Optical microscopy of thin sections taken from the surface show cell walls to be intact and lumen to be filled with dark red iron corrosion products (pers. comm., Jacqui Watson). The availability of small samples of detached wood enabled maximum water content (max) to be tested. This suggested a max of 192%, indicating that the wood was in reasonable condition (Grattan and Clarke, 1987). Drying treatments for waterlogged wood can easily result in significant dimensional changes; therefore, the dimensions of this object have been accurately recorded before treatment (Figure 3.34).

The object was desalinated by placing in fresh tap water and measuring salt levels with a conductivity meter until

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**Figure 3.34 Pike shaft GSP204: pre-treatment measurements**

![Pike shaft GSP204 diagram](image-url)
they matched that of the tap water. A treatment regime 20% v/v PEG 400 and 20% w/v PEG 3350/4000 was calculated using the PEGCON programme (Grattan and Clarke, 1987, 178). The concentration of the PEG 4000 solution was increased in 5% increments over several months. Impregnation was monitored using a hand held refractometer and an associated calibration curve was used to measure the concentration of PEG solutions and manage increments in PEG concentration. After a month in the final PEG solution, the object was taken out, excess PEG was removed from the surface and it was frozen ready for freeze-drying.

**Hammer GSP202.2**

A similar treatment regime was adopted for wood/iron hammer GSP202.2 (dimensions 107 x 120 x 35 mm). Desalination took place in tap water with 1% v/v triethanolamine as a corrosion inhibitor to help protect the ferrous metal elements. The object was impregnated with 20% v/v PEG 400 and 20% w/v PEG 3350/4000, with the addition of 1% v/v triethanolamine, (Plate 8, Fig. 3.35). The iron hammer head was actively corroding and had lost significant material in the cheeks areas. The wooden handle was encrusted and impregnated with iron corrosion products. The juxtaposition of iron/wood as composite objects creates additional problems in the conservation of waterlogged marine objects. PEG-treated wood associated with iron component parts in a composite objects can result in reciprocal damage in the long term (Jones, 2003). This is only partially mitigated by the addition of corrosion inhibitors during the impregnation of PEG. This, however, was not considered sufficient justification to separate the ferrous metal hammerhead from the remains of the wooden handle for separate treatment (Krop and Nordgren, 2011).

The hammer, although a part of the concretion (GSP202) that contained the powder chamber (GSP202.1), could not have been effectively stabilized as part of the concretion. Therefore, a conscious choice was taken to physically separate the wooden handled hammer from its concretion, so that conservation could be carried out. This does, however, diminish the connection between the hammer and the powder chamber. The intellectual and physical association can, of course, be regained after conservation by reuniting the separated elements. Therefore, the archaeological provenance information that recreates the association between the objects becomes a critical tool to reunite dislocated materials.

Physical separation as a result of the archaeological recovery process does routinely occur and was an advantage for the conservation treatment of the pike shaft (GSP204). This allowed the PEG impregnation and freeze-drying treatment to be designed specifically in relation to the condition of the wooden shaft. The treatment of the associated shoe sole (GSP205) attached to wood and the iron pike head was, however, a compromise in order to balance the conservation needs the wood, leather and iron components. The choice of a two stage PEG impregnation treatment followed by freeze-drying was selected for GSP205 in order to conserve the wooden elements of the object. This treatment has some benefit for the leather element (although the use of PEG 3500/4000 is not normally considered appropriate), but provides little benefit of the iron pike tip. This is because the use of PEG and the freeze-drying can have an adverse effect on the chemical and physical stability of the iron. In other words, the treatment of composite objects requires compromises, as the work on shoe concretion GSP88 also demonstrates.

**Other Organic Materials**

Sections of rope fragments were associated with several concretions, as likely to be part of the rigging entangled with heavier objects as the ship sank, or during the time on the seabed prior to concretion formation, or associated with the salvage operations in 1846, as they are to be associated with the particular object during the life of the ship. A fragment of rope GSP211 was connected to the concretions around gun GSP201 and was, therefore, also associated with copper alloy bowl GSP202.1 and the hammer GSP202.2. The rope was separated as a discrete find immediately following excavation and was therefore treated as a separate object (Fig. 3.36). It was identified as a z-spun, S-ply, Z-cabled (zS2(Z)3) rope (Wendrich, 1999, 31). Fibre identification was attempted using polarized light microscopy (PLM) in order to determine whether the rope was hemp or flax or later materials such as jute (that might occur from 17th century onwards). The degree of deterioration meant that
Leather boot fragments: above large piece of leather GSP80 part of a boot upper; top right smaller fragment, possibly from second boot (photos Gresham Ship Project)

Figure 3.39 Leather boot GSP80: centre right detail of tunnel stitch on inside surface, where bootstraps may have been attached; bottom right detail of stitch holes from back leg seam, with larger holes from heel attachment (photos Gresham Ship Project)

diagnostic features (plant cells and crystalline features), could not be clearly identified (Catlin and Grayson, 1982; Ballard and Skals, 1996). An attempt was made after further cleaning (ultrasonic cleaning) and solvent drying. However, the diagnostic features were obscured by deposition of the thick organic matter, so no further identification was possible (Garside and Wyeth, 2006).

The rope fragments were solvent dried in a sequence of solvent baths; 50% v/v de-ionized water/Industrial Methylated Spirits, (IMS) (95% ethanol/5% wood naphtha), 100% IMS, 50% v/v solution IMS/acetone and 100% acetone. This process was monitored using hydrometers to determine when the object was in equilibrium with the solvent bath, after which the object was air-dried. The dried rope was consolidated with Klucel G (hydroxyl propyl cellulose) 0.5% w/v in IMS (Florian, et al., 1990; Weavers, 1991; Peacock, 1990; Smith, 2003; Huisman, 2009). After treatment the rope was slightly stiff, friable and had shrunk in length by 20%. It was however, easier to handle and is suitable for further study and future display.

Leather footwear

A small group of leather objects formed part of the finds assemblage; the remains of two leather shoes (GSP55 and GSP88), three shoe soles (GSP35, 205 and 206) and part of what was initially described as a leather garment or jerkin (GSP80: see Fig. 3.37 on Plate 9 and Fig. 3.38). The identification of GSP80 as a boot upper, allows us to discuss the footwear collection from the ship, representing six items in total. Investigative conservation procedures were performed in order to discover information about the footwear and potentially the wearers (van Driel-Murray, 1987; von Brandenberg, 2009). Each treatment was carried out by a different graduate conservation student and therefore the approach to each object reflects the individual choices made by each conservator. It is therefore appropriate to describe in detail the treatment process of each object and then to reflect how this relates to the overall aim of the conservation process to conserve the objects to reveal archaeological information about the wreck assemblage, whilst seeking to present the finds as shipwreck objects.

Over-the-knee boot GSP80

Four pieces of vegetable tanned calf leather comprising one piece (dimensions 630 x 500 x 5 mm) and three smaller fragments were initially thought to represent the
remains of a jerkin (Frith, 2006), but were subsequently identified by their size, shape and the positioning of stitch holes to be the upper of an over-the-knee boot (Fig. 3.38 and Plate 10, Fig. 3.40). One of the smaller fragments may have come from the matching boot – it was full thickness and had a cut edge. The other two fragments were delaminations, possibly from the larger piece.

The boot upper appears to have been cut from a large piece of leather to a standard pattern, but with the owner’s size and shape in mind (Goubitz, et al., 2001, 31). The line of the back seam follows the profile of the back of the leg, indicating a tight fitting style, with straps on the inside and a peak at the centre front. The main seam down the back of the leg would have been closed with the edges turned inwards, secured with stitches placed 2 mm apart. Although no remains of the stitching was present, it is likely that this would have been flax or hemp thread (Kite and Thomson, 2006, 246). Marks on the flesh side, near the seam, are the remains of tunnel stitching, presumably used to attach a strap with which the wearer would pull the boot on (Fig. 3.39). There are five large holes cut out of the leather at the heel end, these large stitches would have secured the layered leather to create the heel. There is no evidence that the boot was lined.

The additional workmanship and materials meant that boots of this kind were likely to have been reserved for higher-status crew members, if only due to their cost. There are fewer examples of archaeologically recovered leather thigh boots than of other types of footwear (Gardiner and Allen, 2005, 84). A reason for the unrepresentative ratio of boots to shoes found is likely to be that uppers were reclaimed for secondary use after the shoe/sole elements were worn out. It is for this reason that shipwrecks tend to yield more identifiable fragments and complete shoes/boots than land sites (Goubitz, et al., 2001, 230).

**Treatment**

From the time of its recovery until its treatment in 2009, GSP80 was stored rolled in a polythene bag filled with tap water (Plate 9, Fig. 3.37a, top left). The leather was heavily stained with iron corrosion products, covered with silt and mud and was distorted, where it had been folded and rolled within the storage bag. Over half of the large piece, towards the lower end of the leg where only one ankle flap remained, was subject to delamination. The leather was cleaned under gentle running water with a soft brush to remove silt, mud and iron corrosion products (Pearson, 1987a, 129). During cleaning, a polythene tracing was made of the shape of the large piece, marking the position of stitch holes. From this a wool felt replica was constructed to examine the three dimensional form of the object.

The object was desalinated by soaking in fresh water until conductivity of the water was stable, followed by impregnation with of 20% v/v glycerol (1, 2, 3-propanetriol) solution in tap water for three days (Ganiaris, et al, 1982; Wouters, 1986; Suenson-Taylor and Sully, 1997; Peacock, 2001; Kite and Thomson, 2006, 248). The three fragments were mounted around an inner support of a stiffened textile and acid-free tissue to maintain the rough shape of a boot, equivalent to the replica. The outside was wrapped with nylon gossamer and secure with cotton tapes. Prior to freezing the object was patted dry with paper towel and freeze-dried at 20°C for two weeks (GSP80, GSP55 and GSP206 were all impregnated with glycerol and freeze-dried in a similar way). The leather dried with minimal shrinkage and remained flexible. The stitch holes appeared to be more clearly defined after drying (Fig. 3.39 and Plate 10, Fig. 3.40). The boot was stored with padding to maintain the curved shape and take the weight of the leather away from the fold.

**Shoe concretion GSP88**

Shoe concretion GSP88 (dimensions 460 x 180 x 130 mm) was a composite object consisting of concretion, wood and leather and was the most complicated of the leather finds from the Gresham Ship (Plate 10, Fig. 3.41). The leather was partially covered by hard concretion. The interior of the shoe was filled with pieces of concretion and the concretion at the heel end of the shoe was attached to a wooden fragment 430 mm long. The whole object is in relatively poor condition and vulnerable to further damage due to the association of these different materials. The concretion is heavy and liable to oxidation, the waterlogged wood is swollen and liable to shrinkage on drying; likewise the leather is brittle from its mineral content and liable to physical damaged due to the 4 kg weight of the concretion.

Much of the shoe was enclosed in hard concretions, delaminating in areas with the heel and toe both obscured. The remains of this adult-sized leather shoe consisted of the sole and parts of the upper of a right shoe. It appeared to be a simple construction with a single piece vamp, which may have been a slip on or had latched fasteners on the sides (pers. comm., Jackie Kelly). Most of the sole of the shoe was visible and three layers could be seen in profile, which are probably the insole, midsole and treadsole (made in two parts). There was a repair on the toe area of the sole and the sole had been distorted inwards in the middle, which may have occurred during the wrecking event. The post-1500 AD date for this type of shoe construction fits with the late 16th-century wreck, but does not provide additional dating information for the ship’s assemblages (Goubitz, et al., 2001).

**Treatment**

The object was cleaned by gentle brushing under running tap water. Some of the corrosion products were loosened and removed during cleaning, but the majority were too hard to be easily removed. The object was desalinated by immersion in tap water baths, which were changed daily until a consistent electrical conductivity reading close to that of the tap water was reached. The object was impregnated up to a final concentration of 20% v/v PEG 400, 20% w/v PEG 4000, with 1% v/v triethanolamine.
(corrosion inhibitor) solution in tap water, prior to freeze drying at -20°C for several weeks.

**Shoe fragment GSP35**

Shoe fragment GSP35 was the leather sole of a right shoe (dimensions 195 x 65 x 4 mm). Little of the leather surface was visible, as the sole was heavily impregnated and encrusted with iron corrosion products, giving it an ochre colour and obscuring any surface details of the leather (Plate 11, Fig. 3.42). The oxidation of iron salts within the leather is likely cause both physical and chemical damage to the object. The object is particularly degraded near the centre of the sole. The weakening of the leather in this area suggests evidence of use, as it is where the metatarsal head or ball of the wearer’s foot would be when wearing the shoe. X-radiography confirmed the absence of any metal fittings on the object and showed an unremarkable motled appearance in areas of the sole covered by iron deposits.

**Treatment**

Prior to cleaning, the object was desalinated and then soaked in 5% w/v disodium EDTA (ethylene-diaminetetra-acetic acid disodium salt) in water for 23 hours. This was designed to soften the obscuring layers of and encrusted with iron corrosion products. The bulk of softened accretions were mechanically removed with toothbrush and bamboo stick, then rinsed thoroughly with tap water for two days. The object was impregnated with glycerol and freeze-dried. Some warping of the sole had occurred during freeze-drying, which was corrected by re-humidification. A backing support was added to the thin, vulnerable areas of the shoe sole, using tabs of Japanese tissue with Mowilith 50 (polyvinyl acetate) 50% w/v in acetone across the join; then a larger patch of watercolour-tinted Japanese tissue was applied over the area of the repair, with 1% w/v Klucel G (hydroxy propyl cellulose) in IMS. The repairs were not visible from the front of the sole and provided enough support to reduce the risk of breakage during handling. Stitch holes were uncovered with removal of the accretions and can be seen around the perimeter of the sole, but there was no evidence of stitching thread was present (Plate 11, Fig. 3.42).

**Heel fragment GSP55**

GSP55 consists of fragments of a shoe upper attached to a concretion (dimensions 138 x 210 x 60 mm). The remains of the leather shoe consist of a fragmentary sole and heel (heel stiffener), with insole, outer sole, welt and right quarter evident. There is a free standing seam with two rows of stitch holes, characteristic of welts (Plate 11, Fig. 3.43). The insole and outer sole have evidence of stitches. A heel stiffener was typically a triangular piece of leather that was sewn into the heel section of the footwear to strengthen an area that was subject to great stress and wear (Grew and Neergaard, 1988). The quarter is one part of a two part type as it has evidence of being gathered through stitching in the middle of the heel (Evans and Mould, 2005). The bovine leather is delaminated, fragmentary, torn and very fragile, within some impregnation of iron corrosion products.

The shoe was connected to the remains of a concretion that was initially connected to one of the iron guns recovered from the wreck (Plate 9, Fig. 3.37, bottom left). The concretion is broken into two fragments and appears to be holding parts of the leather shoe together. The shape of the concretion and associated impressions of leather suggest that the tip of the shoe was attached to the concretion at some point.

**Treatment**

The object was cleaned in running water, desalinated in repeated baths of tap water for four days and monitored until conductivity reduced to that of tap water. The object was impregnated with 20% v/v glycerol (propane-1, 2, 3-triol) 1% v/v triethanolamine and freeze-dried at -20 °C for 2 days. A backing support was added to repair vulnerable areas using tabs of Japanese tissue with Mowilith 50 (polyvinyl acetate) 30% w/v in acetone across the join; then a larger patch of watercolour-tinted Japanese tissue was applied with 1% w/v Klucel G (hydroxy propyl cellulose) in IMS.

**Leather shoe GSP205.**

This leather outer sole GSP205 (dimensions 280 x 140 x 60 mm) is attached to a wooden timber from the shipwreck and iron pike head, which connect to pike shaft GSP204. The sole is nearly complete; the only areas of loss at the toe of the sole and along the inner edge could be due to original wear. The shoe is late 16th-century in date, vegetable tanned bovine and equivalent to a modern UK adult size 7 (Grew and Neergaard, 2001, 102). The shoe is of welted construction, seen in the punched stitch holes around the perimeter of the sole (Plate 11, Fig. 3.44). There are multiple punched holes associated with the areas of wear, which may indicate a past repair (pers. comm., Jackie Keily). The corrosion from the iron pike head has affected the adjacent areas of the shoe sole.

Following desalination the shoe was impregnated with PEG 20% v/v polyethylene glycol 400, 1% v/v triethanolamine (corrosion inhibitor) solution in tap water. Once freeze-dried, iron pike head will be coated in Paraloid B-44 (a methyl methacrylate copolymer) with a top coat of microcrystalline wax.

**Leather Shoe 206**

Shoe 206 (dimensions 116 x 91 x 265 mm) is possibly the forepart of a left shoe’s leather sole or a midsole or insole, but more likely a repair (Goubitz, et al., 2001). The leather has been cut to shape and the holes left from stitching show that all of its sides would have been stitched to the shoe. There is evidence of use in that this sole is thinner near the top of the shoe where the wearer’s toes would have worn down the leather. There is evidence that wear has worn down the leather (Plate 12, Fig. 3.45). Although the toe of the sole is worn, it is likely, from the rest of the sole, that it would have originally been rounded in shape, late 16th century in style, most likely to be from a slip-on, everyday work shoe (pers. comm., Jackie Keily). It is possible that the sole was added as a ‘clump sole’, a term describing a half
Conservation Studies

sole added to a shoe as a repair or simply thicken the sole (Carlson, 2005). In the case of shoe 206, it was stitched on the inside to strengthen the sole at an area of weakness. This is suggested as the back of the sole is cut diagonally, so it would not have covered the front area of the sole completely, as you would expect if it were added to thicken the whole sole. The follicle pattern is not discernible under high magnification due to abrasion; however, the leather is likely to be bovine leather due to its thickness and the context of the object. As this sole was excavated from beneath GSP205, it is likely that the two were associated, with GSP206 being a repair to GSP205. The archaeological process that allocated separate object numbers to these objects has been emphasised by the separate conservation treatments that each object has undergone.

Treatment

The object was desalinated and then immersed in a 10% v/v glycerol/10% v/v PEG 400 solution, freeze-dried for two days until a constant weight was reached. The treatment was successful, as the object is now stable enough to be handled, examined, transported and displayed. The object can now consequently fulfil its research, educational and outreach potential. The object did suffer inevitable dimensional change as a result of drying, but this was deemed worthwhile, as drying has made the object stable and understandable.

Summary of Organic Small Finds

It is clear from the differing responses to the conservation of the six leather footwear objects that the outcomes of the conservation process are not readily predictable. Despite a group of similar objects conserved within an overarching aim, the outcomes of each treatment differ. The decision-making process associated with these outcomes can be considered in relation to the two extreme examples of how the conservator may alter the physical fabric of the artefact, to achieve a conserved object in its manufactured form or as a shipwreck artefact as found.

For objects GSP80 and GSP206, a stable, legible, conserved object was produced by applying a standard interventive conservation process of desalination, impregnation, freeze-drying and post-drying repair. This is a consequence of the condition of the object and the availability of effective conservation treatments to investigate and stabilize objects of this type. GSP88, GSP55 and GSP205, however, involved technically more complex conservation treatments, due to the presence of composite materials (leather, wood, ferrous metal, concretion), but also due to the desire to retain as much of this material as possible in the conserved object. This limits the shared goals of investigation and stabilization, which in the case of GSP88 in particular, have been compromised by the desire to retain the concretion as part of the conserved object. For GSP88, the aim to produce a conserved object that would be able to communicate effectively as a shipwreck artefact, has resulted in limited archaeological information about the shoe itself, as well as in a conserved object that is vulnerable to physical and chemical change over time. A different approach was taken for GSP35, where the conserved object was altered from the object as found. The desire has been to remove the contained iron salts in order to ensure the object’s long-term stability. The chemical removal of surface accretions was justified in order to satisfy the requirements of investigation and stabilization.

Monitoring the condition of the hull timbers

The most significant waterlogged organic feature is, of course, the ship itself. The relocation of the hull timbers to Horsea Lake and finally to Stoney Cove, provided an opportunity to research the extent and rate of deterioration of the oak-built hull subject to a fresh water oxygenated environment. A repeatable methodology for the condition assessment of timber samples from the ship was developed to monitor the changes that occur over time as a result of this change of environment. This has involved an examination of agents of deterioration and their impact on oak cell structure, in order to understand the mechanisms of decay affecting the ship’s hull. The condition of the hull was quantified through a range of chemical and physical analytical techniques, applied to sample material removed from the ship. From this, a standard methodology was developed to assess the condition of samples of the hull over time. This has provided a means of monitoring ongoing changes to the condition of the timbers that will inform any conservation interventions to stabilize the ship timbers. This will be the focus of a forthcoming conservation journal article (Sully, et al., 2014).

Ceramics and Glass

Two ceramic fragments (GSP31 and GSP34), one glass fragment (GSP58) and one ceramic/concretion (GSP201.2), underwent active conservation (Fig. 3.46). This provided an opportunity to assess appropriate desalination and drying methods for low-fired, high-fired, glazed and non-glazed ceramics and glass finds recovered from a marine environment. The aim of the conservation was to desalinate and stabilize for inclusion in the archaeological archive.

Condition assessment

GSP31 is a fragment of a red, low-fired ceramic. Visual examination of the cross-section indicated that the fragment had been fired in a reducing atmosphere followed by an oxidizing atmosphere, as shown by the colour variation in cross-section (grey central section and red outer edge). The fragment had been stored in tap water in a polythene bag prior to treatment. The surface was soft and easily scratched with a scalpel, particularly the cross-section.

GSP34 is a fragment of a high-fired white ceramic with grey inclusions and a red coloured glaze. Examination under optical microscopy indicated that the body was in a stable condition with glaze intact. The entire inner surface and cross sections were covered with strongly adhered marine incrustation ranging between 1 mm and 4 mm in depth. Exoskeletons within the encrustation
Figure 3.46 Ceramic and glass objects during treatment
top left GSP31; top right GSP58; bottom left GSP34;
bottom right detail of exoskeleton within marine encrustation adhered to GSP34 (photos Gresham Ship Project)
were visible under optical microscopy (Figure 3.46 bottom left). The glaze exhibited star-shaped fractures throughout, while red spots of iron corrosion occurred throughout the glaze.

GSP58 consisted of a base fragment of a free blown cylindrical straight-sided brown/blue glass bottle with pushed in dome-shaped indented base. Examination under optical microscopy indicated the glass to be solid and not liable to fracture. The outer surface exhibited scratches, chips and thin iridescence throughout. Break edges and the inner surface were weathered to a lesser extent than the outer surface and there were no residues visible within the bottle interior. Since it dates to the late 18th century or early 19th century (pers. comm., John Shepherd), it may have been thrown overboard from a passing ship or fishing boat, but there is the distinct possibility that it came from the surface support vessels of the 1846 salvage operation. The stoneware fragment (GSP34) and rope fragments (for example GSP211), might also be associated with this event.

Treatment
Desalination followed by controlled air-drying was considered to be appropriate treatment options for ceramic GSP31, GSP34 and glass object GSP58. These objects were desalinated in separate containers in the following stages: immersion in 100% tap water, immersion in 50% tap water and 50% de-ionized water, immersion 100% de-ionized water. The conductivity of each bath was monitored using an InoLab pH/Cond 750 meter. Bath water was changed once conductivity levels had stabilized. Objects were moved to the next stage once conductivity reached the same levels as the original bath solutions. Each object was air-dried in ambient atmospheric conditions and regularly monitored for salt crystallization. After 30 days objects showed no signs of salt crystallization or fracture indicating that desalination had been completed successfully. The first stage of
desalination in 100% tap water was the most time-consuming as each object took between one and two months to reach the same conductivity levels as tap water. The subsequent stages were completed in one month. The process might have been speeded up, if the bath water had been changed more regularly.

Analysis

A layer of weathered resin was identified on the inside surface of ceramic fragment GSP215 during investigative cleaning (Fig. 3.47). The fragment had previously been dried and identified as a piece of a Spanish olive jar by Wessex Archaeology.

Resin is known to be used as a sealing agent to prevent jar contents from seeping into the porous ceramic fabric (Smith, et al., 1998, 129). Pine resins (Pistacia spp.) have been recorded as being commonly utilised for this purpose and jars with resin probably carried liquid such as vinegar, wine or olive oil (Mills and White, 1989, 37; Beck and Borromeo, 1990, 51; Marken, 1994, 106).

The resin layer was sampled and analysed using FTIR and the resulting bond peaks were compared with several species of pine-resin from the Infrared and Raman Users Group online spectral library www.IRUG.org). Comparative peaks were observed in all pine resin samples of different sub-species in the 1457, 1384, 1246 and 1181 wavenumber (cm⁻¹) regions, indicating the sample consisted of pine resin (Fig. 3.48).

Ceramic Jar GSP201.2 embedded within Concretion GSP201

GSP201.2 consists of an incomplete ceramic vessel, embedded within a concretion (Plate 12, Fig. 3.49). The ceramic vessel is in two parts, one part buried within the concretion, the other being the detached base of the vessel. Both pieces have been partially covered with concretions. The ceramic appears to have been manufactured from coarse grained clay and salt-glazed. The concretion retains a concave ‘cast’ of the gun GSP201. Although the investigation and stabilization of the ceramic jar would benefit from the removal of the concretion, the aim of the conservation process was to produce a shipwreck object, as a ceramic vessel rising out of a concretion. Some of the concretion and calcium carbonate deposits around the ceramic were therefore removed to reveal the extent of the ceramic surface. This will provide information that can be used to describe its typology, date and location of manufacture.

Mechanical cleaning took place using air abrasive, drills and brushing prior to desalination taking place. This revealed a visually impressive object that will become a stable museum exhibit, alongside the associated copper alloy bowl and concretion GSP201.1.

Preparation of finds archive

On completion of desalination, stabilization and drying treatments, all conserved objects will be transferred for archival storage to Southend Museums (Museum of London Archaeological Archive, 2013). Standard packaging for metal finds has been the use of Plastazote cut-outs within Stewart boxes desiccated with silica gel (Fig. 3.50a). Where necessary, this packaging has been adapted to improve the interpretative potential of the conserved object. For example, with GSP200 (Fig. 51b) the resin casts were packaged in orientation to one another as they appeared within the concretion, leaving gaps where there is a loss in information. This was devised from two colours of Plastazote in black for the flat view and blue for the profile view links. The flat view areas were covered with a layer of soft Tyvek (non-
woven high-density polyethylene fibre) then a custom box was made from Correx (propylene/ethylene copolymer board).

Conserving the Palimpsest

Perhaps the least archaeologically significant objects to be conserved as part of the Gresham Ship Project are a fragment of textile GSP201.3 (Fig. 3.51) and a concretion containing a modern steel cable GSP26 (Fig. 3.18). However, these objects clearly reveal the dynamic nature of the maritime environment in which the ship wreck materials were preserved. This was not a stable depositional environment that encapsulated a Tudor world, but a dynamic interactive environment in contact with present throughout its time on the seabed. These links in the chain connect the past with the present and enable us to understand the conserved objects of the Gresham Ship as a construction of the archaeological process. The results of the conservation process, therefore, have meaning within the constraints of this process, but may be less meaningful outside of this context. This acknowledges the local, personal and unpredictable processes that are evident in the conservation of archaeological maritime material.

The textile fragment was found in association with one of the ship’s guns GSP201, preserved within the surrounding concretion material. This object is not from the 16th century ship, but is a 20th-century textile, which is likely to have become incorporated into the wreck via movement of waters and sediment in the channel or perhaps during the channel clearance operation. As such, this modern object has significance as an example of the interaction between the wreck and its surroundings during submersion.

The fragment of synthetic textile has a felted structure and had an extremely regular grid structure pressed onto it, suggesting that it was created by industrial manufacturing methods. The object was a folded fragment of a larger textile (Fig. 3.51). The fibres were impregnated with ferrous corrosion products. The textile was cleaned and desalinated (Jakes and Mitchell, 1992; Landi, 1998; Peacock, 1990), but not all of the deposits, dirt and concretion remains have been removed, as they provide a narrative for the object and are evidence of its association with the wreck and its excavation.

Experimental attempts to air-dry sample fibres resulted in fragile and brittle results. Therefore, the textile was freeze-dried, without prior impregnation at -20°C for three days. After drying the object was more stable, but was still very fragile and difficult to handle without causing damage. The object has been packaged in a ‘book’ made of nylon net on Correx frames lined on one side with a layer of Plastazote covered in non-dyed calico (cotton textile containing no plasticizers). This packaging allows for both sides of the object to be seen, as the book can be turned over and opened from either side, without directly handling the object.
The presence of recent material, such as the 20th-century fragment of textile GSP201.3 and a concretion containing a modern steel cable GSP26, convey the connections that exist between our time and the moments in time that lead back to the sinking of the ship and the lives of those on board. These objects provide direct tangible links that lead us from the current 21st century excavation and conservation of the finds assemblage to the past of the wreck site. The presence of 19th-century objects, such as the bottle fragment GSP58, provides a further link in the chain that connects us to the sinking of the ship (Fig. 3.52). The sinking is revealed in the chaotic melange of objects thrown together during the wrecking of the ship, preserved as concretions. The copper alloy bowl /concretion (GSP201.1), the ceramic jar/concretion GSP201.2 and the shoe /concretion GSP205 all bear witness to the associations between objects created by the sinking of the ship. Groups of objects used on board ship, such as the tableware, for example a fine silver spoon GSP20.1 and decorative pewter salt holders GSP86.1, 14 connect us with late 16th century life on board this merchant ship. The functional foot wear, well-worn and repaired, (GSP205, GSP206) connect us directly to the crew, while the large over the knee boot GSP80 was perhaps hurriedly kicked off as its owner struggled to leave the sinking ship. The laboriously loaded metal cargo of bar iron and ingots represent the preparations and purpose of the ship’s ill-fated final voyage and the guns the dangers of such trading ventures. The ship timbers themselves, with their tool marks and joinery, take us back to the building of the ship and then to the felling of oak trees in the east of England in about 1574 AD (Auer and Firth, 2007; Auer and Maarleveld, 2014).

The conservation treatment records contain detailed information about the conservation process and its motivations. These individual records provide a network of individual discoveries during the conservation of the assemblage. Some reveal the excitement of the discovery of a significant object and the challenges of revealing and stabilizing it as a conservation object. Other records reveal more the frustration of similar processes revealing no information that can add to our understanding of the past of the ship and its crew. Critically the documentation of the conservation treatment reveals the latest phases in the lives of the shipwreck artefacts, as archaeological artefacts subject to the processes of heritage conservation. The individual decisions that create the conserved objects are legible as a conservator’s signature on each conserved object. These objects are therefore a contemporary creation that have been formed through a network of individual, institutional disciplinary nudges that produce a unique result for each of these real time experiments. When considering these objects as objects of research and objects of communication, the fading contemporaneity of this conservation product should not be misunderstood as anything other than a representation of its time and place, in which the past has been renewed in our time. The attempt to represent these objects specifically as conserved shipwreck objects will hopefully prevent the temptation for others to present these objects as things from the past that are disconnected with all the moments in time that link our present to how we see our Tudor past.

**Conclusion**

The changes in society, reflected through an understanding of the technical, cultural, religious, economic and political aspects of the past, can be revealed through the study of wrecked vessels and their accompanying artefact assemblages (Muckelroy, 1998, 24). A ship is a self-sufficient entity, containing everything necessary for its purpose and for the survival, health and recreation of its (usually) male crew (Martin,
The people, practices, techniques, equipment and knowledge that were assembled to sail the ship are symptomatic of the prevailing culture at that time. This can be revealed by examining the objects that are recovered by the archaeological process in the resultant artefact assemblages (Murphy, 1983, 70; Redknap, 1997a, 1997b; Adams, 2001, 294; Gibbins and Adams, 2000).

The conservation of the Gresham Ship Finds Assemblage successfully stabilized the artefacts and also extracted information for further archaeological research. The vestigial nature of the initial Gresham Ship assemblage (not untypical of rescue archaeology) limited our ability to interpret the lives of those on board or add to our understanding of the Tudor world. To compensate, considerable effort was therefore dedicated to processing the concretions, in a way that may not be the case for more complete shipwreck assemblages.

The absence of objects seen just as voids within the altered form of a concretion, provides an exciting opportunity to use the specialist skills of conservation to retain elements of an archaeological object and present it as a representation of the object as it was at the time of the shipwreck. The approach to the conservation of Gresham Ship assemblage has been of particular importance in demonstrating the possibilities of the conservation process. Significant finds, such as powder chamber GSP202.1, pewter salt holders GSP86.1 and GSP14, spoons GSP86.7 and GSP20.1, copper alloy bowl GSP201.1, pike shaft GSP204, shoes and part of an over the kneeboot GSP80, have now been documented, processed, cleaned and conserved for archive deposition. This provides a long-term legacy for future research of the conserved finds. It should therefore be remembered that the conservation process requires arbitrary choices to be made about an object’s care, in order to distinguish what physical states are acceptable and what states require intervention. Archaeological objects in the conservation process are not neutral objective truths, but the subject of complex interactions and changing meaning. Conservation is therefore a vehicle to convey and create meaning and value in conserved objects that bear the personality of the conservator. Far from being a neutral process conducted outside of history, conservation is as much a part of the on-going biography of the object as other interventions which have created a trajectory for the object through time (Sully, 2013). In the search for truth and authenticity, conservators may strip away the obscuring layers of history in order to reveal or retain the ‘true nature’ of the object. Here there is a risk of cutting the threads that link objects with the present which may reduce or limit the stories that can be told about them (Denslagen, 2003, 99). Since every bit of damage and every accretion form part of the evidence of an object’s history, their removal can only be justified by making the telling of certain stories easier (Ashley-Smith, 2009, 18).

The editing tools used in this process can be skewed by the artifice of the apparent timelessness of archaeological objects, immutably located in a past state. The work of a practicing conservator can be seen as the latest action in a series of human interactions that affect the physical state of the object. The multiple interactions relate to the creation and use, ownership and exchange of objects and reflect the shifting meaning that objects have within these frames of understanding (Gell, 1998; Avrami, 2009, 183).

The option of conserving an object as a shipwreck artefact as close to its found state as practicable is an important conceptual step towards the aim of retaining as many possibilities for an object’s conservation and interpretation in the present and in the future. This Finds Study Programme highlighted the gap between a conceptual idea and the hard realities of dealing with maritime archaeological objects, while suggesting practical approaches to address that challenge.

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Figure 3.4 (above) Type 1 Concretion: GSP90 contained a well-preserved iron chain link (above) visible in the X-radiograph (centre) and revealed after conservation as part of well-preserved iron chain link GSP90.1 (bottom) (photos Gresham Ship Project)

Figure 3.5 (above) Type 2 Concretion: GSP25 contained the void of completely corroded nail (above), as seen in X-radiograph (centre); the completed Polyester resin cast is shown (below), revealing a nail or spike (photos Gresham Ship Project)

Figure 3.6 (above) Type 3 Concretion: GSP99, containing a hook with solid core (left) and corroded outer edge seen in X-radiograph (centre) and as a composite object partially cast in Polyester resin following conservation (right) (photos Gresham Ship Project)
Conservation Studies

Figure 3.7 (above) The GSP86 concretion (above) contained well-preserved tin-alloy objects (Type 1) and also voids of corroded wrought iron bar and nails (Type 3), shown in the lower image. NB: the black line in the centre of X-radiograph image represents division between two plates (photos Gresham Ship Project)

Figure 3.8 Type 4 Concretion: GSP202 containing an object of indistinguishable form and preservation. NB. Black line in the centre of X-radiograph image represents the division between two plates (photos Gresham Ship Project)

Figure 3.12 (above) Concretion GSP25: (top) initial fracturing; (upper centre) casting the void cavity with Polyester resin and iron weighting powder; (centre) removing the concretion form the resin cast; (lower centre and bottom) retrieving resin cast fragments from concretion (photos Gresham Ship Project)
Figure 3.13 Concretion GS 99: broken into segments (above); excavation of polyester cast (below). See also Figs 3.6 (lower image) and 3.9 (photos Gresham Ship Project)

Figure 3.14 Concretion GSP203 (above); X-rayograph of Concretion GSP203 (below) (photos Gresham Ship Project)
Conservation Studies

Figure 3.15 Concretion GSP203: reconstruction of metal bolt fragments (photo and drawing Gresham Ship Project)

Figure 3.16 (right) Concretion GSP202 before treatment (above), during treatment (centre) with hammer and with powder chamber (GSP202.1) revealed after concretion removal (bottom). For the hammer and shaft found in the same concretion (GSP202.2), see Fig. 3.36 (photos Gresham Ship Project)

Figure 3.17 (above) Powder chamber GSP202.1 during desalination (photos Gresham Ship Project)
Figure 3.19 Salt holders before conservation: above and centre GSP86.1; below GSP14. See also Figs 3.7 lower image, 3.10 and 3.21 (photos Gresham Ship Project)

Figure 3.21 Salt holders after conservation: above and centre: GSP86.1; below: GSP14. See also Figs 3.10 and 3.19 (lower image) (photos Gresham Ship Project)
Figure 3.25 Spoon GSP20.1 (top): as removed from Concretion GSP20 (upper centre; spoon with ceramic rim fragment from concretion GSP20; (lower centre) spoon and ceramic rim fragment after cleaning; (bottom) spoon and ceramic rim fragment after cleaning (photos Gresham Ship Project)

Figure 3.28 Copper alloy and concretion GSP20.1 showing riveted areas on base (above) and rim (below) revealed during mechanical cleaning (photos Gresham Ship Project)
Figure 3.29 Copper-alloy bowl and concretion GSP201.1 after conservation: chemical cleaning with 30% w/v citric acid in de-ionized water applied by a Laponite RD gel poultice and EDTA disodium salt (photos Gresham Ship Project)

Figure 3.33 Pike shaft GSP204 (photo Gresham Ship Project)
Figure 3.35 Wood and ferrous metal hammer GSP202.2: top left as part of concretion GSP202; centre left and top right as a detached object before treatment; bottom left and right during treatment (photos Gresham Ship Project)
Figure 3.37 Leather footwear as found in 2004: top left over the knee boot GSP80; centre left shoe concretion GSP88; bottom left shoe concretion GSP55; top right shoe sole GSP35; centre right shoe sole GSP205; bottom right shoe sole GSP206. (photos Gresham Ship Project)
Figure 3.40 left and above: leather boot GSP80 after treatment (photo Gresham Ship Project)

Figure 3.41 Leather shoe GSP88 above before treatment; below during treatment (photos Gresham Ship Project)
Figure 3.42 Leather shoe GSP35: above before conservation; below during conservation (photos Gresham Ship Project)

Figure 3.43 Leather shoe GSP55 after conservation (photo Gresham Ship Project)

Figure 3.44 Leather shoe GSP205 showing wood and iron pike head attached (photo Gresham Ship Project)
Conservation Studies

Figure 3.45 Leather shoe GSP206: left before treatment (116 x 91 x 25 mm); right after treatment (113 x 87 x 26 mm) (photos Gresham Ship Project)

Figure 3.49 Ceramic jar and concretion GSP201.2: left above and below before cleaning; right during desalination (photos Gresham Ship Project)