Wheel Wreck

INVESTIGATION 2018

Project Report

Kevin Camidge

with contributions by

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Weezle Undersuites

Otter Watersports

Ambient Pressure Diving

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Contents

Cover Photograph: An overhead view of the cargo mound ©CISMAS 2017.

Project Name

Wheel Wreck Investigation 2018

Summary Description

The site was discovered by local divers in 2005. Assessment in 2006 indicated that this discrete cargo mound consists of components of mining equipment, the majority of which appears to have been pumping equipment. It was concluded that the cargo represents a consignment from a Cornish foundry, thought to date from 1850 onwards. No ship structure was found. The identity of this wreck is currently not known. The site was designated under the Protection of Wrecks Act on 5th April 2007.

The Wheel Wreck was dated to the latter half of the nineteenth century (post 1850), mainly on the identification of a quantity of 'boiler tubes' on the site. These socketed pipes have now been subjected to analysis and found to be made of cast iron, and are therefore unlikely to be boiler tubes. They appear, in fact, to be interlocking cast iron pipes – probably used for transport of water at low pressure. Therefore the post-1850 date previously assigned to the site is no longer valid.

In April 2018, CISMAS carried out a six-day survey of the site. The cargo mound was measured, surveyed and enumerated. This has allowed the production of a cargo list, site plan and identification of most of the cargo items lying on the seabed. A limited search around the cargo mound produced a small quantity of pottery and glass which was used to indicate an earlier date for this site.

It has not been possible to identify the vessel which carried this cargo. However, we have estimated the hold size, beam and tonnage of the vessel from the disposition and quantity of the cargo. This, along with the revised date for the site, should help to narrow down the documentary search for the name of the wreck.

Finally, the data gathered from the fieldwork phase of the project will be used to inform a conservation and management plan for the site which will be executed directly.

Background

Location

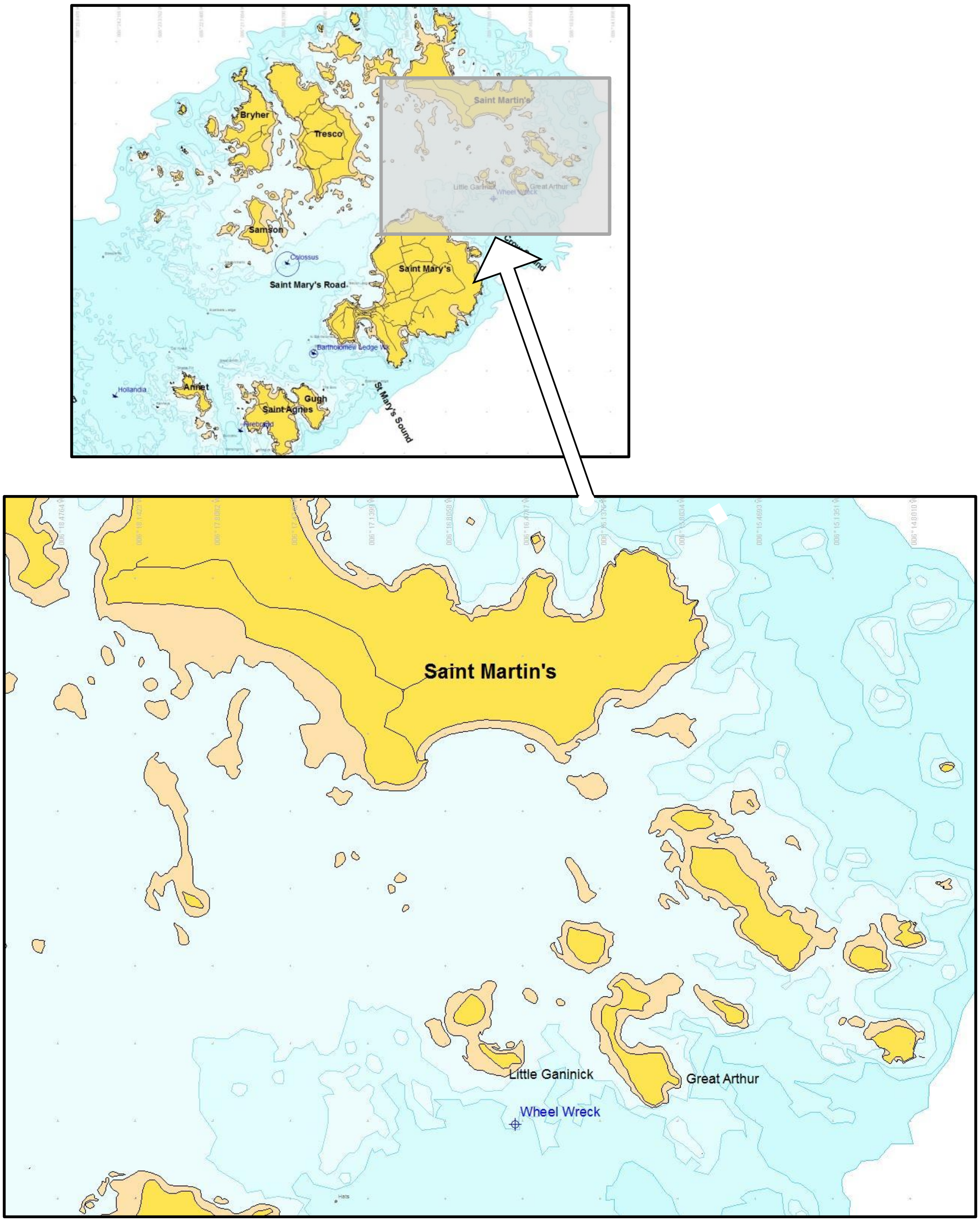


Fig 1
Location of the Wheel Wreck to the south of Little Ganinick in the Isles of Scilly

The Site

The site lies to the south of the Island of St Martins in the Isles of Scilly, and was discovered by local divers in 2005. It consists of a rectangular pile of iron pipes and wheels 12 metres long by 7 wide, lying on the seabed in an orderly pile which appears to be a cargo mound. Almost nothing of the vessel carrying this cargo survives. The cargo mound sits on a boulder-strewn rocky seabed in about 16m of seawater.

Previous Work

An undesignated site assessment was undertaken in 2006 by Wessex Archaeology. It was concluded that the cargo represents a consignment of mining equipment from a Cornish foundry, thought to date from 1850 onwards. The assessment report included a basic site plan and photo-mosaic of the cargo mound, as well as drawings of some of the individual components of the machinery (Wessex Archaeology, 2006).

The site was designated under the Protection of Wrecks Act on 5th April 2007. The protected area extends 75 metres around 49° 56.445' N 006° 16.381' W.

CISMAS visited this site in August 2017 as part of the Designated Wrecks Interpretation project (Camidge et al., 2017). The purpose of the visit was to make a photographic 'Structure from Motion' (SfM) 3D model of the site, and produce videos for use in the virtual site tour commissioned by Historic England. The virtual site tour has now been completed and can be viewed at http://vdt.cismas.org.uk/trails/the-wheel-wreck/. The dating of this site to the latter half of the nineteenth century (post 1850), was based mainly on the identification of a quantity of 'boiler tubes' on the site. These tubes appear to be made of cast iron, and are therefore unlikely to be boiler tubes – which in the nineteenth-century were usually made of wrought iron. This discovery formed the genesis of the present project – the key aspiration of which is to determine the date and thus move closer to an identification of the wreck itself.

Project Objectives

This project was designed to investigate a number of problems concerning this site - with the aspiration of establishing the date and identity of the wreck, and determining the place of origin of the cargo. This report will be used to inform a Conservation Statement and Management Plan for this site. Key objectives are to:

- Identify the material and function of the smaller tubes (previously identified as boiler tubes) which exist in large quantities at the south end of the site
- Establish a date range and possible function for the material in the cargo mound
- Produce a list of the numbers and dimensions of each of the different items in the cargo mound. This should enable a better understanding of what function the cargo was intended to serve
- Search for casting marks on the iron of the cargo, with a view to establishing the foundry of origin
- Investigate the underside of the cargo mound to determine what lies under the visible items (using a miniature remote video camera)
- Establish whether there are any vessel remains (in particular iron fastenings) under or around the cargo mound
- Use the results of the investigation to inform the Conservation and Management Plan for this site. This will include an assessment of fragility, and recommendations for physical site access taking this into account
- Enhance the virtual site tour for the Wheel Wreck by including the knowledge gained in the investigation of the cargo mound, and also add a brief timeline of the technical development of mine machinery to the VDT - thus advancing the non-diving public’s understanding of the site
- Add a technical page to the virtual site tour to include a list of the cargo mound contents, as well as scale drawings and photographs of the different cargo components (useful for dissemination to ‘experts’). This will advance our specialist knowledge of the period

Methods

The fieldwork was undertaken by six divers between 28th April and 3rd May 2018. The diving was accomplished from the dive charter boat *Moonshadow*, operating from the island of St Martins in the Isles of Scilly. Six days of diving were planned, but only five days were achieved due to adverse weather conditions, which also caused poor underwater visibility throughout the project. April is very early in the diving season and carries an increased risk of adverse weather – sadly this charter 'slot' was all that was available by the time this project was approved.

Each diver undertook two dives per day, with a surface-interval of two hours between dives. Each dive was of approximately one hour's duration. An overall total of 55 hours of diving took place.

Site Plan

The site plan was created in the first instance from an orthogonal view generated from the Structure from Motion 3D image of the site. This was augmented by notes, sketches, photographs and measurements made by divers. Identification of the individual cargo items was mostly made after inspection by the divers. Where objects were obscured by other cargo items, inspection using the underwater remote video was invaluable.

Peripheral Searches

The seabed around the cargo mound was searched methodically around the edge of the cargo for a distance of 4m. Four datum lines 30m long were also extended beyond the cargo mound to determine how far from the cargo mound artefacts were scattered (see plan of searches fig 40). The end of each datum line was fixed relative to the cargo mound and its alignment established by use of an underwater magnetic compass – the bearing was taken at the end of the datum farthest from the cargo mound to minimise the magnetic influence of the cargo itself.

The seabed either side of each datum was searched visually by a pair of divers for a distance of 2m either side of the datum line (thus each datum resulted in 120 m^2 search area). The position of any objects located was fixed by offsets from the datum line.

Remote video

To inspect obscured cargo items an underwater video camera mounted on a long thin pole was employed. After various trials, it was found that a long 'selfie' stick served this purpose well. Illumination was achieved by two 1000 lumen LED wide-angle underwater torches, also attached to thin poles. In practice the video camera was slowly inserted into a gap in the cargo mound, then slowly panned around before withdrawing the camera. The torches were usually placed into adjacent voids to illuminate the field of view. Each video location was marked on an underwater site plan. A total of 23 videos were made of the inside of the cargo mound. The videos can be difficult to interpret as the objects within the mound are often very close to the camera due to the very limited space within the cargo mound.

The video thus collected allowed us to identify two additional windbores as well as showing important detail on other partly obscured objects. The main problem with the setup was the lack of any underwater viewing system so that the camera could be guided by the operator. Several systems to achieve this were considered – but they were all beyond the available budget.

Concretion Removal

The iron of the cargo mound is coated with a concreted layer of corrosion products, and this concretion makes it difficult in some places to determine the exact shape of the underlying object. Previously, three of the wheels on site had been reported as having gear-teeth on their outer edges (SW1, SW2 and LW1). In each case a small (10cm square) section of concretion was removed mechanically. This allowed the size and pitch of the gear wheels to be recorded (where they existed – in fact SW1 did not appear to have any gear teeth on its outer edge).

To mitigate any corrosion issues that could potentially result, the small de-concreted areas were treated with aquatic epoxy putty – a technique already employed successfully on designated wreck sites (Dunkley & Steyne, 2013, pp.182-83). Attempts to mix the two-part putty underwater were not successful. However, if it was mixed on the surface immediately before the dive and transported in a polythene bag all worked well. Using plastic gloves, the diver then applied the pre-mixed epoxy putty using fingers only. The putty appeared to adhere well, and was still in place when inspected two months later.

Casting Marks

Manufacturers' marks were sometimes cast into the surface of steam engine and pitwork parts, and these have been observed at historic mine sites in Cornwall. A careful visual search of the objects in the cargo mound was made with this in mind. Unfortunately, the concretion covering the items made this very difficult and no such marks were located.

Documentary Sources & Concordances

A search of the documentary sources was made in order to establish whether any concordances exist between the material of the cargo mound and documented output of eighteenth and nineteenth century foundries. Unfortunately, no new illustrations were located. However, a brief appraisal of some of the sources was made and material of possible interest was identified. This is reported separately in Appendix V 'Concordances' by Tehmina Goskar

Results

The Cargo Mound

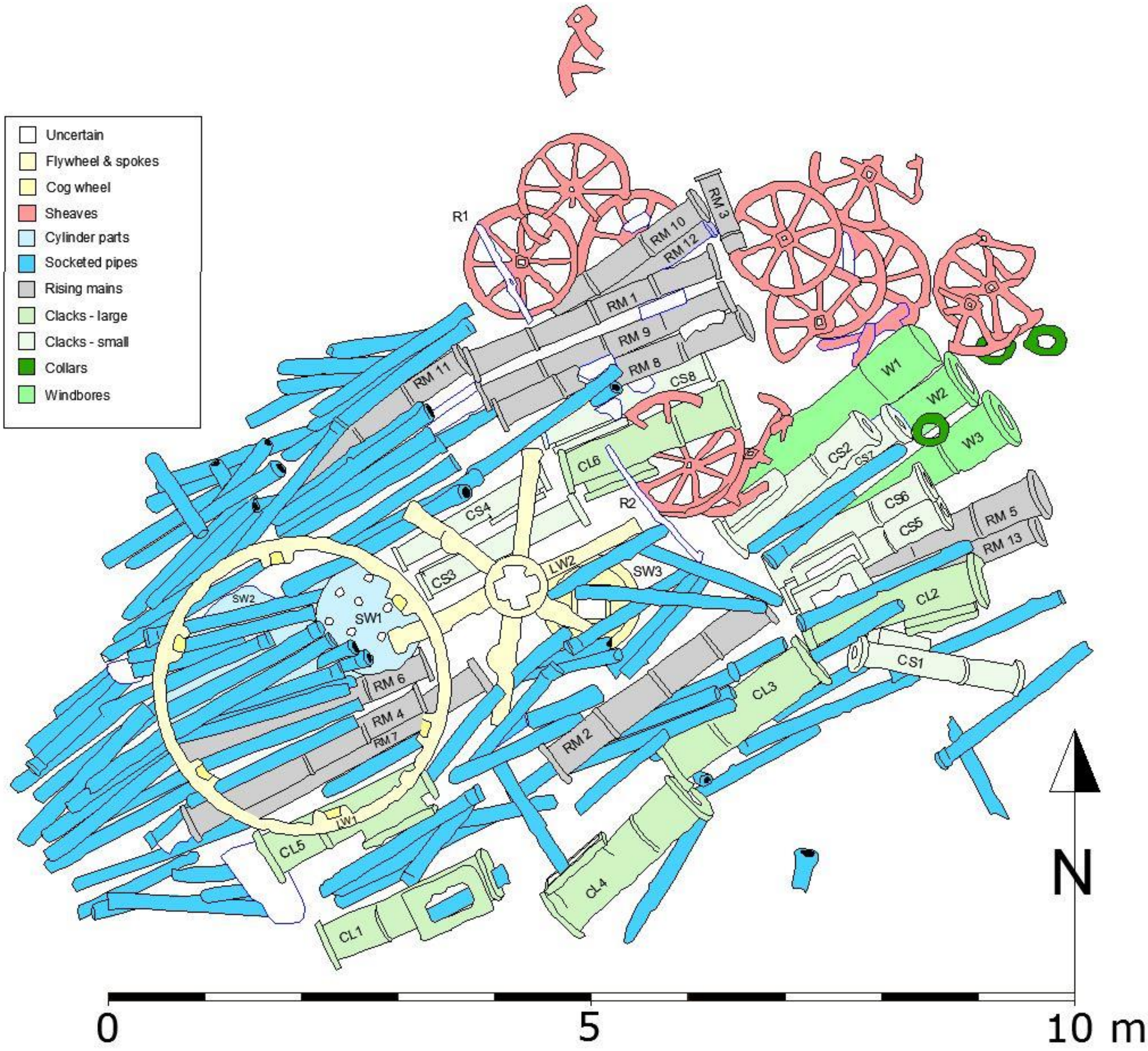


Fig 2
Plan of the cargo mound with the identified cargo elements differentially colour coded

The cargo mound is some 12m long and 7m wide, and while the depth of the mound varies it is never more than 1m - and considerably less in places. The cargo forms an essentially rectangular mound and the individual elements appear to be stacked in an orderly fashion with the various pipes aligned along the long axis of the rectangle. The overall impression is that the cargo was confined within the hold of the vessel transporting it and that it has not shifted significantly since it was loaded. Many of the individual elements are stacked next to similar items, for example the windbores, sheaves and socketed pipes (see fig 2 above).

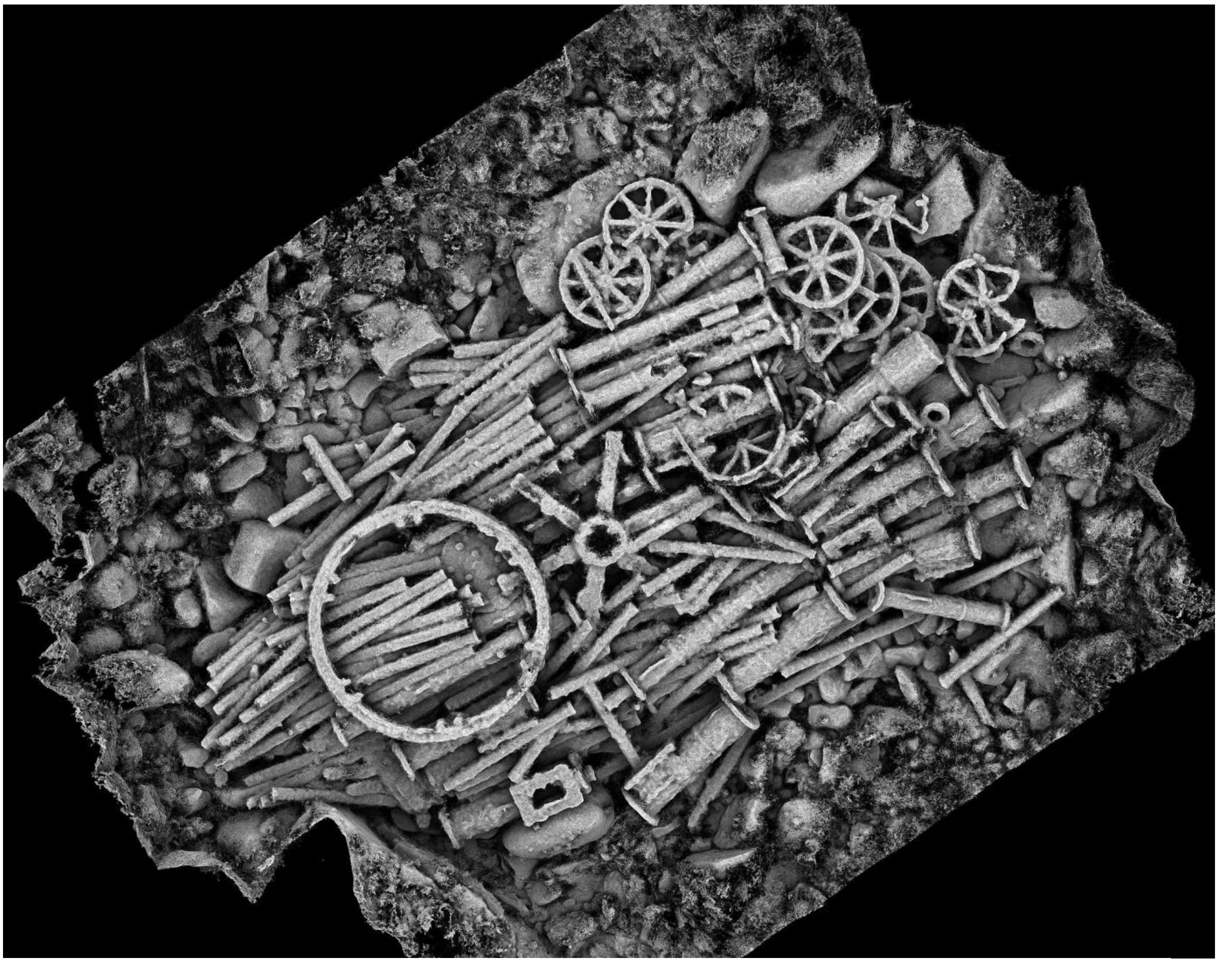


Fig 3
View from above of the cargo mound created from the SfM 3D model of the site – north is up. The image gives a good impression of the rocky seabed around the cargo mound. This image can be viewed in 3D at [*www.vdt.cismas.org.uk*](www.vdt.cismas.org.uk)

The cargo seems to have been loaded with the most delicate objects on the top (the flywheel rim and the sheaves). In many cases larger pipes and clack pieces have had socketed pipes placed within them, presumably to save space. All the cargo items appear to be made of cast iron and as such would be brittle and subject to breakage. The majority of the cargo is still intact; the most numerous breakages have occurred in the sheave wheels - only three wholly intact, and the socketed pipes - where several have been broken.

The Socketed Pipes

These pipes are by far the most numerous cargo items present, with about 100 recorded on site – there are probably more in the body of the mound obscured by other items of cargo. The socketed pipes are largely confined to the western end of the cargo mound and are stacked in parallel rows at least three layers deep (fig 4).

Fig 4
The socketed pipes at the western end of the site; note how they are stacked at least three layers deep

These pipes are 1.95m long, with an external diameter of 0.12m and an internal diameter of 0.10m. They have a socket at one end (0.11 long, external diameter 0.16, internal 0.13) which is large enough to accept the un-socketed end of the next pipe with a small gap (see fig 5 below).

They were identified as replacement boiler tubes in the 2006 site assessment (Wessex Archaeology, 2006). This identification resulted in a post-1850 date being assigned to the site – multi-tubed boilers are not in general use until after this date. However, we now know that these socketed pipes are made from cast 'white' iron, and as such are not likely to be boiler tubes (see Appendix II – Analysis of Socketed Pipes). In fact very similar pipes have been observed in Penzance functioning as storm-water drainage pipes. The small 'fins' reported in the site assessment are in fact corrosion fins, formed by corrosion products exuding from cracks in the cast iron (the same effect results in 'finned cannon' often seen on cast iron guns on historic wreck sites). These pipes are the only item of cargo identified to date which have no concordance with Cornish mine pumping machinery.

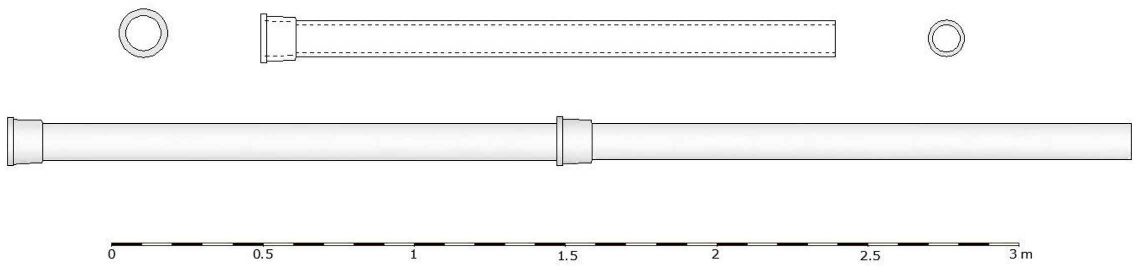


Fig 5
A reconstruction drawing of the socketed pipes showing how the pipes would have been fitted together

These pipes were probably intended to convey water at low pressure – such as those employed in gravity-driven drainage systems. They could have been used to convey water around a mine or steam engine installation, but the large number of socketed pipes present (over 180m total length) perhaps suggests another function. This type of iron socketed pipe (aka spigoted pipe) was usually sealed using a mixture of iron filings and sal ammoniac (or sometimes urine) which caused the two pipes to rust together. This apparently forms a very tight and durable joint, and has been used successfully in repairs at historic engine sites (Levant and Crofton Beam Engines – personal correspondence).

Unlike the flanged pipes (rising mains) in the cargo mound, these pipes would not have been able to withstand any substantial pressure and furthermore this type of pipe is unknown in mine pumping. They perhaps suggest a destination for this cargo other than a mine – possibly a waterworks or canal supply system.

Fig 6

Section of cast-iron socketed pipe forming part of a storm water drain on Abbey Slip in Penzance

Fig 7

Small section of the socketed pipe (Fe Sample 4) showing a clear casting seam running longitudinally along the pipe

Rising Mains

Fig 8
A group of rising mains on the north side of the cargo mound (the rising mains are indicated by the yellow arrows)

Rising mains are iron flanged pipes used in pumping systems, especially in mines. The term 'rising main' is now commonly used but in the nineteenth century these were simply called 'pumps' or sometimes 'pump pipes'. The types used in Cornish pumping systems are usually nine feet long (Farey, 1827, p.221) and (Barton, 1966, p.92) with flanges at each end to allow pipes to be bolted together (the bolt holes were square until the end of the nineteenth century, after which they are sometimes round). Rising mains were manufactured in a number of diameters varying between six and 20 inches in the eighteenth and nineteenth centuries (Barton, 1966, p.92). They are usually made from cast iron and have a number of reinforcing rings cast around the outside (usually three, evenly spaced).

Thirteen rising mains have been identified on site, and there are probably more concealed within the cargo mound. At least two different diameters of pipe have been observed. The lengths vary between 2.74m (8.98 ft) and 2.77m (9.08 ft). The pipes are all covered with an irregular layer of corrosion products – consequently all measurements should be considered approximate. It is traditional to categorise rising mains by their internal diameter in inches. Although it was not possible to take accurate internal measurements from the pipes due to the concretion, RM1 and RM13 are probably eight-inch rising mains, while RM2 and RM5 are probably 10 inch rising mains (see fig 2). The flanges of the eight-inch rising mains were 0.41m (16 inches) in diameter, while those of the 10 inch rising mains were 0.51m (20 inches) in diameter. The external flange diameter is significant as it indicates which elements could be bolted together – there are other flanged items in the cargo including the clack pieces and the windbores.

Rising mains also usually have a number of fillets reinforcing the junction between the outer surface of the pipe and the flanges (see fig 11) but none of the rising mains on this site have these fillets. It has not been possible to establish the significance of this absence but it could possibly be a feature related to early pipes or those from a particular foundry. Further work in this area may yield useful results.

The rising mains all have three, evenly spaced reinforcing rings along their length – these are very similar in appearance to the reinforcing rings found on the barrels of historic cast iron cannons. The actual form of these reinforcing rings is mostly obscured by corrosion – but in one case (RM2) it appears to be in the form of a flat strap with a half-round central band – fig 10.

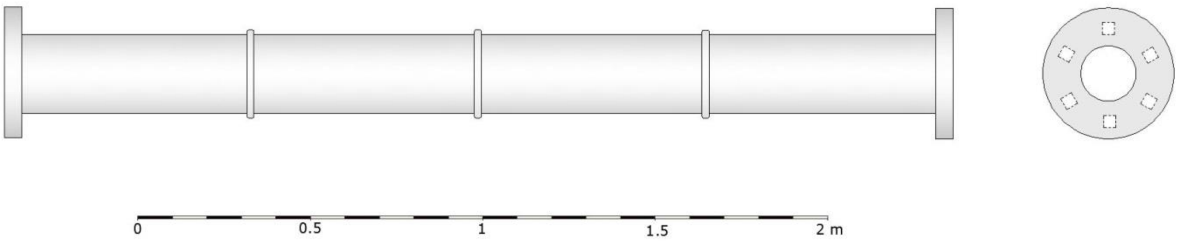


Fig 9

A reconstruction drawing of the 8 inch rising mains – the 10 inch rising mains are structurally similar and of the same length but have a larger diameter. Note that the bolt holes in the flanges were not clearly visible on site due to the concretion. The reinforcing rings are the three bands around the middle of the pipe

Fig 10

A detail of one of the rising mains on site (RM2) showing the reinforcing ring – this is one of only two rising mains in the cargo mound which are broken. The pipe is 0.25m external diameter

Rising mains were often reused for purposes other than mining during the late nineteenth century. A great many examples have been found locally being used as mooring posts, architectural pillars and as structural supports for piers. There were a number of mining depressions in Cornwall in the nineteenth century caused by falling metal prices, and one consequence of this was a burgeoning trade in second-hand mining machinery. This probably accounts for the prevalence of reused pitwork in the Cornish landscape.

Fig 11

A selection of reused rising mains in Newlyn and Penzance. Note the reinforcing fillets between the flange and the pipe body visible in the two upper examples

Top Left: A rising main reused as a mooring post at the Penzance dry-dock

Top right: Rising main reused as a mooring post on South Quay, Penzance

Bottom: A rising main used as a structural support on a shop front in Newlyn

Clack Pieces

Clack pieces (also known as clack valves) are one-way flow valves incorporated into the pump system to prevent the water from flowing back down the pump pipes (rising main). There was a hinged flap inside the clack valve, which closed onto an iron seat. This flap is usually faced with leather to form a watertight seal. They are said to have been called clack pieces due to the noise they made as the flap closes. The rectangular opening visible in the photograph (fig 12) is for maintainance of the clack valve – in use it would be covered with a removable iron door which is missing on this example.

Fig 12
One of the larger clack pieces (CL1) situated at the south-west corner of the cargo mound. It is 1.87m (6.1 ft) long

Clack pieces can also be used as 'bucket doors' (in which case the actual clack valve is omitted) – these are inspection covers to allow maintenance of a bucket pump (also known as a lift pump) (Farey, 1827, p.215). Two different sizes of clack pieces have been identified within the cargo mound. There are six of the larger clack pieces and eight of the smaller type. The two different types are of similar length (1.86m which is essentially 6 feet) but the diameter of the pipes and flanges is different. The larger (CL1-CL6) have flanges 0.51 to 0.55m in diameter with the outer pipe having a diameter of about 0.43m. The smaller have flanges 0.41 to 0.45m in diameter with an outer pipe diameter of about 0.28m). Both types have a single reinforcing band between the clack door and the far flange (see fig 13).

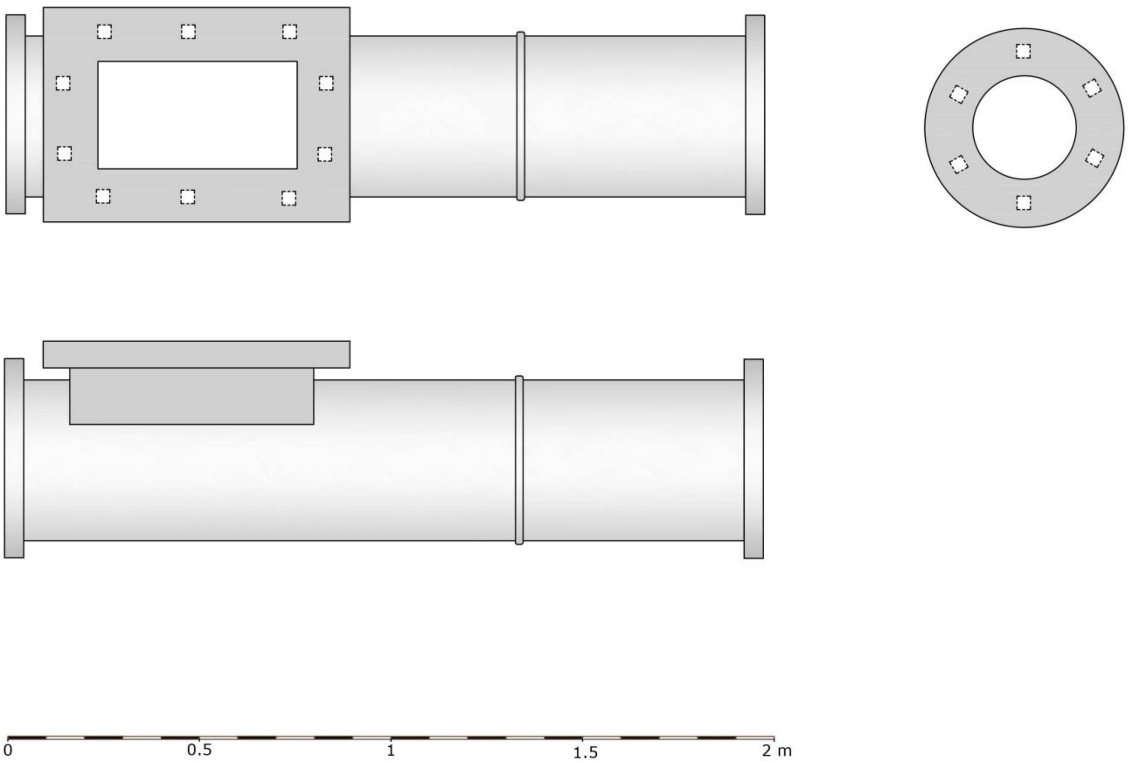


Fig 13
A reconstruction drawing of one of the clack pieces. Note that the bolt holes in the flanges were not clearly visible on site due to the iron concretion. Note also the absence of reinforcing fillets between the flange and pipe body.

In several instances (CL1, CL3 and CL5) the larger clack pieces have smaller pipes stowed within them, presumably an attempt to make the cargo more compact. Despite a fairly diligent search, no clack doors were identified anywhere in the cargo mound.

Fig 14
One of the clack-pieces (CL1) with a socketed pipe stored inside

The clack piece flange is 0.55m in diameter

The Windbores (W1, W2 & W3)

Fig 15
The large pipe in the centre of the picture is a wind bore. The ridges mid-way along the barrel of the wind bore are corrosion fins, formed as corrosion products are exuded from cracks in the cast iron. It is 0.5m in diameter and 2.8m long

The windbore is the bottom section of the pumping gear. It is an iron cylinder with perforations in the end to prevent stones and debris from being sucked into the pump. There are three windbores in the cargo mound (see figs 2 & 15) all stacked next to each other at the eastern end of the cargo mound. The holes in the windbores are largely obscured by the thick layer of iron concretion covering the object. The parallel ridges or fins visible in the centre of the windbore are probably corrosion fins formed as a result of longitudinal cracking of the cast iron, and are thus a post-wrecking feature.

Initially only one windbore was apparent, but further investigation using a remote video camera mounted on a pole with underwater video lights showed that there were in fact three. They are 2.86m (9.3 ft) long and 0.51m (20 inches) in diameter at the closed end. Each windbore has two reinforcing bands cast into their outer surface and a flange of 0.63m (25 inches) in diameter (see figs 15 and 16). It is notable that in common with the other items of pitwork on this site there are no reinforcing fillets on the flanges as is common in windbores seen elsewhere (for example fig 17).

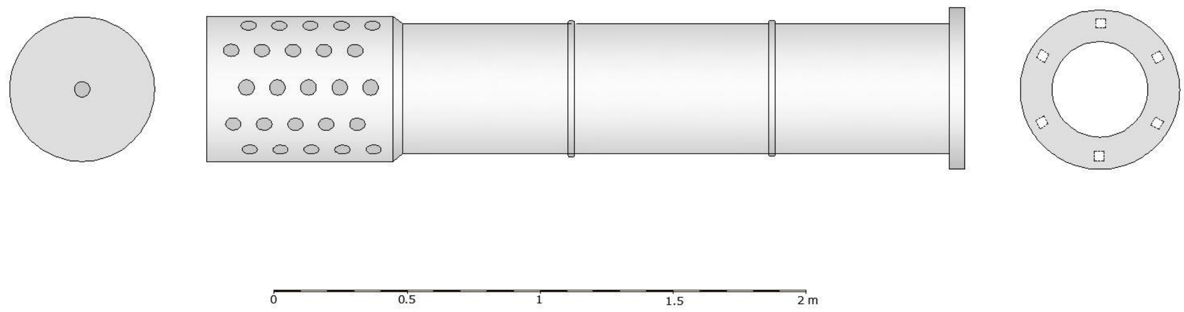


Fig 16
A reconstruction drawing of windbore (W1). Note the absence of reinforcing fillets around the inner face of the flange. The holes in the pipe and flange are conjectural – on site they are covered with a thick layer of corrosion products

Pumping gear in mines was usually arranged in several 'lifts' or sections (see Appendix IV) – each lift being of '20 or 30 fathoms' (35-55m) (Pole, 1844). Thus for many pumping applications multiple windbores would be required.

Fig 17
A wind bore on display at East Pool mine, Cornwall. Note the reinforcing fillets between the flange and the body of the pipe

1.85m – (6ft) long

Iron Collars

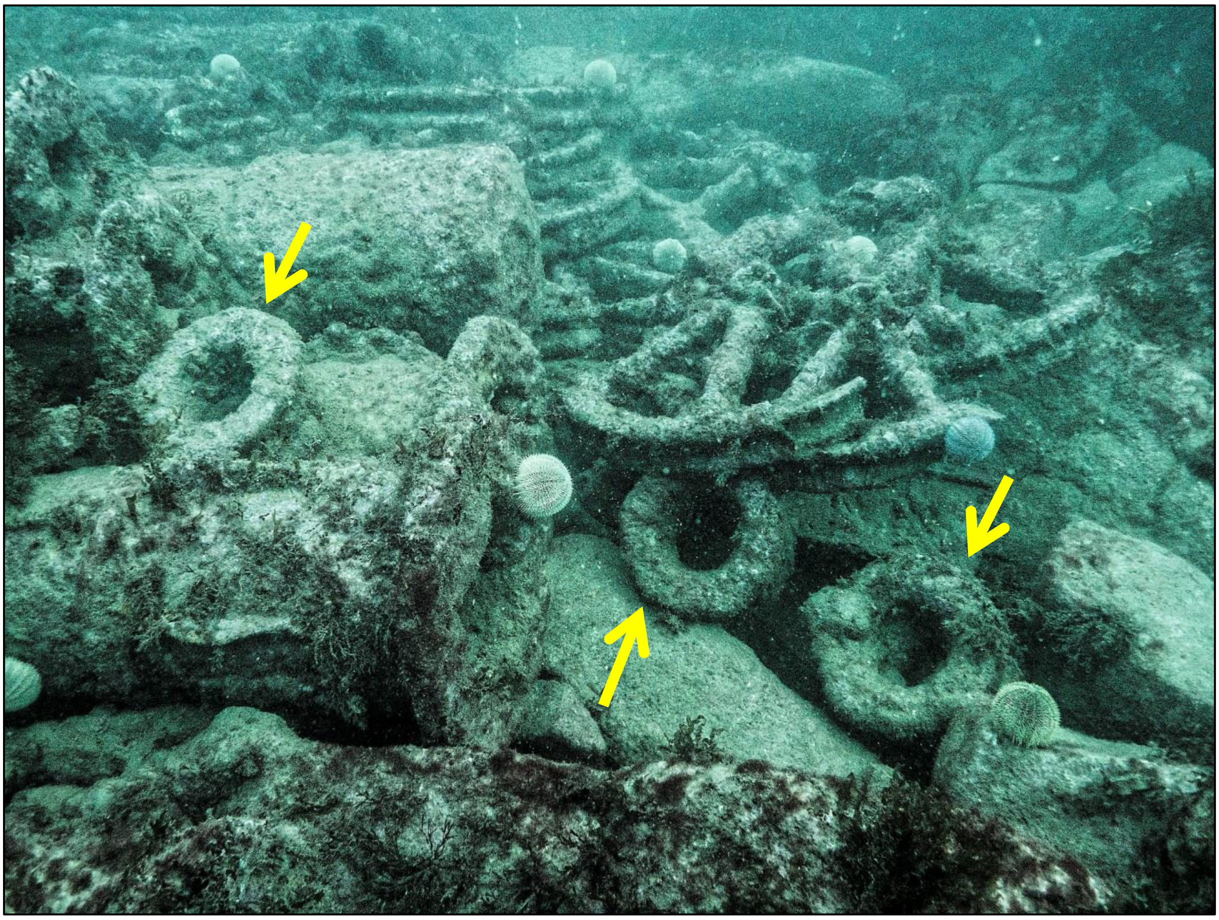


Fig 18

Three iron 'collars' or very short lengths of iron pipe. They are indicated in the photograph by arrows. The 'collars' are 0.4m in diameter. The collar on the left in this image is sat on one of the wind bores (W2)

It was not possible to determine the function of these three items. They are short lengths of cast iron pipe with a wider ring at one end (possibly a flange). They are heavily concreted which precludes any determination of their exact form. They are 0.38m in diameter at the widest point and about 0.275m long. Their close proximity to the three windbores and numerical equivalence perhaps suggests an association with the windbores?

Fig 19

Detail of one of the iron 'collars'

It is 0.4m in diameter

Large Wheel (LW1)

This large cast iron wheel rim (LW1) lies on the top of the flanged pipes near the western end of the cargo mound (figs 2 and 3). The wheel rim is 3.07m (10ft) in diameter and is 0.19m deep and 0.15m wide. The spokes and hub of the wheel (LW2) have been manufactured as a separate part and lie just to the west of the wheel rim. The wheel rim has teeth cast into its outer surface; a small area of the outer face of the wheel rim was de-concreted to expose two of the cog-teeth to establish their nature and size. The teeth were found to be 0.03m wide and 0.15m long, with a space of 0.05m between tooth faces. The depth of the teeth could not be established as the concretion was particularly tenacious between the teeth. Plotting this size and pitch around the outer edge of the wheel rim suggests a total of 126 teeth (see fig 21).

Fig 20

The wheel rim (LW1) and the separate hub and spoke casting (LW2) next to it on the cargo mound. The wheel rim is 3.07m in diameter. Note the sockets on the inside of the wheel rim where the spokes would fit

The Wheel Hub

The spoke casting has six essentially square sectioned spokes radiating from a central hub which has a cruciform hole at its centre. The spokes were probably intended to locate within the six rectangular sockets cast into the inside face of the wheel rim. The method by which these were secured into position could not be determined. The reason for manufacturing this wheel in two parts was probably connected with the logistics of transport, as it is estimated that the wheel rim weighed about 1.5 tonnes and the spokes a further 1.25 tonnes, a combined weight of almost 3 tonne (see Table of Cargo Items on page 43).

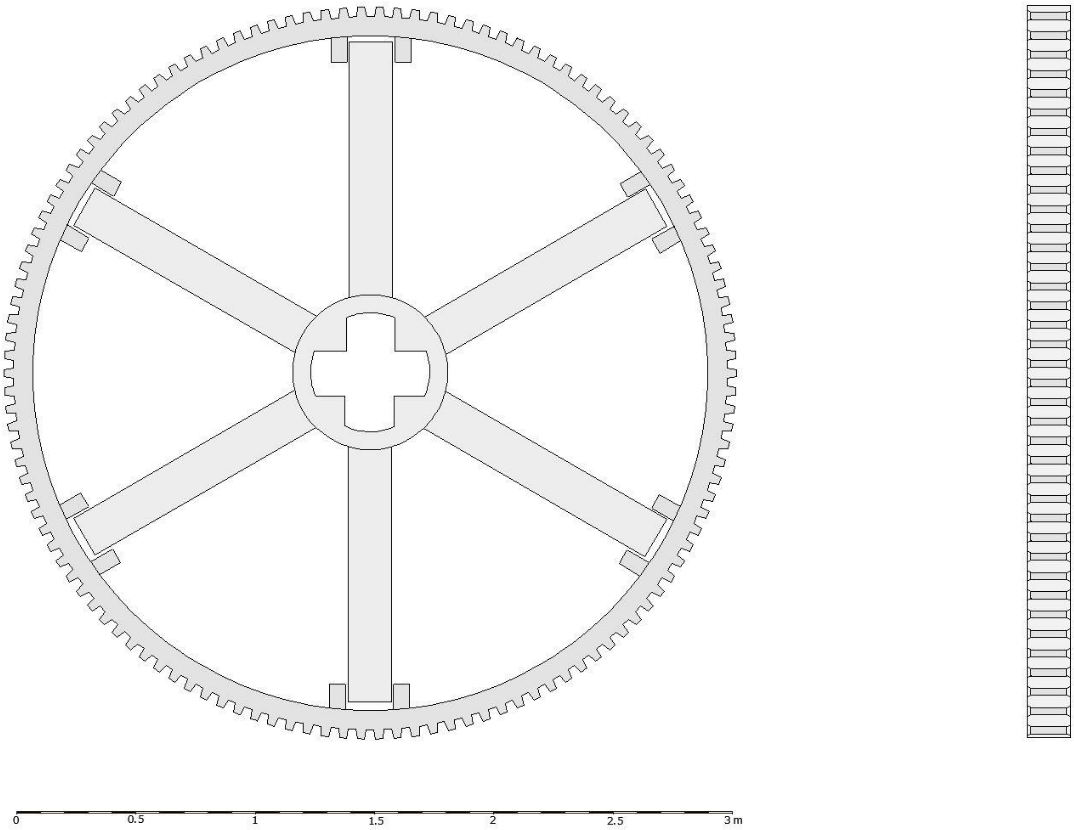
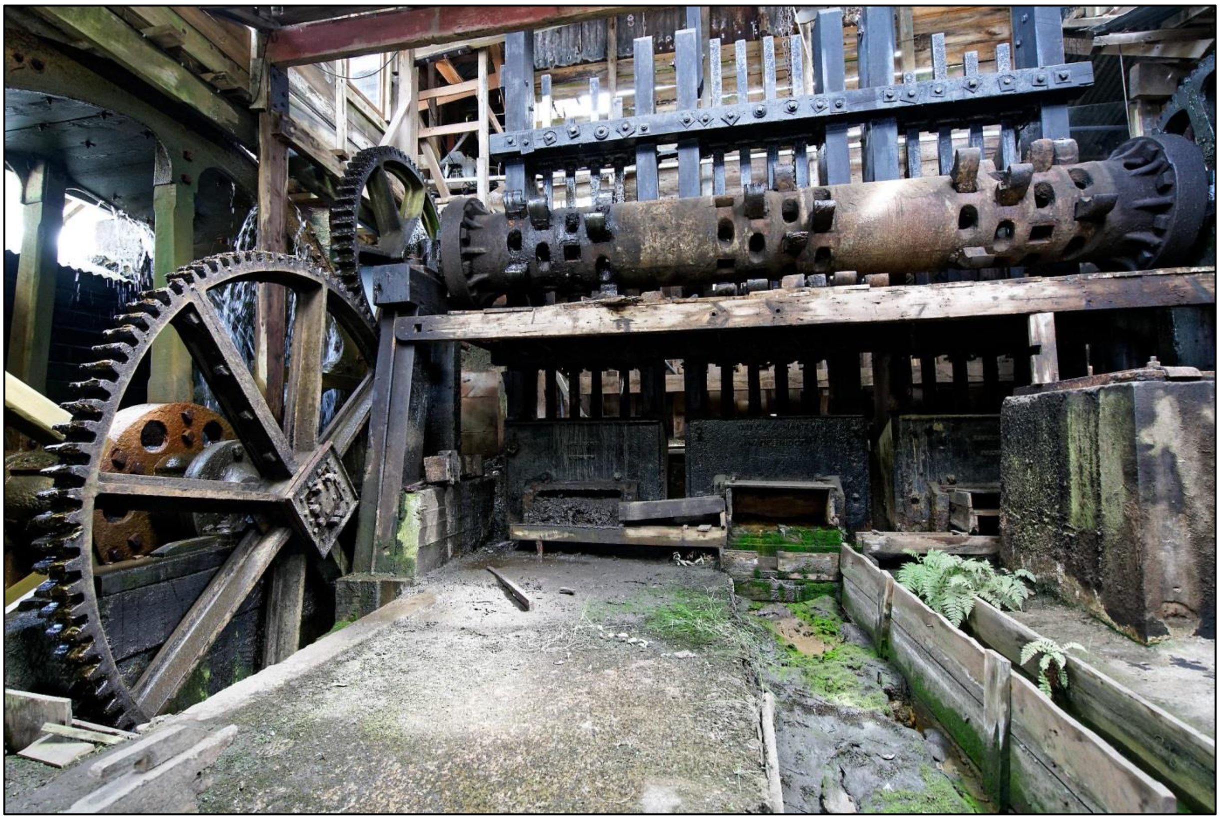


Fig 21
A reconstruction drawing of the wheel rim and spoke assembly fitted together. The actual depth of the cog-teeth has been estimated

Fig 22

Large toothed wheels on display at East Pool Mine (above) and Tolgus Tin Streaming Mill (below)
These wheels have been cast in two halves and bolted together. They have eight spokes rather than the six found on the Wheel Wreck spokes. However, they are the same diameter as (LW1). These wheels were probably made in the 19th century.



Smaller Wheel (SW3)

Fig 23
The small toothed wheel (SW3) just visible (arrowed) under the spokes of the larger toothed wheel and other cargo items

This small wheel lies under the spokes of the large toothed wheel and is only just visible (fig 23). It is 1.02m (40 inches) in diameter and 0.2m thick at its widest point (see fig 24). A small section of the outer rim was de-concreted and revealed teeth cast into the wheel, of similar size and pitch to those found on the large toothed wheel (LW1). The teeth were 0.03 wide and 0.145m long with a gap of 0.05m between teeth. Plotting this size and pitch around the outer edge of the wheel rim suggests a total of 42 teeth.

These two toothed wheels are the only two gear wheels observed on the site. Given the similarity of the size and pitch of the teeth on the wheels, it is tempting to assume that they were designed together as part of a gear train. The number of teeth extrapolated for this smaller wheel is exactly one third the number present on the larger wheel (126) – possibly not a coincidence. The gear-ratio produced by these two wheels working together would have been 3:1. This is the same gear ratio as that employed on the Levant Mine 22” whim engine built in 1839.

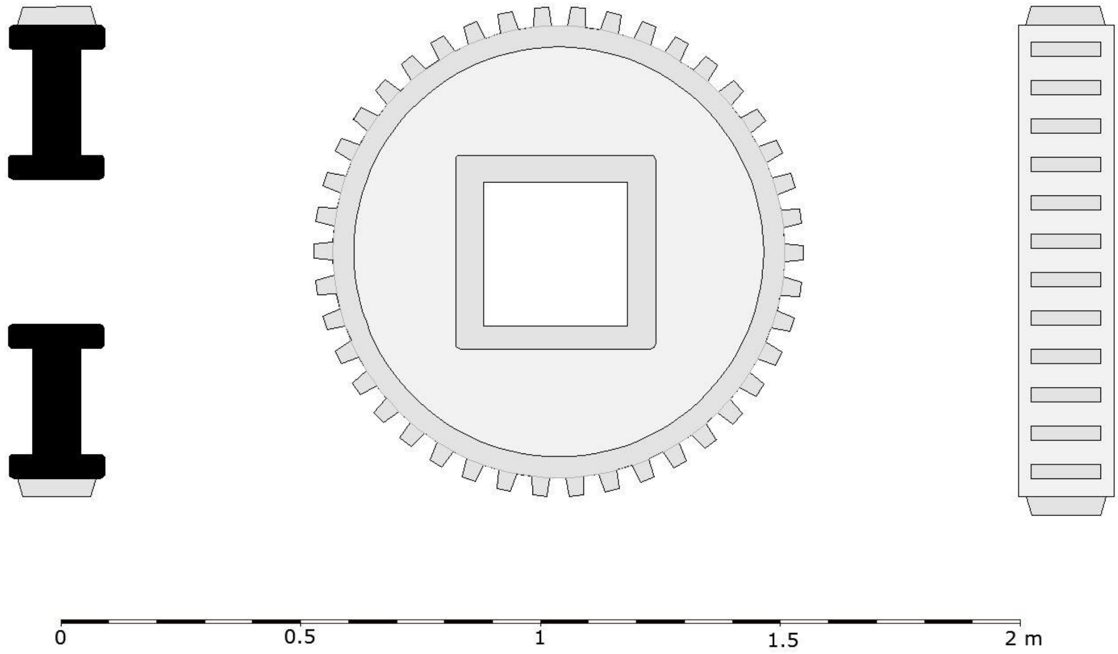


Fig 24
Reconstruction drawing of the small toothed wheel (SW3). On the left is a section through the wheel, centre is the view of the upper face (the lower face is completely inaccessible) and on the right a side view. The actual depth of the cog-teeth has been estimated

Iron Sheaves (S1 – S12)

Fig 25
A pile of iron sheaves at the north-east corner of the cargo mound. The sheaves are 1.2m in diameter

At the north-eastern corner of the cargo mound is a pile of twelve eight-spoked cast iron wheels (fig 2). The wheels, which appear to be identical, have a square hub with a central aperture of 0.06 x 0.06m. The sheaves are 1.16m in diameter and are thickest at the hub where they are 0.15m wide. The wheel rims have a semi-circular runnel around the edge, probably to accommodate a rope or rod. This runnel is 0.08 wide and 0.055m deep internally with a metal thickness of approximately 0.015m.

Of the twelve sheaves there are only three which are completely intact; several of the sheaves now consist of dispersed fragments. The sheaves appear to have suffered the highest breakage rate of the various items in the cargo mound.

There are a number of functions these sheaves could have fulfilled: the obvious ones being lifting or hauling items by rope, or facilitating a change of direction for pump rods in crooked mine shafts.

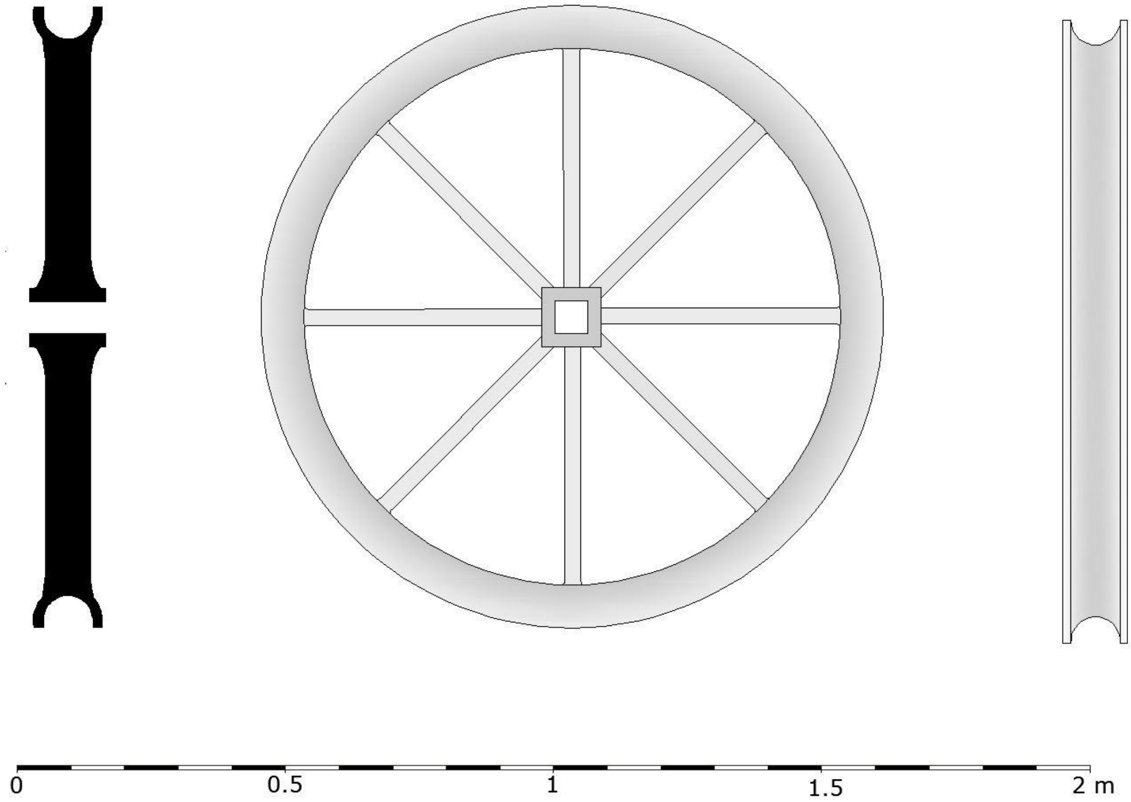


Fig 26
A reconstruction drawing of one of the iron sheaves found in the cargo mound. On the left is a section, centre face view and on the right a side view. Note the square hub

Fig 27

Detail of the hub of one of the iron sheaves. The square hub is 0.06m x 0.06m. Note how thin the spokes are where the concretion is missing

Unidentified Items

There are several items in the cargo mound which have not been identified. The first of these are two iron rods R1 and R2 (fig 2). R1 which is sat over one of the ion sheaves is 1.15m long and approximately 0.025m in diameter. R2 which sits partly over CL6 is 1.5m long and is also about 0.025m in diameter. As both rods are covered in iron concretion, it is not possible to determine their exact form.

Fig 28
Iron rod R2 – function unknown. The rod is 1.5m long

Fig 29
Iron rod R1 – function unknown. The rod is 1.15m long

Parts of a small iron box are located beneath the eastern end of one of the windbores (W1). This object appears to be a box with its top and front missing. The box is 0.44 x 0.42 x 0.36m, and the iron of which it is made is approximately 0.012m thick. There is what seems to be a small iron plate within the box. The function of this item has not been determined.

Fig 30

The iron 'box' located beneath wind bore (W1) on the eastern edge of the cargo mound. The box is 0.44m long

Photograph by Martin Davies

Also observed at the eastern end of the cargo mound was an iron rod with a possible coupling on one end. It is situated under one of the clack pieces CL2. The rod is more than 0.5m long with a rectangular open-ended feature on its eastern end. It was not possible to define the precise dimensions (or indeed to get a good photograph) of this object as it is partly buried under other cargo items. The rectangular feature is redolent of some kind of coupling.

Fig 31
Rod with rectangular feature at its eastern end, located beneath CL2. The 'pipe' running diagonally across the picture is a small clack piece (CS1) which is 1.85m long

The Iron Cylinder

Fig 32
The iron cylinder fragments found some 11m to the north-west of the cargo mound (top left of the plan). It is not clear why this particular cargo item is so far from the rest of the cargo

A small group of iron fragments was observed some 11m to the north-west of the cargo mound. These fragments all appear to be the remains of a cast iron cylinder which has been broken into six major pieces and a greater number of smaller fragments. The seabed in this area is composed of large stone boulders, so locating all the smaller fragments was problematic.

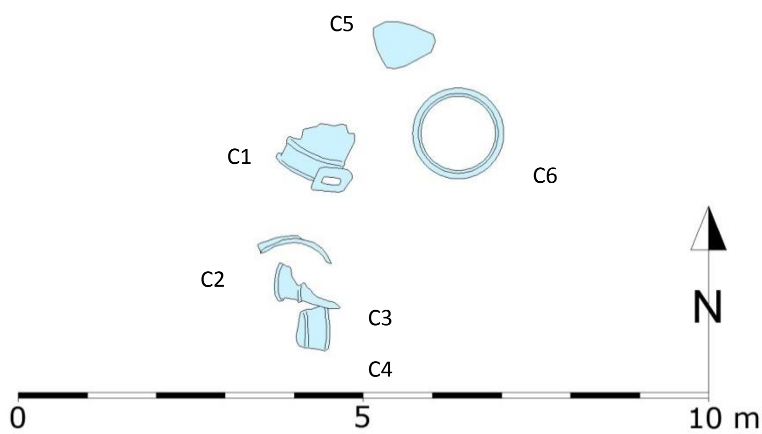


Fig 33

Left: Plan showing the distribution and context numbers of the main cylinder fragments

Below: A screenshot of the 3D structure from motion model of the area of cylinder fragments. Note the boulder strewn seabed. The two small white circular targets are exactly 1m apart

The largest fragment (C6) consists of an open ended cylinder, broken at one end with an iron flange with holes at the other end (figs 34 & 35). The cylinder has an internal diameter of 1.08m (42.5 inches), and external diameter of 1.16m – the flange with bolt holes has a maximum diameter of 1.32m. Note the diameter of this cylinder is given as 1.6m in the Undesignated Site Assessment (Wessex Archaeology, 2006) – this is incorrect and is perhaps a typographic error. This is probably a steam engine cylinder – engine cylinders of this period are usually categorised by their internal diameter in inches (Barton, 1966). If this is a cylinder from a steam engine, it is probably from a pumping engine rather than a rotative engine as rotative engine cylinders of this period are usually of smaller diameter than this example (Stewart, 2017).

Fig 34
The large cast iron cylinder lying upright on the seabed. Note the flange at the bottom and the reinforcing ring on the outside – 0.33m above the flange. The cylinder survives to a height of 0.84m

Fig 35
Fragment (C1) in the foreground and the largest fragment (C6) in the background – (C6) has an external diameter of 1.16m

Cylinder fragment one (C1) is particularly noteworthy as it has a rectangular opening or port cast into its surface. This is approximately 0.55m x 0.4m with an opening approximately 0.26m x 0.1m. By analogy with late eighteenth-century engine drawings, this would appear to be a steam inlet or exhaust port.

The flanges present on the ends of the open cylinder (exhibited on frags C1 and C6) have, as previously stated, holes which would presumably allowed the cylinder top and bottom to be bolted to the cylinder.

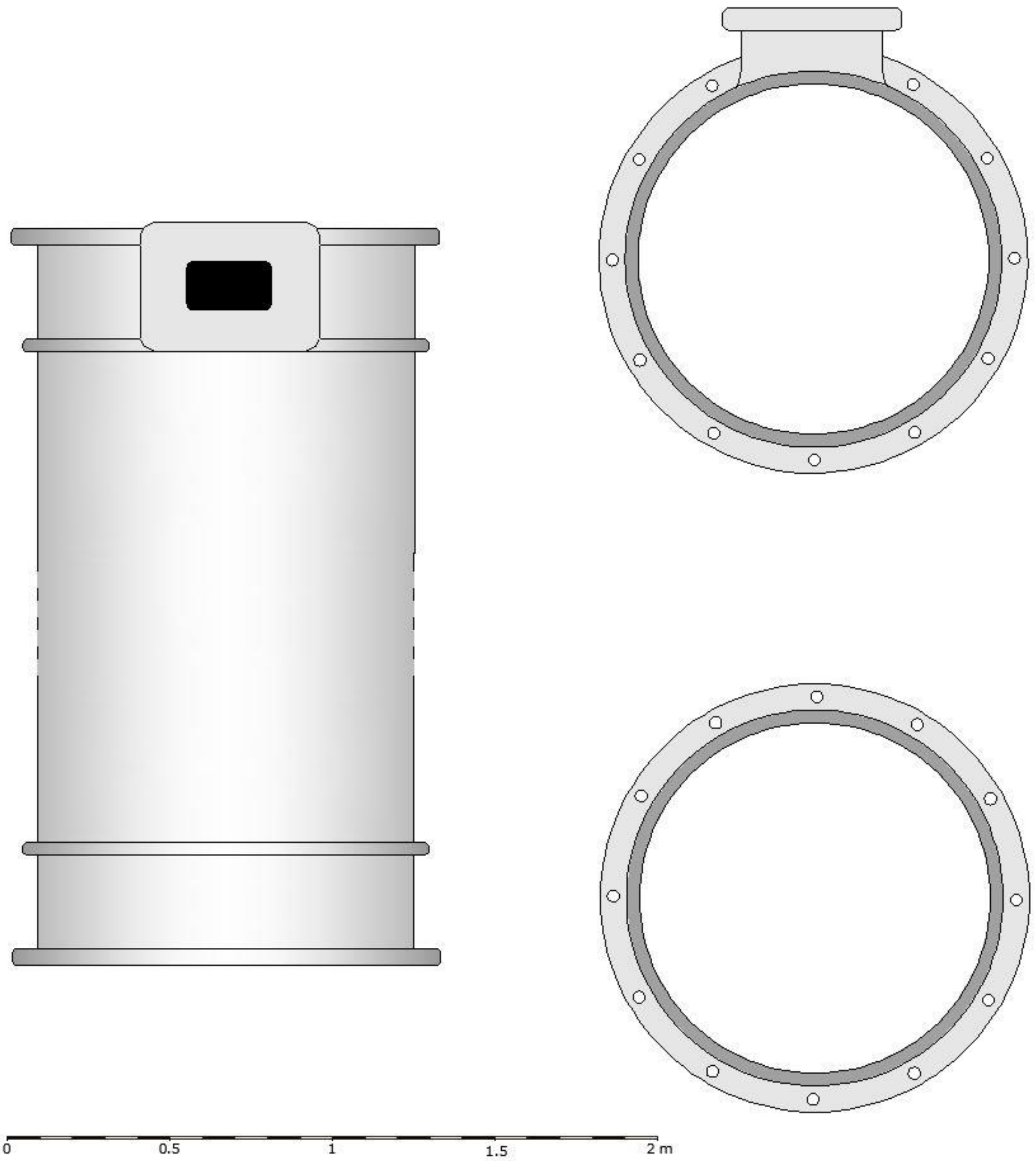


Fig 36
A reconstruction drawing of the iron cylinder found in fragments to the north west of the cargo mound. The length of the cylinder has been estimated at eight feet from reference to similar contemporary cylinders

The location of the cylinder fragments so far from the cargo mound is puzzling. There are no other significant cargo items located away from the cargo mound, so why are the cylinder fragments so far from the other items? The cylinder is likely to have been the most valuable item of the cargo (and also probably one of the most fragile). Cylinders had to be accurately bored after they had been cast – only a limited number of foundries had the machinery to accomplish this. Given the lack of any large 'cylinder-shaped' holes in the cargo mound it is reasonable to assume that the cylinder was carried above the other items in the hold or possibly carried separately as deck cargo. This could explain the displacement, but does not tell us 'why' and 'how'.

Small Wheels (SW1 & SW2)

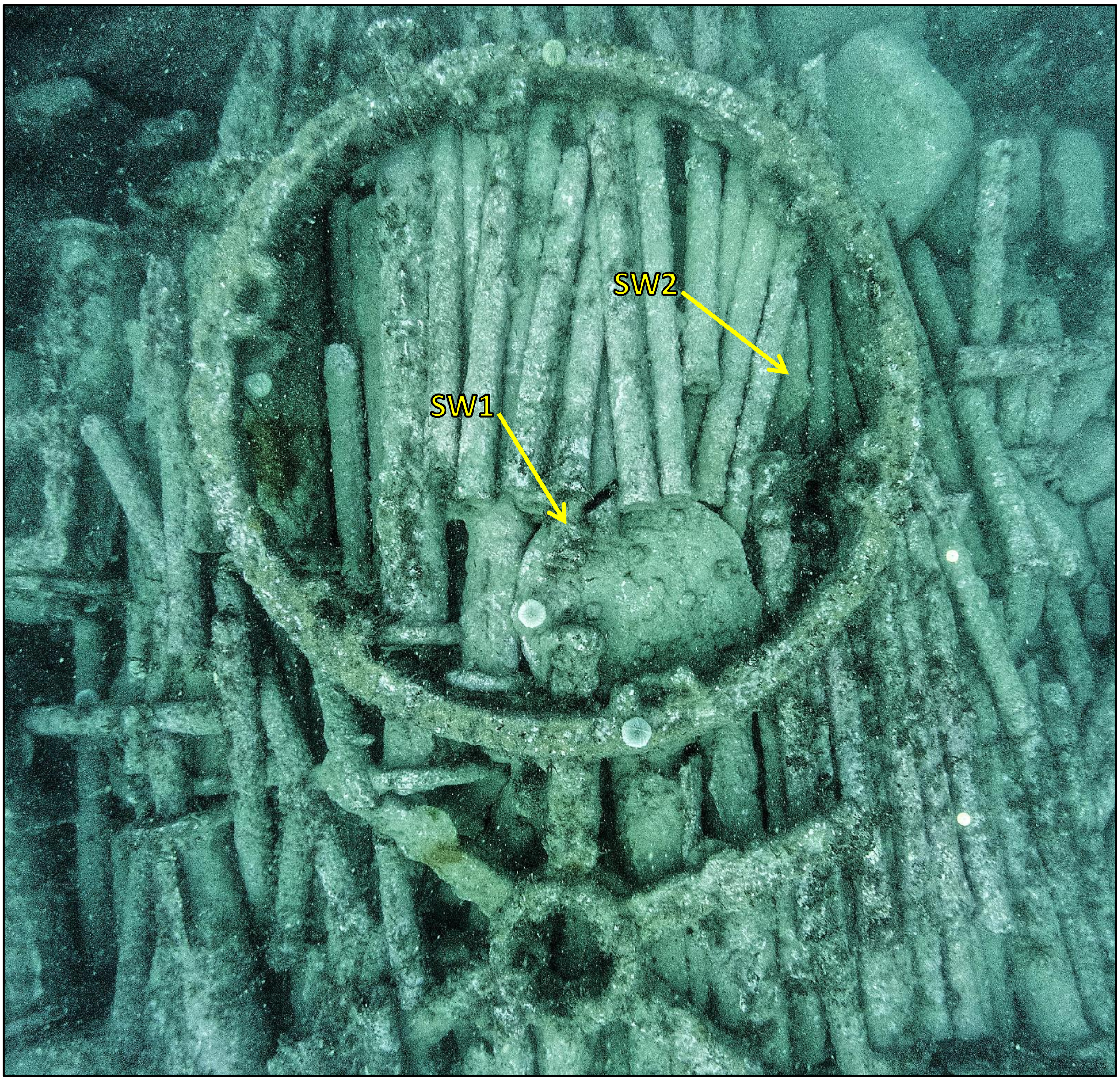


Fig 37
The location of the two small 'wheels' (SW1) and (SW2) within and partly under the large toothed wheel (LW1) – which is 3.07m (10 feet) in diameter

There are two small circular iron objects situated under the large toothed wheel (LW1). These are both partly obscured by other cargo items. The smaller of the two (SW1) appears to consist of two circular iron plates held together with iron bolts or rivets. It is about 1.18m in diameter and 0.3m thick. No details of the underside of the disk were visible. If allowance is made for the corrosion products concreted around this object, its diameter is very similar to that of the inside of the iron cylinder (C6) – which leads to the possibility that this could be the piston for the iron cylinder.

Fig 38
Detail of the two small 'wheels' (SW1) and (SW2) within and partly under the large toothed wheel (LW1) – which is 3.07m (10 feet) in diameter

The larger of the two small iron wheels (SW2) lies beneath the northern edge of the large toothed wheel (LW1) and is almost entirely obscured by other cargo items (figs 2 and 38). It was not possible to measure this item as access was severely limited; however, the general form and rough dimensions were reconstructed from the remote video footage taken in this area. The reconstruction drawing shown (fig 39 below) should be considered a 'best guess' rather than a definitive drawing. The size and form of this item perhaps suggests that it may be a top cover or cylinder head intended to be attached to the top of the iron cylinder (C6) – the piston rod passing through the central hole.

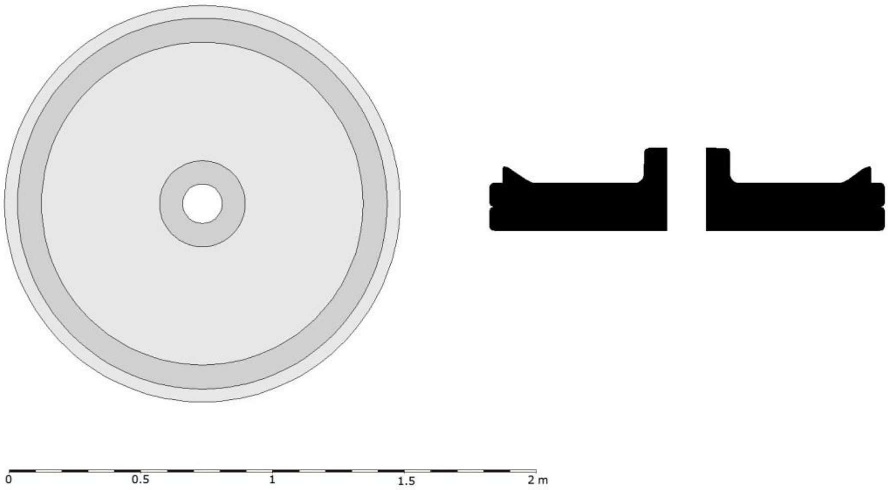


Fig 39

Reconstruction drawing and section of (SW2) – a small circular iron object partly buried under the large toothed wheel (LW1). Reconstructed from remote video footage

Cargo Items

The following is a synopsis of the items which make up the cargo mound

Item (context Nos)	Min N^{o}	Dimensions In metres	Dimensions inches (ft)	Estimated Weight kg per item	Comment
Socketed Pipe	100	Len 1.95 Ext 0.122 Int 0.010 Socket: Ext 0.162 Int 0.134	76 4.8 4	50	Cast iron pipe with a socket at one end - the plain end fits inside the socketed end. Fitted together, each pipe probably covers 6ft – thus at least 600ft of pipe. Analysis has determined that these pipes are made of white cast iron
Large Clack (CL1-6)	6	Len 1.87 Ext 0.43 Int 0.24 Flange 0.55	73 (6) 17 9.4 21.6	380	Clack pieces. No clack doors were found. These could also be bucket/lift pump inspection hatches (which look identical) See (Pole, 1844)
Small Clack (CS1-8)	8	1.85 Ext 0.28 Int 0.21 Flange 0.45	72.8 (6) 11 8.2 17.7	260	Smaller clack pieces are the same length but have smaller diameter pipe and flanges – door openings are also slightly smaller; no clack door covers were seen. These could also be bucket pump inspection hatches (which look identical)
Sheaves (S1-12)	12	Dia 1.16 Wide 0.10 Runnel: 0.075 wide 0.05 deep	45.6 3.9 3 2	100	Eight spoked iron sheave wheels. Only three are completely intact. Central hole is square (0.06 □) The eight spokes radiate from this square hub. The outer rim has runnel, probably for rope
Rising Main Small (RM1-11)	11	Len 2.74 Ext 0.25 Int 0.16 Flange 0.41	108 (9) 10 6.3 16	350	Cast iron flanged pipes. Each has three evenly spaced reinforcing bands on the outside of the pipe. Probably eight-inch rising mains.
Rising Main Large (RM1-2)	2	Len 2.77 Ext 0.33 Int 0.22 Flange 0.51	108(9.08) 13 8.6 20	400	At least two of the rising mains are of a larger diameter (RM2 & RM5) with the same length, but greater diameter of pipe and flange. Possibly 10-inch rising mains
Large Wheel Rim (LW1)	1	Dia 3.07 Wide 0.14 Deep 0.19`	120 (10) 5.5 7.5	1500	Cast iron 10ft diameter wheel rim – possibly part of a rotative (whim) engine. Gear teeth cast into the outer rim (probably 126T). Six sockets are cast into the inner face of the rim – probably for the attachment of the spokes.
Wheel Spokes (LW2)	1	Dia 2.82 Spokes 0.15x0.12	111 (6.25) 6x4.7	1250	Hub with six spokes which appear to fit into sockets in the wheel rim (LW1). The central hole in the hub is cross-shaped
Cylinder (C1-6)	1	Int 1.08 Ext 1.16 Flange 1.32 0.04 thick	42.5 45.6 1.32 1.5	2000	One section of cast iron cylinder (broken at one end) and several fragments – one fragment has a rectangular opening. The flanges on the end of C6 and C1 have regular bolt holes. Possibly the remains of a steam engine cylinder

Item (context Nos)	Min N°	Dimensions In metres	Dimensions inches (ft)	Estimated Weight kg per item	Comment
Windbore (W1-3)	3	Len 2.86 Flange 0.63 End 0.51 Mid 0.48	112 (9.3) 24.8 20 19	750	Cast iron pipes with one end closed and the other end open with flanges. Windbores are the sieve on the end of the pipe column. There are three windbores stacked next to each other. Note the large flange diameter and longer than usual length
Small Wheel (SW1)	1	Dia 1.18m Thick 0.33	46 13	2000	Cast iron wheel. Has at least 11 square-headed bolts, possibly holding multiple disks together. There are no gear teeth on the outer edge.The diameter suggests this is possibly part of the iron cylinder (C6) – piston??
Small Wheel (SW2)	1	Dia ~1.5m Thick 0.2?	59 8	2500	Cast iron disk with a central hole. The diameter is an estimate – not possible to measure – item is badly obscured by overlying elements. Cylinder head?
Small Wheel (SW3)	1	Dia 1.02 Thick 0.20	40 8	1200	Cast iron wheel – sits under the wheel spokes (LW2) and socketed pipes. Central 0.30m square 'drive' hole. Teeth match those on the flywheel in size and pitch (42T)
Collars	3	Len 0.27m Ext ∅ 0.38 Int ∅ 0.21		40	Short iron tubes with possible shallow iron flange. Possibly associated with the windbores (W1-3) – use uncertain
Rod (R1-2)	2	Dia~0.025m Len 1.5m	1	6	Round sectioned iron bar, one 1.15m long other 1.5m long - function unknown
Box	1	Len 0.44m Wide 0.42m Deep 0.36m		100	Iron box, no top and front partly missing. Appears to be cast iron 0.012m thick. Located under W1 and partly hidden.
Bar	1	Len ~1.8m		50	Located under (CL2) - possibly solid bar with rectangular 'socket' at eastern end - possibly a coupling?
CARGO TOTAL	**155**			**28,442**	

The table above lists the 155 separate cargo items identified to date. There are more items in the cargo mound which are buried beneath the visible items – it is difficult to estimate how many. The estimated weights give some idea of the magnitude of the cargo – certainly at least 30 tonnes in total and possibly as much as 50 tonnes when making allowance for 'hidden' items.

Peripheral Searches

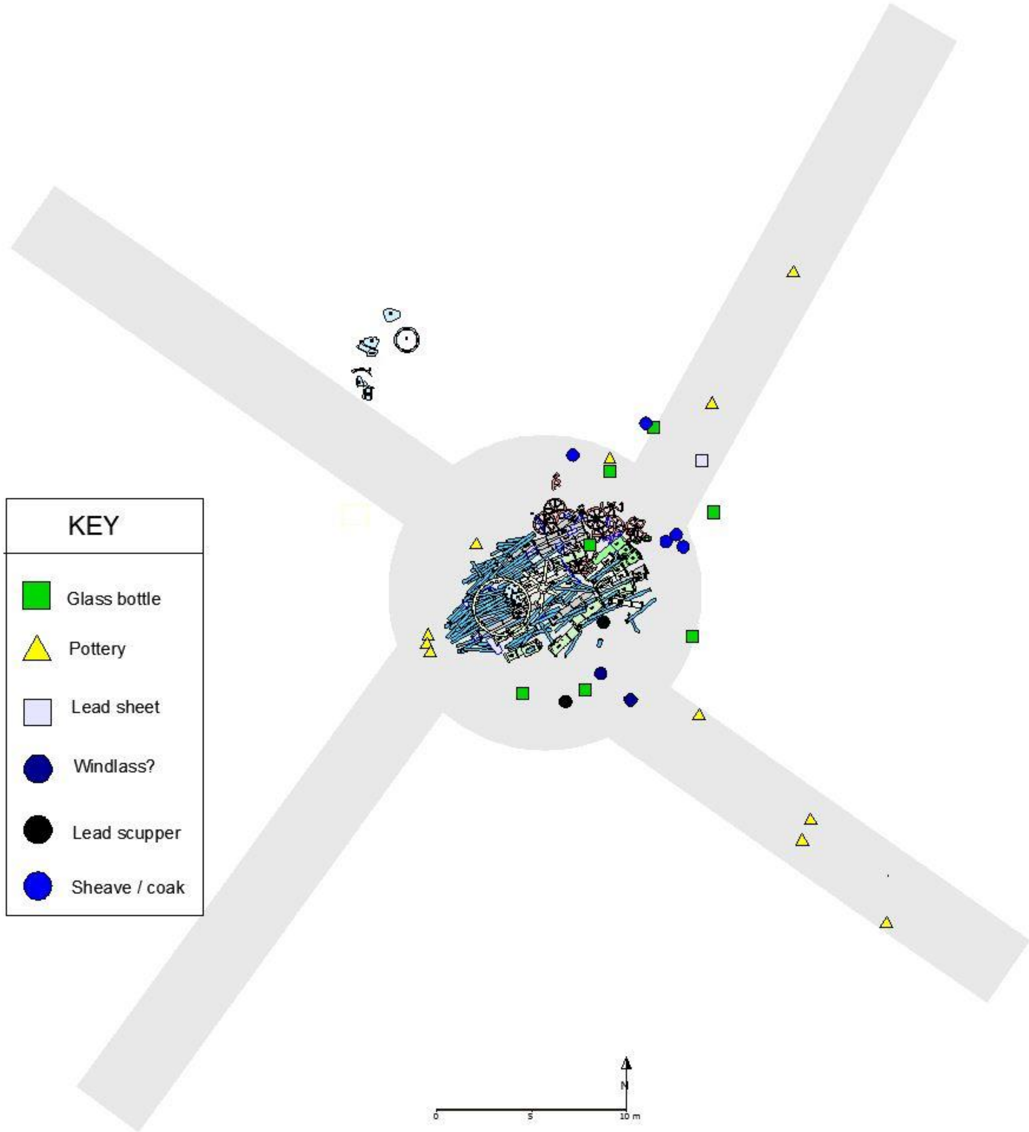


Fig 40
The area covered by the peripheral searches is shown shaded grey. The location of the objects found is indicated by the small triangles, squares and circles – type of object is indicated by the key.

A number of areas around the periphery of the cargo mound were searched in order to locate datable material. The areas searched in detail are shown coloured grey in fig 40 above. The seabed around the cargo mound is covered with large granite boulders, which makes searching difficult. All artefacts found were recorded and the ceramics were recovered for further study and dating. A total of 11 fragments of pottery and 11 fragments of glass bottle were recovered. In addition, five copper-alloy coaks were recovered as these are often stamped with makers marks.

It is interesting to note that the distribution of objects found is centred on the cargo mound, with outlying objects found to the south and east - but no outlying objects were found to the north or west. The significance of this asymmetric distribution is not clear, but it mirrors the finds locations reported in the site assessment (Wessex Archaeology, 2006, p.17) so is probably relevant to understanding the wrecking process. There is no significant tidal flow over the site so this is unlikely to be a factor in the artefact distribution.

Table of Objects Located in the Peripheral Searches						
Search	**Easting**	**Northing**	**Dims (mm)**	**Description**	**No**	**Recovered**
W	265165.93	5537174.85	300x340x40	Flat iron object, concreted	O1	x
E	265184.41	5537194.51	95x55x3	Pot frag	F7	✓
E	265184.32	5537194.32	26x20x20	Fe frag	F8	✓
E	265180.12	5537187.64	140x50x14	Pot frag (base)	F9	✓
E	265179.57	5537184.71	148x85x2	Lead sheet with nail holes	F28	✓
E	265180.26	5537181.96	60x50x5	Glass bottle neck	F30	✓
E	265176.96	5537186.52	90x20x5	Three glass bottle frags	F10	✓
E	265176.66	5537186.64	80x105x25	Copper alloy sheave coak (three-lobed with flat ends) - eroded remains of wooden sheave	F29	✓
P	265172.74	5537184.97	150x100x35	Sheave frag and copper alloy coak (three-lobed with rounded ends)	F33	✓
P	265174.71	5537184.76	140x70x8	Pot frag (rim)	F34	✓
P	265170.14	5537172.43	105x80x5	Glass bottle base	F24	✓
P	265173.88	5537180.20	90x70x4	Glass bottle base & shoulder	F1	✓
P	265177.69	5537180.42	110x100x45	Remnants of wood sheave with copper alloy coak (coak three-lobed with flat ends)	F21	✓
P	265178.61	5537180.14	85x80x40	Copper alloy sheave coak, three-lobed with flat lobe ends	F22	✓
P	265178.27	5537180.70	70x25	Copper alloy sheave coak, three-lobed flat ends	F23	✓
P	265165.23	5537174.57	190x140x11	Pot frag	F25	✓
P	265165.09	5537175.05	210x160x8	Pot frag	F26	✓
P	265165.14	5537175.48	110x85x9	Pot frag	F27	✓
P	265174.73	5537184.05	80x50x7	Two frags of bottle glass	F46	✓
S	265184.90	5537164.61	58x55x3	Pot frag, glazed	F3	✓
S	265185.44	5537165.68	60x60x5	Pot frag	F4	✓
S	265179.46	5537171.28	70x65x9	Pot frag (rim)	F5	✓
S	265177.08	5537172.94	111x60x30	Iron, concreted	O2	X
S	265175.62	5537172.07	700x250x300	Complex iron object – see sketch	O3	x
S	265172.38	5537172.02	340x60∅	Lead scupper pipe	O4	X
S	265176.96	5537186.52	85x22x5	Glass frag (green)	F6	✓
S	265174.31	5537173.53	70x30x30	Complex iron object – see sketch	O5	X
S	265189.36	5537160.36	30x20x3	Pot frag	F32	✓
N	265167.69	5537180.25	105x90x10	Pot frag	F2	✓
N	265164	5537191	1.16∅	Iron cylinder	O6	X
NE	265179.08	5537175.46	50x25	Glass bottle frag	F31	✓
P	265174.3	5537176.3	335x61∅	Lead scupper	O7	X
NW	265166	5537177		Fragment of iron – sample for analysis	FS 1	✓
NW	265166	5537177		Fragment of iron – sample for analysis	FS 2	✓
NW	265166	5537177		Fragment of iron – sample for analysis	FS 3	✓
NW	265166	5537177		Fragment of iron – sample for analysis	FS 4	✓
NW	265166	5537177		Fragment of iron – sample for analysis	FS 5	✓

The Size of the Vessel

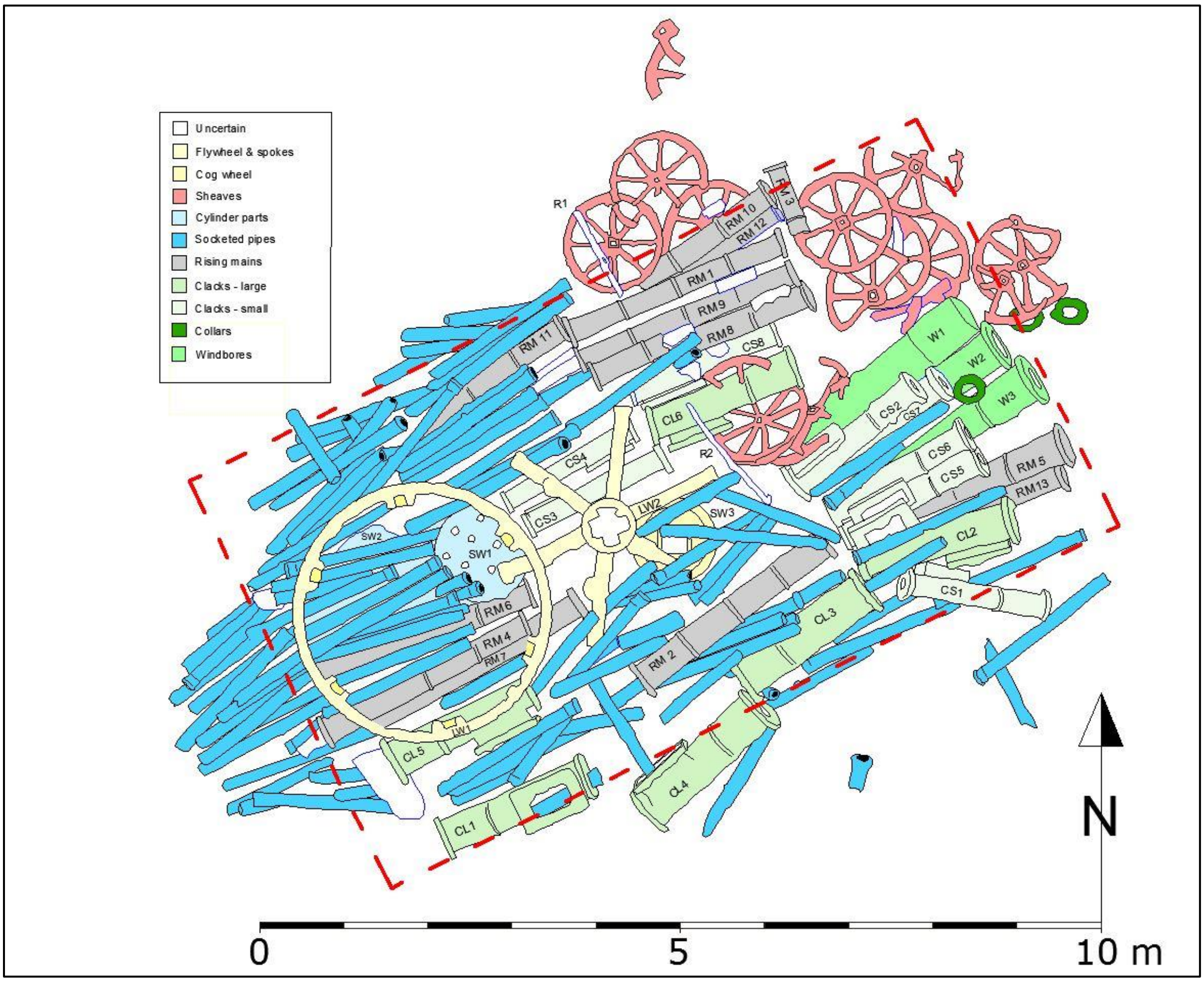


Fig 41
The cargo mound with a conjectural outline of the hold which originally constrained these items (shown as a red dashed line)

The cargo mound presents as a coherent, orderly pile of iron objects some 12m by 7m. However, in several places around the edges it is clear that some collapse has occurred, presumably as the wooden sides of the hold decayed. A conjectural reconstruction of the hold outline is presented above (fig 41) – this results in a hold which is 5.4m (17.6 ft) wide and 9.65m (31.7 ft) long. It is difficult to measure the depth of the cargo mound accurately – but nowhere was it observed to be more than 1m, and in most places was less than this. The cargo sits on a seabed of rounded granite boulders – which vary in size from 2m down to a few centimetres. As a consequence of these boulders there are considerable voids in places beneath the cargo mound, the iron of which has now concreted together, in most places to form a single cemented mass.

If we take this estimate of the hold dimensions – especially the width of the hold, which has to be less than the beam of the ship - we can compare the width with the beam of ships known to be engaged in the transport of this type of cargo and arrive at an estimate of the size of the vessel concerned. There is a list of the vessels owned by the Cornish foundry Harveys of Hayle. This list consists of 23 ships spanning the years 1787 to 1844 (Vale, 1966, pp.333-35) – and it is of interest as these vessels would have been used to transport similar cargo to that on this site (see table below). From this record, it would appear that our hold width of 17.6ft could be accommodated by a vessel of 70 - 100 tons. Two examples from the Harveys fleet are *Fame* (1814) brigantine, 106 tons, 63ft long and 20ft wide and *Park* (1829) snow, 117 tons, 66ft long , 23ft wide. This probably gives us a rough idea of the size of the vessel which we are dealing with here. In any case, we are almost certainly looking for a vessel with a minimum beam of 18 feet.

Ships owned by Harvey's of Hayle 1787-1844 – after Vale, 1966					
Date	**Name**	**Type**	**Tonnage**	**Length**	**Beam**
1787	*Providence*	Sloop	36	41.3	14.5
1795	*Henry*	Brigantine	60	55	17.2
1805	*Elizabeth*	Sloop	50	45	16.6
1810	*Alfred*	Brigantine	71	56	17.7
1814	*Fame*	Brigantine	106	63	19.9
1820	*John Adams*	Schooner	59	57	16.8
1827	*Rosewarne*	Brigantine	111		
1829	*Park*	Snow	117	66.3	23
1830	*Providence II*	Brig	90	62.2	18.8
1832	*Phoebe*	Brig	200	86.4	23.3
1834	*John Harvey*	Schooner	77	55	18
1834	*Nautilus*	Smack	52	47.9	16.3
1835	*Hayle*	Brig	129	71.8	20.3
1836	*Carnsew*	Sloop	61	51.3	17.2
1836	*Elizabeth II*	Schooner	107	65	18
1837	*Henry II*	Schooner	104	67	17
1838	*Nancy*	Schooner	104	67	17
1939	*Trelissick*	Smack	66	53	16
1839	*Mellanear*	Smack	37	47	13
1840	*Jane*	Schooner	134	74	19
1841	*Joanna*	Schooner	112	68	18
1842	*William*	Schooner	115	70	18
1844	*Frank*	Schooner	95	63	18

It should be noted that the registered tonnage of vessels of this period was a measure of the cargo space within the vessel rather than the weight it could carry. The measure was formulaic and did not always reflect the actual capacity. It was derived from the number of wine barrels (tuns) the ship could theoretically carry (hence 'tunnage'). The method of calculating this tonnage was changed by act of Parliament in 1836, the 'new' measure being slightly less than the 'old' measure.

Fig 42
A view of the cargo mound from seabed level (north side). This gives an idea of the relatively shallow depth of the mound. The scale rule is 1m long

Remains of the Vessel

A small number of objects originating from the vessel (rather than personal items or the cargo) were also located during the peripheral searches: two lead scupper pipes (O4 & O7), five sheaves with copper-alloy coaks, as well as two complex iron objects which were possibly windlasses. In addition some lead sheathing (F28) may also have originated from the vessel. The distribution and location of these objects in shown in fig 40 above. The scuppers and 'windlasses' were found to the south of the cargo mound and the sheaves, coakes and lead sheet to the east of the mound – a distribution which is similar to that of the pottery and glass.

The paucity of remains from the vessel itself is puzzling; at the very least the anchors should be evident. Even a simple wooden vessel requires iron or copper fastenings to hold the hull together – no hull fastenings have been located on this site. The lack of ironwork associated with the masts and rigging is perhaps more easily explained as these could easily have drifted away or been salvaged shortly after the loss of the vessel. Lastly, it should be born in mind that only four radial sample 'lanes' were searched – more remains from the vessel would probably be located if the remaining area around the cargo mound was investigated.

However, we now know that at least three lead scuppers survived, and these would have been firmly attached to the hull timbers until the timber rotted away – perhaps indicating that parts of the hull remained on site until it decayed. The decay of the timber would have been fairly rapid given the rocky nature of the seabed, which would have precluded burial and preservation of timbers within anaerobic sediments. The only timber seen on this site is the badly gribbled and eroded remains of lignum vitae sheaves recovered with the copper-alloy coaks (fig 45 & 46). The lead scuppers are very similar to a scupper previously removed from the site and illustrated in the site assessment (Wessex Archaeology, 2006). They appear to be deck scuppers and their relatively small diameter (0.06m) and short length (0.33m) would seem to indicate a fairly small vessel.

Fig 43

Lead scupper (O7). When first seen in 2016 this was on the seabed about 1m south of the cargo mound. By 2017 it had been moved northwards to its present position on the cargo mound (see fig 40)

The scupper is 0.33m long and 0.06m in diameter – the iron pipes it is now sitting on are the socketed pipes of the cargo mound

Fig 44

Lead scupper (O4) situated on the seabed some 3.5m to the south of the cargo mound. Note the similarity between this and (O7) above

Five copper alloy sheave coaks were found, all on the seabed to the east of the cargo mound (see fig 41). Three of these (F21, F29 & F33) had the badly eroded remains of the wooden sheave still attached; the remaining two coaks (F22 & F23) had no surviving timber attached when found. Four of the coaks are of similar size and shape. Interestingly, although superficially the same, the dimensions vary significantly, suggesting that they were handmade or finished. They are three-lobed with square ends to the lobes (fig 44). These coaks appear to be fairly large and substantial for such a modest vessel –possibly because they were associated with the cargo-handling rig.

Fig 45

Remains of wood sheave with copper-alloy coak (F21). Note how the coak is countersunk into the surface of the remains of the sheave

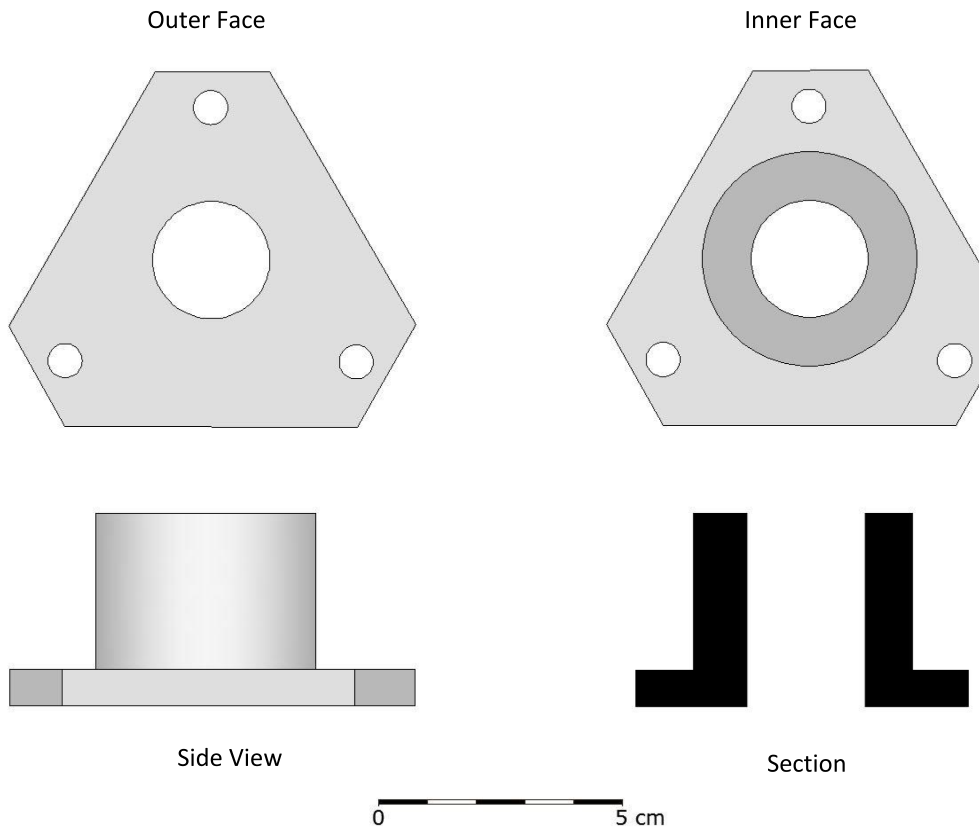


Fig 46

Reconstruction drawing of one of the copper-alloy coaks (F22). Coaks formed a hard wearing bearing around the pivot hole of the sheave

Fig 47

Remains of wood sheave with a round three-lobed copper-alloy coak (F33)

Other items found which may be attributable to the vessel are the two complex iron objects (O3 & O5) which were found on the seabed to the south of the cargo mound (see figs 40 & 48).

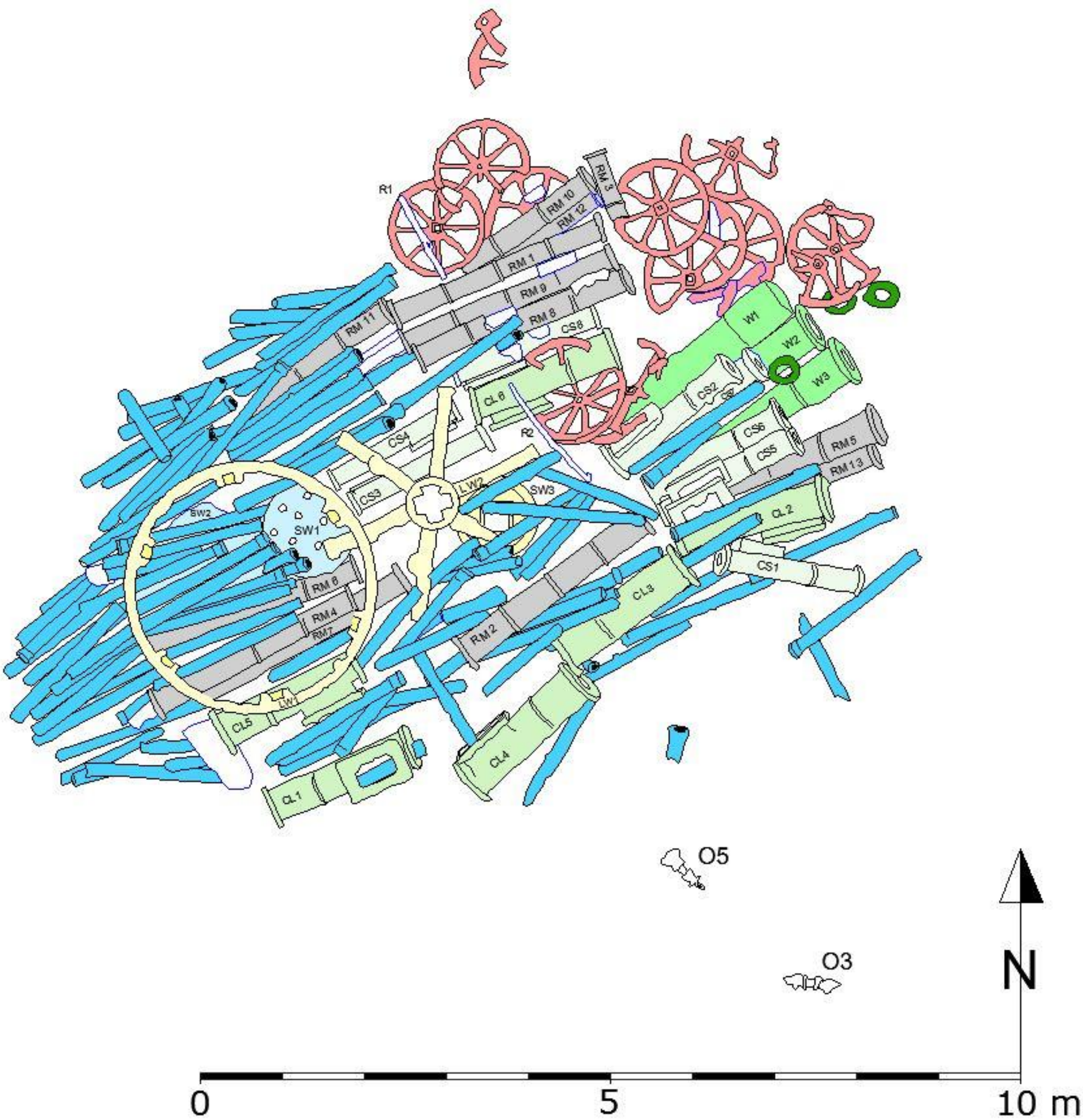


Fig 48
The location of the two complex iron objects (O3) and (O5) to the south of the cargo mound

These two complex iron objects are heavily corroded and appear to be made from wrought iron rather than the cast iron seen in the cargo items. It is not possible to discern the exact form of these objects, but they appear to be very similar. They have a central drum-like structure which looks as if it might accommodate a rope. The two ends are bilaterally symmetrical and appear to include extensions which could be used to fasten the objects to a horizontal surface. It is not possible to be certain what these items are – but one suggestion is that they were windlasses, perhaps originally fastened to the deck of the vessel. Whatever they are, they do not appear to be part of the cargo.

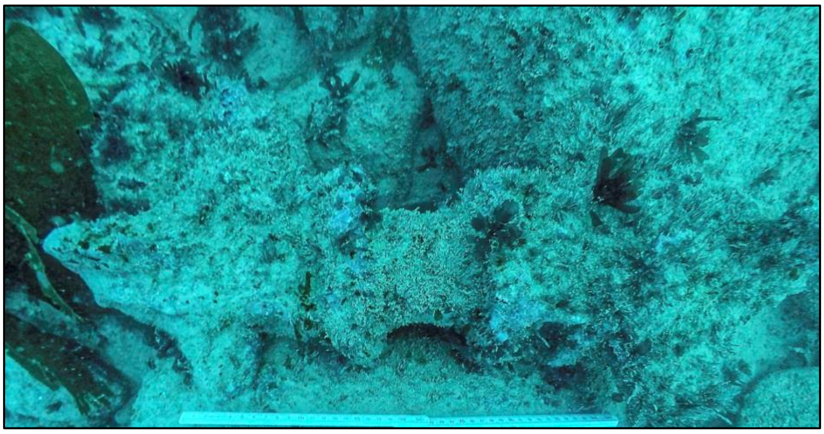


Fig 49

Complex iron object (O3). The object is 0.7m long

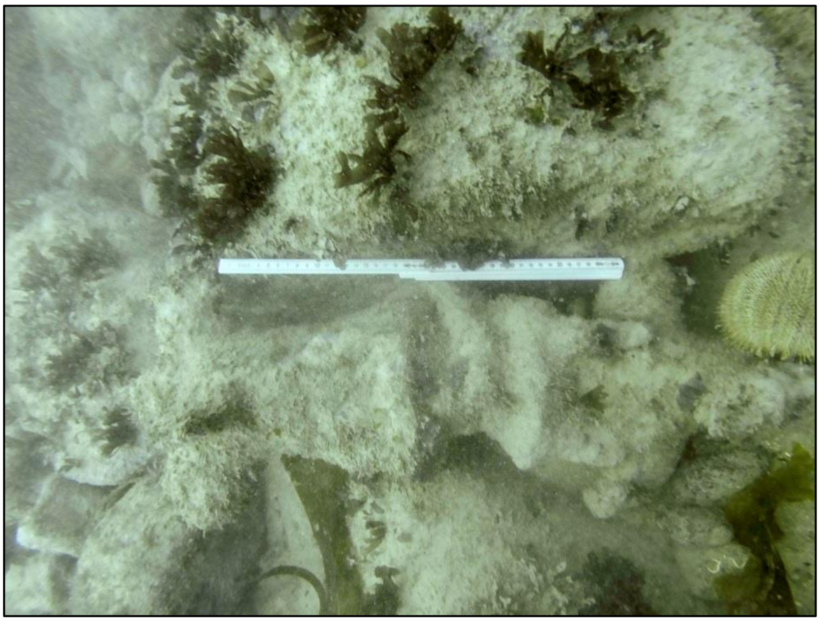


Fig 50

Complex iron object (O5). The object is 0.7m long

The rule is 0.42m long

The sheet lead (F28) - which has nail holes along its edges - is probably lead sheathing, which was probably part of the vessel. In 2017, during filming on the site for the Scilly virtual dive trails project, three similar lengths of lead sheathing were observed at the western end of the cargo mound. These were of similar width and thickness to (F28) but were longer (approximately 0.6m long).

Fig 51

Fragment of sheet lead (F28) with nail holes around its edges suggesting that this is lead sheathing

Scale = 0.10m

The Anchor

An anchor was observed by the original finders some '60m south west of the main site'. The anchor was identified as a Trotman type, and as such dates to after 1852. The Trotman anchor was a development of an earlier design by William Porter designed in 1838. John Trotman patented his improved design in 1852. In the same year a comparative trial of anchors was undertaken by the Board of the Admiralty, where it was found that the Trotman anchor was '28% better than the Admiralty pattern anchor'. Despite this, the Admiralty declined to adopt the design. It did, however, find favour with merchant vessels due to its lighter weight. It was also adopted for the Royal Yacht (1854) and for Brunel's *Great Eastern (1858)* (Curryer, 1999). The Trotman consists of semi-circular arms with 'L'-shaped horns forming the palms. The arms are connected to the shank by a bolt which allows the arms to swivel – and incidentally forms the major weakness of the design.

This anchor was inspected by CISMAS and was found to be incomplete – the shank of the anchor has broken off and is not in evidence. The arms of the anchor lie on the seabed between two large boulders with one 'palm' upright in the water. It seems likely that the anchor was wedged in the rocks and attempts to recover it resulted in the shank breaking off at the bolt. There is no evidence, other than proximity, to connect this anchor with the Wheel Wreck. The absence of the shank would suggest that this was recovered by the vessel which deployed the anchor.

The recent dating evidence gathered from the site (1770 – 1830) would suggest that this anchor is not connected with the Wheel Wreck.

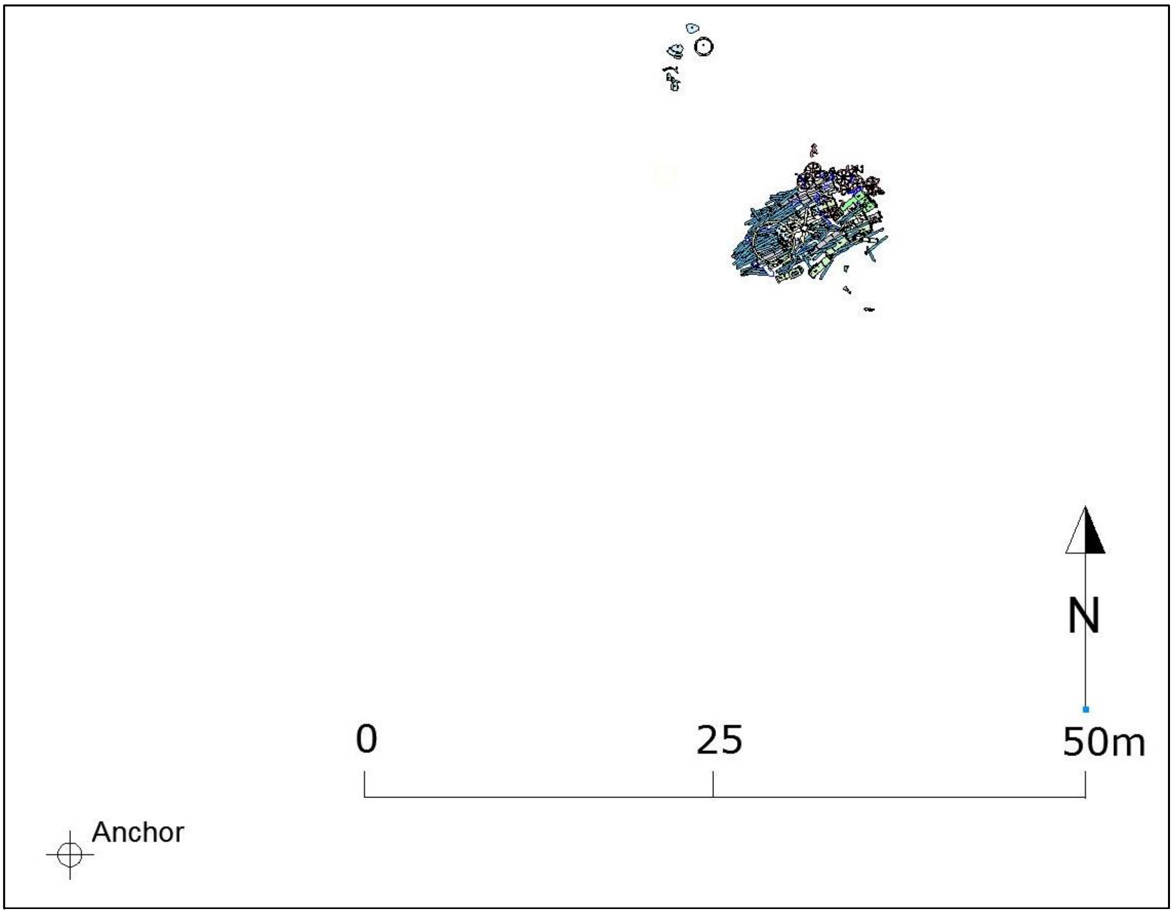


Fig 52
Location plan showing the position of the anchor relative to the cargo mound

Fig 53

The Trotman-style anchor found some 60m south west of the cargo mound. The anchor measures 1.6m from fluke to fluke

Scale = 1m

Dating Evidence

Eleven fragments of pottery and eleven of glass were recovered from the site by CISMAS in 2018 for the purpose of determining the date of the site. Previous work had assigned a date of post 1850 to the site. However, this date was based on the identification of the socketed pipes as boiler tubes – which it was claimed were not introduced until after this date. We now know that these pipes are made from 'white' cast iron and as such are likely to be drainage pipes – cast iron is too brittle to function as boiler tubes in such thin-walled pipe. Also, replacement boiler tubes were swaged to fit the boiler end-plates. It is not possible to swage white cast-iron – replacement boiler tubes of this era would have been made of wrought iron.

Discounting the boiler tubes, it is interesting to note that Wessex Archaeology assessed the pottery and glass recovered by the original finder of the site as 'late 18th century' (Wessex Archaeology, 2006, p.12) – a date wholly consistent with our current findings.

Pottery and Glass recovered for dating				
Context	**Type**	**Description**	**Preliminary date**	**Author**
F1	Glass	Green bottle base with deep kick and pontil mark. Formed in a dip mould with kick made after removal from the mould. Plus a fragment of shoulder	1760s -> 1820s	IS
F2	Pot	Rim of a buff earthenware vessel, soft-fired. Plant pot?	?	JA
F3	Pot	White ware chamber pot with part of the handle	Post 1770	JA
F4	Pot	North Devon gravel-tempered coarse ware	17-18th C	JA
F5	Pot	Grey brown salt glazed stoneware seltzer bottle. Possibly German	18th C ->	JA
F6	Glass	Fragment of green vessel glass	?	
F7	Pot	Rim of white ware bowl – Staffordshire type	Post 1770	JA
F9	Pot	Base of Jackfield or Buckley type coarse ware with internal black glaze	Late 17-early 19th c	JA
F10	Glass	Bottle base neck and body frag. Free-blown (three frags)	1770-1830 Later 18thc -> early 19thc	JA & JP SP
F24	Glass	Green bottle base with kick and pontil mark		
F25 F26 F27	Pot	English brown salt glazed stoneware bottle. Possibly Bristol	18-19thc	JA
F30	Glass	Small green bottle fragment from shoulder		
F31	Glass	Green bottle neck. Neck rim craked off and fire polished. String rim uptooled	1770s -> 1780s	IS
F32	Pot	White ware Staffordshire earthenware	Post 1770	JA
F34	Pot	Rim – North Devon gravel tempered ware	17-18thc	JA
F46	Glass	Two frags of green bottle glass (base and body)	?	

JA = John Allan : SP = Sarah Paynter : IS = Ian Scott : JP = Jacqui Pearce

John Allan very kindly undertook the initial assessment of this material. His specific comments are incorporated into the table above. His preliminary date for this material was 1770-1830. John also opined that a more precise date may be possible by further study of the glass bottle fragments. Accordingly a number of specialists were contacted – of those who replied the following dates have been suggested: Sarah Paynter (Historic England) looked at photographs of the bottle base and neck (F10) and concluded they were attributable to the later 18th century – early 19th century. This agrees with the dates proposed by John Allan. Jacqui Pearce also looked at photographs of (F10) and affirmed John's dates (1770-1830).

Sarah Paynter and Florian Stroebele undertook chemical analysis of some of the glass (Appendix VI). This is a nascent technique still under development, but their conclusion was 'The Wheel Wreck bottles have fairly consistent compositions however, with relatively high strontium contents, which are consistent with a manufacturing date towards the end of the 18th century (1770 to 1800), rather than the beginning of the 19th century'.

Ian Scott (Oxford Archaeology) has examined the bottle glass (see Appendix VII). While the majority of the glass is probably late 18th century in date, his overall assessment is that 'broadly the bottles can be confidently dated to the period from about the mid-18th century to about 1820'.

Overall, it would seem that the site probably dates to the end of the 18th century but could be as late as 1820. This accords with the dates of the small finds observed in 2006 by Wessex Archaeology. Given the very small number of objects available for the dating of the site, it would probably be beneficial to collect more dating evidence when the opportunity presents.

Fig 54
Green wine bottle base F1

Fig 55
Green wine bottle base and neck F10

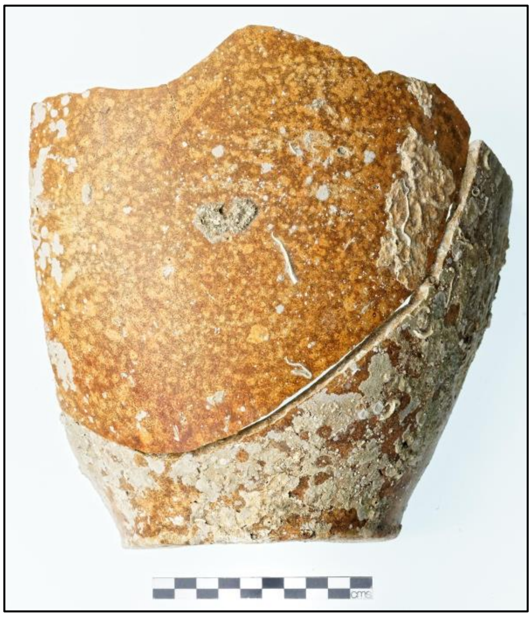
Fig 56
Green wine bottle neck F31

Fig 57
Two fragments of green bottle glass F46

Fig 58
Fragment of white ware chamber pot F3

Fig 59
Coarse ware base fragment F9

Fig 60
English salt glazed stoneware bottle F25 (above),
F25&F26 (right)



Discussion

The most significant result from the current project is that the Wheel Wreck is somewhat older than was previously thought. The previous perception of the site as a deposition occurring after 1850 was based on the identification of the socketed pipes as replacement boiler tubes. We now know that these pipes are not boiler tubes, and as such we are able to date the site from the pottery and glass found on the site – which is somewhat earlier. The pottery and glass has been dated to between 1770 and 1820 by several specialists. Furthermore, some of the bottles appear to have been made between 1780 and 1800. The pottery and glass seen by Wessex Archaeology from the site in 2006 was thought to originate in the late eighteenth century. Taken as a whole, the evidence suggests that the site seems most likely to date to the end of the eighteenth century – but could be as late as 1820. It is perhaps surprising, and somewhat disturbing, that this 'industrial' site may well be older than the nearby 'Napoleonic' wreck of *HMS Colossus* which sank in 1798.

It has not been possible to identify the vessel associated with the Wheel Wreck cargo mound. A number of wrecks have been proposed by other workers. These include the *Padstow*, wrecked in 1804 (proposed by Richard Larn), the *Victoria*, wrecked 1838 (proposed by John Macken) and the *Plenty* wrecked in 1840 (proposed by Ed Cummings). The *Victoria* can be eliminated as we now know she was carrying iron and tin plate - which is not present in the Wheel Wreck cargo. The latter two are probably too late, and indeed the first (*Padstow*) may also be too late. The only association between these wrecks and the Wheel Wreck is that they were carrying iron and were wrecked in or near Scilly. Serena Cant has carried out work to identify possible candidate wrecks from documentary sources – see Appendix III. She has identified 21 candidate wrecks, of which 17 are post-1800 and six are pre-1800. Unless we can discover details of the actual cargo these vessels were carrying, we are unlikely to be able to make an association between the site and a known wreck. Only six candidate wrecks were identified for the eighteenth century, which raises the possibility that we are dealing with a wreck not currently on the candidate list. More focused documentary research may be possible if a more precise date for the site can be determined, and this will only be possible if more dating evidence can be collected from the site.

The site plan produced this year has allowed an estimate of the size of the vessel's hold to be made. From this we were able to conclude that the vessel was at least 18 feet (5.5m) in beam and likely to have been between 70 and 100 tons in capacity. Very little has remained of the vessel itself. The assumption is that the hull was wood and has decayed. That said, the scarcity of metal remains is somewhat puzzling; in particular, the anchors and iron fastenings should have been evident. The survival of lead scuppers does, however, suggest that parts of the hull decayed in situ rather than floating away. The most likely explanation is that parts of the vessel were salvaged shortly after the loss. Salvage activity on site could also account for the displacement of the iron cylinder (C1-6) to the north of the cargo mound.

Detailed study of the cargo items has raised more questions than it has answered. The previous perception of the cargo as consisting of mine pumping equipment as used in Cornish mines in the eighteenth and nineteenth centuries is probably largely valid. However, the cargo does not seem to represent a coherent set of mine pumping equipment, but rather a collection of equipment relevant to water movement. In particular, the enumeration of the cargo items undertaken this year has demonstrated that the cargo cannot be a complete set of pumping equipment. Mine pumping gear was arranged in stages or lifts of 20 to 30 fathoms per lift (Pole, 1844) – see Appendix IV. This means that each lift would consist of one windbore, two clack pieces (in bucket pump systems one of the clacks would be a pump inspection cover) and 13 to 20 sections of rising main. The cargo mound contains three windbores (sufficient for three lifts), 13 rising mains (only enough for one 20 fathom lift) and 14 clack pieces (enough for seven lifts).

Also the large number of socketed iron pipes (about 100 recorded) would have no place in a Cornish mine pumping system. These are low pressure pipes and would not have been able to withstand the pressure in a mine pumping column. They were probably intended to convey water around a site rather than to drain a mine (an example of this is Claverton Pumping Station – see appendix V).

The two geared wheels (LW1) and (SW3) were probably intended to form a gear train and were possibly part of a rotative engine, while the 42 inch diameter steam engine cylinder (C1-6) was probably part of a pumping engine. Rotative engines had smaller cylinders, so these parts do not appear to be part of the same system. No other steam engine parts have been observed: the boiler, control gear, condenser, beam and steam pipes are all absent from the cargo mound. We cannot be certain how many items are hidden from view within the bottom of the cargo mound. But there were sufficient voids in the mound to allow inspection of much of the lower layer by remote video camera – and it seems likely that major items such as an engine beam, boiler, condenser or steam pipes are not present (see fig 3). It should be noted that until the 1790s the beam of a steam engine was made of wood, iron starting to replace wood after this date (see Appendix I – 1790s).

Another notable omission from the cargo is that of 'T' pieces (aka 'H' pieces). These were necessary for the employment of plunger pumps in pitwork (see Appendix IV). Plunger pumps were not widely employed in Cornish mines until about 1800, although Boulton and Watt had used them in Cornwall as early as 1786 (Stewart, 2017). In the nineteenth century the use of plunger pumps was widespread except for the lowest lift where the older bucket pumps were still used. This lack of 'T' pieces may indicate that the cargo predates 1800.

The re-dating of the site raises questions of the cargo's origin. It now seems less likely that the Wheel Wreck cargo was the product of a Cornish foundry. In the nineteenth century, Cornish foundries were pre-eminent in the production of mine steam engines. In the eighteenth century, however, production of the more complex parts took place outside Cornwall, notably the casting and boring of the cylinders '[until after 1800] The more easily manufactured parts were produced by the existing Cornish foundries but the casting of large cylinders and the accurate boring of them was then beyond their capacity' (Barton, 1966, p.148). Until the early nineteenth century, the more complex parts such as cylinders were manufactured by Neath Abbey Ironworks (Wales), the Soho Works (Birmingham), by Wilkinson or Darby at Coalbrookdale (Shropshire) or at the Carron Ironworks in Scotland (Guthrie, 1994, p.121). There is also the question of whether these parts were newly manufactured or were in fact used machinery being transported to a new owner. Mine machinery, especially engines, was often sold once the mine in which it was employed became worked out or uneconomic. This was expensive machinery and mine owners (or 'adventurers' as the Cornish financiers were called) would be keen to recoup their losses once a mine closed. New ventures just starting up would be all too willing to acquire cheaper, used mining equipment. Many of the candidate wrecks identified to date originated in Wales, and the Neath Abbey Ironworks, an early manufacturer of cylinders, was owned by the Perran Foundry situated near Falmouth. It is tempting to speculate that the cargo was being transported from Neath to Falmouth where it would be batched up with locally made ironwork for onward shipment.

An unusual feature of the pitwork contained in the cargo mound is the lack of fillets between the flanges and the bodies of the rising mains and clack pieces. The junction of the flange and pipe body was a weak point and apparently subject to cracking – the fillets were a means of combating this. Certainly all the nineteenth century pitwork observed in Cornwall appears to be equipped with these fillets and their lack may be an indication of pre-nineteenth century manufacture. Compare figs 8 and 11 for examples of this.

Our understanding of the items comprising the cargo mound has been improved by the current project. We now have some idea of 'what' and 'how many'. Sadly, we now think this was not the product of a Cornish foundry and its origin could be any one of five foundries capable of casting and boring the cylinder at this time. What is required now is the identification of the vessel concerned, which will allow us to establish origin and destination of this unique cargo. This will only be possible with a great deal more documentary research. We at least now know roughly 'when'. Gathering of further dating material may allow us to refine the date further, which would narrow down the range of documents which have to be searched.

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Appendix I - Cornish Mining Machinery Milestones

The following table gives a brief summary of the main developments in Cornish mining technologies in the eighteenth and nineteenth centuries. It documents the three successive types of steam engines used in the west country mines ; Newcomen, Boulton & Watt and finally the Cornish Engine – each of which was a development of its precursors. It also outlines the development of the pumping equipment (pitwork) itself – which is what the Wheel Wreck cargo mound mainly comprises.

Date	Event	Detail	Source
c.1675	Plunger pump	Samuel Morland patented (175) a plunger pump capable of raising great quantities of water	JTS 7/34
1689	Blasting	Thomas Epsley is said to have introduced blasting with black powder to the Cornish mines – a year later he is recorded in the Breage burial register – apparently a victim of his own invention	Rowe p 9
1698	Savery	Thomas Savery patented an engine for raising water by the impellent force of fire. Patent extended by act of parliament to run until 1733. At a trial of the engine in 1706 'the steam was very strong and tore the engine to pieces'. There are legends of this engine being used at Wheal Vor (Breage) but this is doubted by Barton & Stewart	Stewart p 18 Rowe p 7
1698	Coal tax	Import tax on seaborne coal introduced	Stewart p 39
1709	Coalbrookdale	Abraham Darby made cast iron in a small blast furnace using coke as the fuel (derived from coal) at Coalbrookdale. This allowed mass production of cast iron – continued casting iron (including making of first iron bridge, first railway engine and AGAs) until 2017	JTS3 p 25
1712	Newcomen engine	First documented use for pumping at Dudley Castle colliery, Staffordshire, 21 inch cylinder. Newcomen never patented his engine but worked within Savery's wide ranging patent. X section drawing. Drawing p48 Stewart	Barton p 15 Rolt&Allen p 46 Stewart p 26 Barton p 17
1714	Water driven pumps	Coster and Coster patent in 1714 for a pumping system for mines – used an ingenious water driven chain and rag engine to drive pumps of 'mettall cilinders and bored elemes'	Stewart p 12
1716	Early engine	The first engine in Cornwall was possibly erected at Wheal Vor (Breage) and worked for about four years. Pole puts this engine at c.1714 and Rolt&Allen at 1710-14. Rowe says Wheal Vor ceased working in 1715 'after an apparently unsuccessful attempt to use an early Savery or Newcomen engin'	Stewart p 33 Pole p 12 Rolt&Allen p 44 Rowe p 186

Date	Event	Detail	Source
1720	Newcomen engine	Early use in Cornwall at Wheal Fortune, Ludgvan. 47" cyl, pumping from 30 fathom in 15" pitwork – some have argued this was not built until 1746. Pole claims first 'fire engine' at Wheal Vor (Breage) c.1714	Stewart p 35 Stewart p 36 Pole p 12
1720s	Cast iron	Cast iron starts to replace brass for cylinders – Coalbrookdale start casting iron cyls in 1722	Stewart p 158
1723	Water driven pumps	Marquis copper mine (Devon) used a 'water engine' driven by an overshot waterwheel to drain the mine. Waterwheel-driven pumps mentioned as early as 1480	Stewart p 7 Stewart p 9
1726	Waterworks	In 1726 a Newcomen engine was erected at York Buildings waterworks in London	Rolt&Allen p 80
1727	Newcomen engine	In 1727 fifteen years after the first atmospheric engine only five engines recorded in Cornwall	Barton p 16
1729	Newcomen dies	London	(Davey; 12-13)
1730s	Pump pipe	Rise in demand at Coalbrookdale in the 1730s for cast iron pipe probably marks the transition from bored wood to iron. However, in Bjorling 'In the year 1798, we still found them boring out wood pumps in Cornwall'	Stewart p 158 Stewart p 161
1733	Newcomen engine	Savery patent expires	
1741	Newcomen engines	Only three Newcomen engines said to be working in Cornwall in 1741	Rowe p 7
1741	Coal import	Import levy on seaborne coal of 50% – exemption for Cornish mines after lobbying of parliament (this was by a drawback or reclaiming of the duty) NB Barton says this happened in 1739	Barton p 18 Rowe p 43 Pole p 15
1740s	Manufacture	Most cylinders made by the Coalbrookdale company who maintained an agent in Truro. Stewart lists 16 cylinders supplied to Cornwall between 1744 and 1768, 40"-70" made by Coalbrookdale. They also made cast iron pipe	Barton p 19 Stewart p 52 JTS3 p 25
1752	Stannary Parliament Stannery Courts Coinage Towns	The last stannary parliament held in Helston (wiki says Truro). There were also stannary courts which tried miners instead of the usual legal system. In return, duty had to be paid on all tin at designated coinage towns where the tin blocks were stamped to show that the duty had been paid. In medieval times the coinage towns were Liskeard, Lostwithiel, Truro and Helston – Penzance was added in 1663, Calstock and Hayle after this.	Rowe p 46 Guthrie p 88 Rowe p 13
1755	CCC	Cornish Copper Co founded in 1755 in Camborne, moved to Hayle in 1758	Guthrie p122
1758	Timeline	Nelson born	
1760	Coal	Coal landed in Cornwall cost 15s ton	Barton p 20
1762	Boiler	Samson Swaine erects a boiler made of stone (granite) at a mine near Wheal Weeth – a block from such a boiler is reputedly on display at East Pool mine	Stewart p 56
1769	Smeaton	Smeaton computed the duty of fifteen engines in the Newcastle-on-Tyne district, and found the average duty to be 5 millions of foot lbs. per bushel or 84 lbs. of coal	(Davey; 12-13)

Date	Event	Detail	Source
1769	Watt	Watt patent (913) granted for 14 years. The patent specifies a separate condenser, evacuated by pump.	Stewart p78
1770	Wheel Wreck	Terminus post quem for the Wheel Wreck	
1770	Smeaton observation	Smeaton made note of eighteen large engines in Cornwall, eight of which had cylinders from 60 to 70 in. diameter	(Davey; 12-13)
1770	Boilers	The Haystack boiler (copper then wrought iron) is largely replaced by the wagon boiler (rectangular shape with rounded top) c. 5psi	Barton p115
1774	Cylinder boring	In 1774 John Wilkinson patented a machine for boring iron cannon from solid casting (this technique continued until the end of smooth-bore cannon). Shortly after this he invented a machine for accurately boring cast iron engine cylinders. He made many cylinders for Bolton & Watt at his Bersham works – including the early Cornish engines at Wheal Busy and Ting Tang	Stewart p82
1775	Engine	Smeaton engine at Chacewater 72" built by Carron Co	Barton pp 21-22
1775	Watt	Boulton & Watt patent extended to 1800 by act of parliament – covered separate condenser and use of steam as the driving force B&W charged $^{1}/_{3}$ cost of coal saved by their engine	Barton p 22 Stewart p 82
1775	Newcomen engine	One of the last Newcomen engines erected in Cornwall at Dolcoath in 1775. 45" cyl. Erected by John Budge. The iron pumps were supplied by John Jones Co Bristol and Dale Co. By the 1770s at least 78 engines had been erected in Cornwall	Stewart p 50 Stewart p72
1775	Depression	In 1775 only 18 of the 40 engines in Cornwall were being worked	Rowe p 72
1776	Watt	First Watt engine in Cornwall ordered by Ting Tang (Gwennap) 52"	Barton p 22
1779	Harvey's Foundry	Established in Hayle by John Harvey. Woolf was superintendent from 1816. By 1880 Harvey's were the only surviving main engine maker in Cornwall. Closed 1903	Barton p 142
1779	Whim	Newcomen engine adapted for rotative motion but had a 'prodigious appetite for coal'	JTS3 p 27
1780	Pickard rotary	James Pickard patent (1263) on rotary engine using a crank and flywheel	
1781	Hornblower	Two cylinder compound engine patent. Steam passed from the first, larger cyl to the second, smaller cyl. Was more successful in rotary engines	Barton p 25 Pole p 30
1781	Watt rotary	Watt patents (1306) planet-and-sun gearing on flywheel for his rotary engine (two revs per engine cycle) to circumvent the Pickard patent of 1780	EB

Date	Event	Detail	Source
1782	Watt rotary	Watt patents (1321) double acting engine (push and pull) this required solid connection to the beam as opposed to chain. Expansive working also included (although at very low pressure)	EB JTS3 p 27
1783	Newcomen engine	By 1783 only one Newcomen engine left working in Cornwall. Coal consumption was said to be 'massive'. Newcomen engines continued in coal mines where coal was effectively free until the late 19th or even early 20th century	Barton p 23 Stewart p 39
1784	Iron	Henry Cort patented 'puddling', a process to produce wrought iron from cast iron using coal as the fuel	JTS3 p 26
1784	Whim engine	The first whim engine in Cornwall (a B&W @ Wheal Maid) this had sun-and-planet gearing instead of the simple crank which was usual after 1794 – drawing p 188. Previously horse whim was usual – Wheal Harrier in Camborne was still drawing ore to surface by horse whim in 1858. Round hemp rope until iron chains around 1820; wire rope about 1860	Barton p 185 Barton p 191
1784	Watt rotary	Watt patent (1432) parallel motion (aka 3 bar motion) for cyl to beam connection – also a steam carriage	EB
1785	Watt furnace	Watt patent (1485) for improved furnace	
1786	Plunger pump	Boulton & Watt were using plunger pumps on a limited scale in Cornwall from 1786	Stewart p 162
1787	Transport	Harvey's foundry acquired their first ship *Providence* for transporting castings and raw materials. 23 ships owned by them are listed up to *Frank* 1844	Vale pp 333-335
1788	Watt rotary	Watt designs centrifugal governor	EB
1790	Watt	Watt designs pressure gauge	EB
1790	Bull	Ex-Watt engineer designed engine with cylinder over shaft – no proper beam. In 1790 court ruled this was piracy and ordered halt to production. Not as efficient as conventional beam and wore more quickly	Barton p 25 Barton p 105
1791	Engine manufacture	First known complete engine built in Cornwall (a Bull at Harvey's) – previously cylinders were made out of county. By 1830 the Cornish 'big three the equal of any foundry'. Previously engines were made at: Neath Abbey, Soho Birmingham (B&W), Carron Scotland and Coalbrookdale	 Barton p 148 Guthrie p 121
1791	Perran Foundry	The foundry was set up on the site of a tin smelting works (Perran Wharf on the Fal) by Robert Were Fox and John Williams of Scorrier to supply machinery to the Gwennap copper mines.	Wiki Barton p 153
1792	Neath Abbey Ironworks	In 1792 the Perran owners also leased the Neath Abbey Ironworks in Wales which was founded c.1785	Barton p 153
1792	Hornblower Wherry Mine	In 1792 a Hornblower (2 cyl compound) engine was installed at the Wherry Mine in Penzance	Stewart p 128
1792	Harvey's	Harvey's build their first 'steam pump – probably a Newcomen'	Guthrie p 124

Date	Event	Detail	Source
1790s	Inverted engine	Inverted engine introduced	Barton p 30
1790s	Beam	Cast iron starts to replace log (wood) beam for engines	Barton p 30
1798	Timeline	HMS *Colossus* wrecked on Scilly	
1798	Hornblower rotary	1798 Hornblower takes out a patent for a rotary engine	Stewart p 130
1800	Watt	The Boulton & Watt patent expires	Barton p 27
	Engine manufacture	From 1800 the majority of pumping engines in Cornwall were built by the 'big three': CCC, Harvey's & Perran	Guthrie p 122
1801	Foundry	Holman Bros of Camborne established	Barton p 162
	Engines	In 1801 there were about 80 engines at work in Cornwall – all but three were pumping. The majority were B&W	Barton p 252
1801	Locomotive	Trevithick's road locomotive built in 1801 with parts made by Harvey's	Guthrie p 122
1801->	Bucket pump Plunger pump	Replacement of bucket pump by plunger pumps begins (but see 1786). In 1827 Farey published plan of pitwork showing all bucket pumps. Windbore about 7.5ft long, clack pieces also 7.5ft long. Working barrel 2ft longer than bucket stroke. Common pipes (rising main) were 9ft long with 3" broad flanges. Note shorter rising mains are known but rare. 'The windbore may be 6 or 8ft long' In 1801 Lean replaced bucket pumps with plunger 'wherever practical' at Crenver and Oatfield. Pole in 1844 describes the pump column at Wheal Vor where there were four bucket pumps and nine plunger pumps in a rise of 219 fathoms	Barton p 30 Farey p 217 Farey p 221 Stewart p 162 Pole p 119
1803	Boiler	Woolf patent on sectional cast-iron boiler – they proved troublesome and disappeared about 1825	Barton p 116
1805	Timeline	Battle of Trafalgar	
>1810	Copper	From 1801 to 1810 Cornwall produced over 65% of the world's copper. By 1861-1870 this had fallen to 10%, and was 3% in the following decade (see table below)	Rowe p 128
1810	Duty	Reporting of engine performance begins – monthly publication continues for almost a century. Duty measured as pounds of water raised 1ft by a bushel of coal	Barton p 32 Barton p 28
1811	Boiler	Woolf cast iron boiler advertised	Barton p 33
1811	Engine	Two 90" engines for Consols made at Neath Abbey – at the time the largest engines in the world	Barton p 41
1812	Boiler	Wagon boilers largely replaced by cylindrical boilers in Cornwall. Single flue introduced by Trevithick – first built by Holmans in 1812 and became known as the Cornish boiler – in almost universal use in Cornwall by 1830s	Barton p 115 Guthrie p 122
1812	Wheal Vor	Wheal Vor tin mine reopened after long closure. Up to 1812 most pumping engines were in copper rather than tin mines – exceptions were Wherry Mine and Ding Dong.	Rowe p 188
1818	Foundry	In 1818 the Perran Foundry known as Foxes & Perran Foundry Co, and Neath as Foxes & Neath Abbey Co	Barton p 154

Date	Event	Detail	Source
1824	Boilers	Woolf cast iron boilers installed at Wheel Alfred driving his 2 cyl compound engine, alongside Trevithick's Cornish boiler driving a single 90". No clear winner in duty but unreliability of Woolf boilers led to their abandonment	Barton p 44
1824 ish	Engine improvement	Groce at Wheel Hope (Gwinear) insulated pipe and cylinders improving duty	Barton p 45
1820	Copperhouse foundry	Copper house foundry begins making engines. Set up by the Cornish Copper Company. In 1841-2 supplied parts for Clifton suspension bridge. Closed 1869	Barton p 151
1820s	Engines	Many 2 cyl compounds altered to singles	Barton p 47
	Harvey's Foundry	Harvey's so busy they have to share work with Neath Abbey Ironworks in Wales	Barton p 157
	Foundry	1820s St Austell Foundry established	Barton p 159
1827	Foundry	Charlestown Foundry established	Barton p 162
1830	Wheel Wreck	Terminus ante quem for the Wheel Wreck	
1830	Engines	By 1830 single acting engines had largely replaced double acting engines for pumping	Barton p 107
1830	Foundry	Harveys have 52 draught horses for moving machinery	Barton p 123
1830	Perran	Perran foundry making complete engines after 1830	Barton p 154
1832?	Engine duty	The Austen 80" at Fowey Consols provokes controversy by reporting 125m duty (first past 100m) – normal duty for this engine under 100m	Barton p 49
1830s	Waterworks	By the 1830s Cornish engine duty figures were exciting interest upcountry. In 1837 Thomas Wichsteed Engineer to East London Waterworks came to Cornwall to investigate. An 80" pumping engine was purchased. Subsequently many engines were built esp. in period 1860-70 by Harvey's for London waterworks Drawing p 260	Barton p 258
1834	Foundry	Nicholas Holman leaves Camborne and sets up foundry at St Just – set up a branch Foundry at Penzance in 1840	Barton p 162
1838	Engines	About 250 engines at work in Cornwall	Barton p 252
1838	Tin coinage	The Tin Duties Act (1838) abolishes the system of duty on refined tin (called tin coinage) payable to the Duchy of Cornwall – this had been in force since at least 1156 – but applied only to tin (not copper)	Wiki Guthrie p 88
1839	Compound engines	Compound (2 cyl) engines reappear	Barton p 52
	Engine	Taylors engine drawing in 1870 Perran catalogue – but built 1840	Barton p 55
1840s	Perran	Perran builds a 64" engine for Vauxhall Waterworks	Barton p 154
1841	Engine - compound	Sims patented combined cylinder compound engine about 55 built – few if any after 1849. Required taller engine house	Barton p 108
1842	Man engine	A total of 16 man engines in Cornwall – introduced from overseas starting about 1842 at Tresavean	Barton p 212

Date	Event	Detail	Source
1844	Boiler	Lancashire boiler patented (two fire tubes v one in Cornish). This type popular outside Cornwall - some in Cornwall by 1880 but never displaced the Cornish boiler in Cornwall.	Barton p 117
1846	Pump rods	First recorded use of wrought iron for pump rods (usually pine). Rods 8" diameter – suffers from failure of couplings	Barton p 95
1850	Pumping	By 1850 double acting engine abandoned – single cylinder with steam acting on top of piston. Pitwork is by now all plunger pumps every 20-30 fathom. Bottom pump only is still the old bucket or lift pump Diagram of bucket and plunger pumps	Barton p 88 Barton p 91
	Pumps	Usually cast iron 9ft long, diameter 6" to 20", diameter increases towards the top of the shaft. Pumps lined with slips of wood or occasionally bronze. Buffalo or rhino hide used for the clacks. Pine used for pump rods is usually imported.	Barton p 92
1850->	Boilers	Boiler explosions occurring periodically. Engine men blamed by owners but enquiry in 1870s concludes that corrosion and operating pressures were the main cause	Barton p 116
1850->	Engines	Engines and machinery moved frequently from mine to mine especially in the later 19th C	Barton p 118
1850s	Perran	Perran Foundry name changes to William's & Perran Foundry Co about 1850	Barton p 154
1850s	Copper	The value of copper mined in Cornwall in the 1850s is about twice that of tin. It is estimated that three out of four miners in Cornwall are employed in copper mining	Rowe p 305
1856	Duty	Bushel replaced by cwt in duty calculation	Barton p 59
1850s	Duty	Decline in reported duty of engines probably to avoid breakages and because of declining coal quality	Barton p 60->
1850s	Boiler pressure	Boilers run at about 40lb in^2 experiments with higher pressures not successful	Barton p 63
1856	Mild steel	Invention of the Bessemer process introduces mild steel	JTS3 p 28
1857	Strike	First recorded strike in the Cornish mining industry at Balleswidden due to cuts in wages	Rowe p 311
1858	Foundry	Perran advertises a boiler wagon for sale capable of carrying 40 tons	Barton p 123
1860s	Depression	Depression in Cornish mining. Trade in used engines and exporting engines develops in Cornwall	Barton p 64
1860s	Foundry	Hayle foundry have their own boats for moving engines with strengthened hatches and hold bottoms. Increasing use of the railway to move engines	Barton p 124
	Whims	Wire rope first used for winding about 1860	Barton p 195
1862	Inverted engine	Last inverted engine built in Cornwall (continued elsewhere until the end of the century)	Barton p 108
1865	Engines	554 Engines recorded working in Cornwall	Barton p 252
1866	Copper	Copper slump/depression = hard times for Cornish miners	Rowe p 310

Date	Event	Detail	Source
1866	Emigration	Estimated that 'no less than 5000 Cornish miners' had emigrated in 1866 in search of work	Rowe p 319
1868	Engine	80" engine drawing 1868	Barton p 77
1867	Copperhouse Foundry	Passes into the control of Harvey's and closed two years later in 1869.	Barton p 157
1870s	Waterworks	90" engine sold for waterworks use	Barton p 71
	Steel ropes	From 1870s onwards steel capstan ropes come into use	Barton p 233
1873	Engines	Last big engines 90" & 85" for Cornwall by Perran Foundry	Barton p 71
1870s	Depression	Mines closing and engines idle. Rock bottom prices for second hand engines. Cornish foundries on short time	Barton p 72
1879	Perran	Perran foundry closed	Barton p 159
1880s	Foundry	Increasing use of traction engines to move machinery	Barton p 130
1890s	Depression	Pitwork often left in deeper parts of mine. Buyers for larger engines but below 50" scrapped wholesale	Barton p 76
1903	Harveys	Harveys foundry at Hayle closed	
1906	Pumps	First use of electric pumps at Tywarnhaile Mine near Porthtowan	Barton p 79
1909	Duty	Engine duty reporting ends	Barton p 79
1913	Engine	Last big Cornish engine built in the county – 36" by Charlestown Foundry	Barton p 80
1919	Man engine	Man engine failure at Levant - 31 killed and 11 serious injuries	Barton p 218

Appendix II - Analysis of Socketed Pipes by Brian Gilmour

Introduction

Degradation of iron under conditions of long term immersion in sea water presents very particular and challenging problems for identification and analysis of any ironwork involved. For storage his kind of ironwork should be kept wet, carefully packed and handled to avoid further degradation. The ironwork involved in this case here consists of long, relatively thin-walled tubes which could in theory have been made either of wrought iron or cast iron, both having been suggested. The aim of the present investigation was to answer this problem of identification – are these tubes made of cast or wrought iron?

Several fragments (measuring 5-10 cm long) of very degraded iron tubing from the Wheel Wreck site were submitted for detailed examination to see if it was possible to identify the type of iron used – wrought or cast iron – and also to look at the significance of the results for the assessment of the overall technological dating of the site. On one of these fragments a raised longitudinal line on the surface suggested the presence of a probable junction of two parts of a mould, which in turn would suggest that these tubes were cast (Fig. 1), although it is also possible that this line is misleading.

Fig. 53
Fragment of iron tube showing a longitudinal line across the middle of this view, this being the likely junction between two mould parts

Examination of the iron tube fragments

All the fragments submitted were clearly very degraded with little metal surviving although there was some response from a small metal detector suggesting that at least some small fragments or three-dimensional network of metal survived. This being the case it was suspected that further consolidation may not be necessary for the purpose of sub-sampling and microscopy. To test this two lateral slices were taken from across the tube fragment at right angles to the possible casting line observed on the surface. Given the suspected presence of an internal surviving supportive structural framework these slices were carefully and successfully dried out ready for mounting (in an epoxy resin block). The block containing these sub-samples was then prepared for photomicroscopy (HM1262a).

At low magnification the evenly corroded nature of the tubes through the thickness of the wall can be seen here in section (Fig. 2). It is also clear in the central part of the section visible here (in Fig. 2) that the tube wall is thicker on one side of the longitudinal casting/mould line visible on the surface (in Fig. 1). The relatively thin walls of the iron tubes varied in thickness measuring approximately 11mm and 12mm either side of the line marking the now more probable position of mould junction (Fig. 2). The inside diameter of the tubes was approximately 100mm. Thus when the prepared sections are viewed life size we get a much clearer indication of the likelihood of these tubes having been cast but it is still necessary to demonstrate that this is the case and to find out what kind of cast iron might have been used.

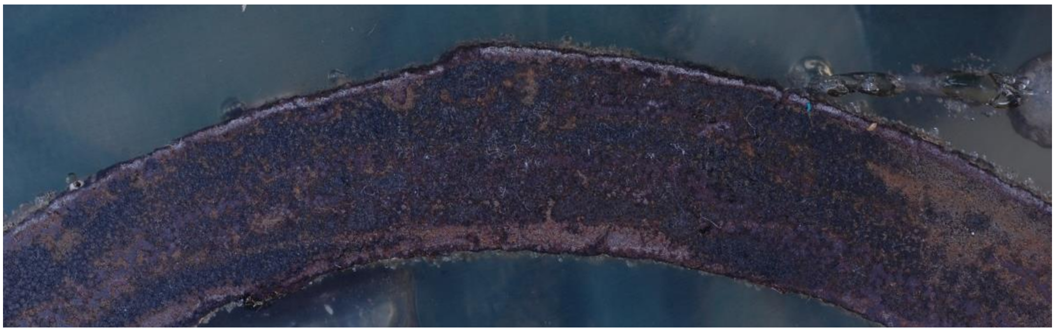


Fig.54
Prepared section through the same piece showing the overall corroded nature of the iron and the differential thickness of the tube either side of the line marking the position between two mould parts

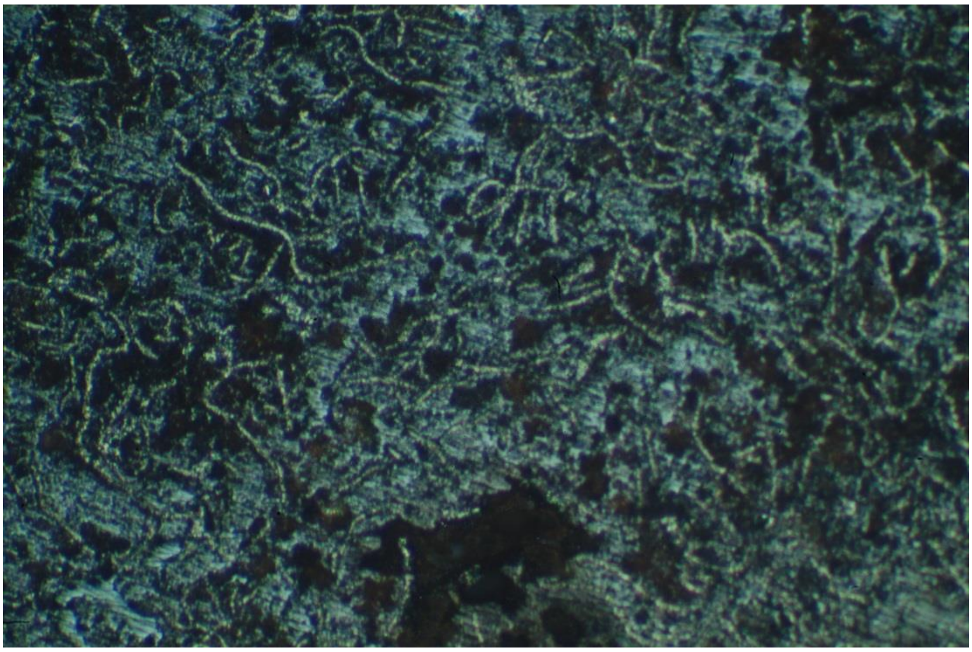


Fig. 55
A relic framework of cementite (iron carbide) showing here as the white lines surviving in a generally corroded matrix of the original white cast iron metal (field of view is about 1mm across thus the magnification as shown here is approximately x100)

In section at higher magnification it became clear that although most of the iron was lost to corrosion a sponge-like relic framework of cementite (iron carbide) from the metal survived which was enough to identify the original metal of the tubes as having been a hypo-eutectic white cast iron the original carbon content of which was very approximately 3-4% (Fig. 3). In section this shows up as a series of interconnecting white lines in a corroded matrix of what was once a ground mass of pearlite. Thus although the tubes are now almost entirely corroded we can still see that they were originally made of white cast iron. This survives only as a sponge-like network of cementite (iron carbide showing as the white lines in section) showing that the corrosion process was not quite complete. It is not unusual for iron corrosion either to be not quite complete or to be slow enough for some relic structure of the original metal to survive. A relic structure like this is often the only way of identifying the original type of ferrous metal used.

Technological and dating implications

From a dating point of this is suggestive that the tubes were probably made somewhere between the early to mid-18th century – when foundry technology would have advanced enough to make the production of relatively thin-walled cast-iron tubes viable – and the earlier 19th century after which iron tubes like this are more likely to be cast as the more durable grey cast iron, cast iron making technology having advanced again by then.

Despite these tubes having been initially suggested to have been ‘boiler’ pipes, thin walled white cast iron pipes would have been unsuitable for this because the metal is too brittle and prone to distortion and shrinkage on casting. It would have been much more suitable for water pipes, perhaps associated with mine drainage.

Different branches of iron (and other metal) technology went through a series of changes and advances at different times through the Industrial Revolution. The upshot of this is that the analysis of a variety of metallic objects is likely to yield a series of overlapping date ranges. This in turn means that it should be possible to achieve a closer overall dating span for the metalwork from this (and other) wreck sites by putting together the results of the different analyses from any one particular site. For instance, had the tubes been found to consist of wrought iron it may have been possible to say whether or not the metal was likely to predate or postdate the period 1785-95, depending on the nature of the wrought iron used. This may still be possible if and when any wrought iron from the same wreck site is examined.

Appendix III Wheel Wreck Candidates by Serena Cant

1. Background:

1.1 The Wheel Wreck, located 300m south of Little Ganinick, Eastern Isles, Isles of Scilly, was designated under the Protection of Wrecks Act 1973 in 2007.[i]

1.2 It comprises a cargo mound of the eponymous wheels without any associated ship's structure, suggesting a vessel constructed of timber, organic material which has disappeared. This cargo is mining equipment, specifically interpreted as pumping equipment.

1.3 As currently interpreted in the present designation, this cargo is believed to originate from a Cornish foundry and to date to around 1850, but to date remains unidentified.

1.4 However, it appears that the majority of possible candidates for the identification for the wreck antedate this period by some margin (first half of the 19th century). The pumping function may suggest that it was destined for some other contemporary industry, such as, for example, sewerage works in London, or for export.

1.5 The site may even date back as far as the latter half of the 18th century[ii] and the material may be of Welsh origin, destined for Cornwall or elsewhere.

1.6 The *Wheel Wreck Investigation 2018* project 7698 aims to obtain a better understanding of its date and origin. As part of the methodology Serena Cant (HE) has been approached to provide a list of candidates from the National Record of the Historic Environment (NRHE) database.

1.7 This work has been split into three strands:
wrecks of Welsh origin 1800-1899; other wrecks 1800-1899; and wrecks 1750-1799.

2. Candidate Scoring

2.1 Chronological searches were run on the NRHE database using the base parameters **Casualty** (i.e. documented wreck event) + **date** = 1800-1899 + **location** = Isles of Scilly.

2.2 It was crucial to score on documented wreck events only, since by definition wreck sites are excluded from being possible candidates for the Wheel Wreck (with one possible exception).

2.3 The first tranche of wrecks were additionally scored with Wales as an originating or destination port, with a cargo of iron where that was made explicit, resulting in **82** hits.

2.4 The second tranche was thrown open more widely using the base parameters as expressed in **2.1** only, resulting in **271** hits.

2.5 The third tranche, resulting in **165** hits, changed the date parameters to **1750-1799**.

2.6 Data is occasionally sparse, with any or all of departure port, destination port, or cargo often missing, partly as a result of historical survival rates of primary sources, and partly as a through the sift for inclusion in *Shipwreck Index of the British Isles* Vol. 1, which comprises the greater part of the source data for the NRHE database.

2.7 Where possible further research was undertaken in the British Newspaper Archive to assess a candidate for inclusion or elimination, particularly in terms of location, voyage or cargo. This was especially the case where the location was unspecified, e.g. 'stranded among the Isles of Scilly'.

2.7 All candidates were scored on their departure, destination, cargo, location, manner of loss, and whether recovery of the vessel took place. Location and recovery were the features most likely to result in automatic elimination.

3. Remarks on Tranche 1 and Tranche 2 candidates

3.1 The highest-scoring candidates are listed in chronological order as follow below. Where no detail (e.g. location) is given, this is because the information is missing at the present state of the record (though some records have been improved). Some candidates may repay further research for inclusion or elimination.

3.2 It is noteworthy just how vague many records are in terms of position of loss, although towards the latter half of the period more specific locations tend to be given, and more information tends to become available from multiple sources. These observations are valid for Tranche 1 and Tranche 2 candidates

3.3 It is also notable among Tranche 1 and Tranche 2 candidates how few records specify a location of loss towards the eastern part of the Isles of Scilly.

3.4 Conversely, some candidates may be eliminated on the grounds of a very precise position of loss being given, e.g. on the NW side of a named island.

3.5 The most credible candidates to emerge from Tranche 1 are the ***Victoria*** (1838) and the ***Plenty*** (1840) which have most in common with the Wheel Wreck in terms of cargo, location, and voyage details consistent with one of the export theories for the wreck (i.e. Wales for Cornwall), and with the attributed mid-19th century date for the wreck (mid-19th century being interpreted as the second third of the 19th century, i.e. 1834-1867).

3.6 The ***Bordelaise*** (1874) may also be in contention, particularly in terms of location, on the Hats, Crow Sound,[iii] although the cargo of railway iron may be an eliminating factor.[iv]

3.7 The ***Emma (***1843) and ***Pauline*** (1861) may be the Tranche 2 candidates which may repay most investigation

4. List of Tranche 1 candidates

1801 ***Thomas and William*** (880077), 'lost', Isles of Scilly, Neath for Falmouth

1804 ***Padstow*** (878573), 'wrecked', Isles of Scilly, Cardiff to London, iron

1814 ***Good Intent*** (1217705), burnt and sunk off Isles of Scilly as a result of privateer action, Newport for Teignmouth

1817 ***Linnet*** (878615) stranded on Crow Bar while waiting to enter St. Mary's

1820 ***Shannon*** (1224224) wrecked among the Isles of Scilly, Newport for Dartmouth

1833 ***Searcher*** (1392799), foundered in or near the Isles of Scilly, Cardiff to London with coal

1838 ***Victoria*** (878671), stranded on Crow Bar, Newport for Newcastle-upon-Tyne with iron and tin plate

1840 ***Plenty*** (1124610), grounded and foundered 1 mile east of the Eastern Isles, outward-bound from Newport with iron

1867 ***Good Intent*** (858270), grounded and foundered among the Eastern Isles, outward-bound from Cardiff with coal

1874 ***Bordelaise*** (858307) stranded on the Hats, Crow Sound, Newport for Oporto with railway iron, partially salvaged

1884 ***Moel Rhiwan*** (858669), sprang a leak and foundered NE of the Isles of Scilly, Newport for Valparaiso with coal.

5. Tranche 2 Candidates

1807 ***Duck*** (878579) Stranded on the Isles of Scilly, while bound from Padstow for Falmouth

1838 ***Paquebot de Cayenne*** (878677) grounded and bilged on Hats Ledge, Crow Sound, Rio for Le Havre with hides, coffee. Perhaps unlikely in view of voyage

1843 ***Emma*** (878696) stranded on Crow Rock, Crow Sound, Liverpool for Livorno with iron and bale goods, vessel sold, iron recovered or partially recovered, unclear if moved for breaking

1844 unknown brig (878702) seen to founder from St. Martin's – this may indicate it was on the eastern side of St. Martin's but perhaps too doubtful – would merit some research

1861 ***Pauline*** (859236) stranded and bilged on Crow Bar, Crow Sound, Ardrossan for Rouen with railway iron

1882 ***St. Vincent*** (1146770), grounded and foundered at the entrance to Crow Sound, St. Vincent's for IoS, sugar and cotton goods. The possible remains of the St. Vincent are charted less than 0.5 mile away but these remains are unconfirmed as that vessel, though the voyage details make it unlikely.

6. Remarks on Tranche 3 candidates

6.1 Details for late 18th century wrecks are generally much sparser than those for 19th century wrecks, particularly for cargo, consistent with the increasing development of wreck details over the course of the 19th century.

6.2 Additionally, where a precise position of loss is given, it may be derived from a secondary source and may not be reflected in the primary sources: for example 'lost at Scilly' against 'Pednathise Head'. These may, of course, be derived from intervening sources.

6.3 Unlike Tranches 1 and 2, no records have yet been researched for their potential to shed light upon the documented events, simply because there are so many (165) and because they are likely to be radically improved by the access to documentary sources in the British Newspaper Archive.

6.4 It has therefore not proved possible to eliminate many vessels on location grounds, although voyage details may eliminate more. Further research may similarly reveal candidates for inclusion.

6.5 As with previous tranches, it was notable how few records specified a location of loss towards the eastern islands.

6.6 Nevertheless a number of candidates are recommended for suitability for further research as to their potential for the identification of the wreck site, on a 'first pass' trawl basis.

6.7 These candidates all have differing characteristics and points of contact with the desired characteristics of the wrecked vessel (e.g. iron cargo or voyage from Wales to Cornwall).

6.8 As all the candidates with readily identifiable potential date from the last quarter of the 18th century, this suggests that records for that period should be targeted for improvement in the first instance to yield more candidates, in a 'second pass' analysis.

7. Tranche 3 Candidates

1775 *Weddel* (880183) Stranded on a rock ledge, thence possibly removed to Hugh Town?, Hull for Grimsby with iron and textiles

1787 *Duke of Cornwall* (880223), 'tin ship' from London for Falmouth with general, St. Agnes (which may eliminate this vessel but suggests a potential vessel type to search for?)

1788 *Mary* (880224), stranded among the Isles of Scilly, en route from Truro for Swansea

1790 *Fanny* (1335917) stranded on the rocks off St. Mary's, Swansea for Falmouth

Appendix III endnotes

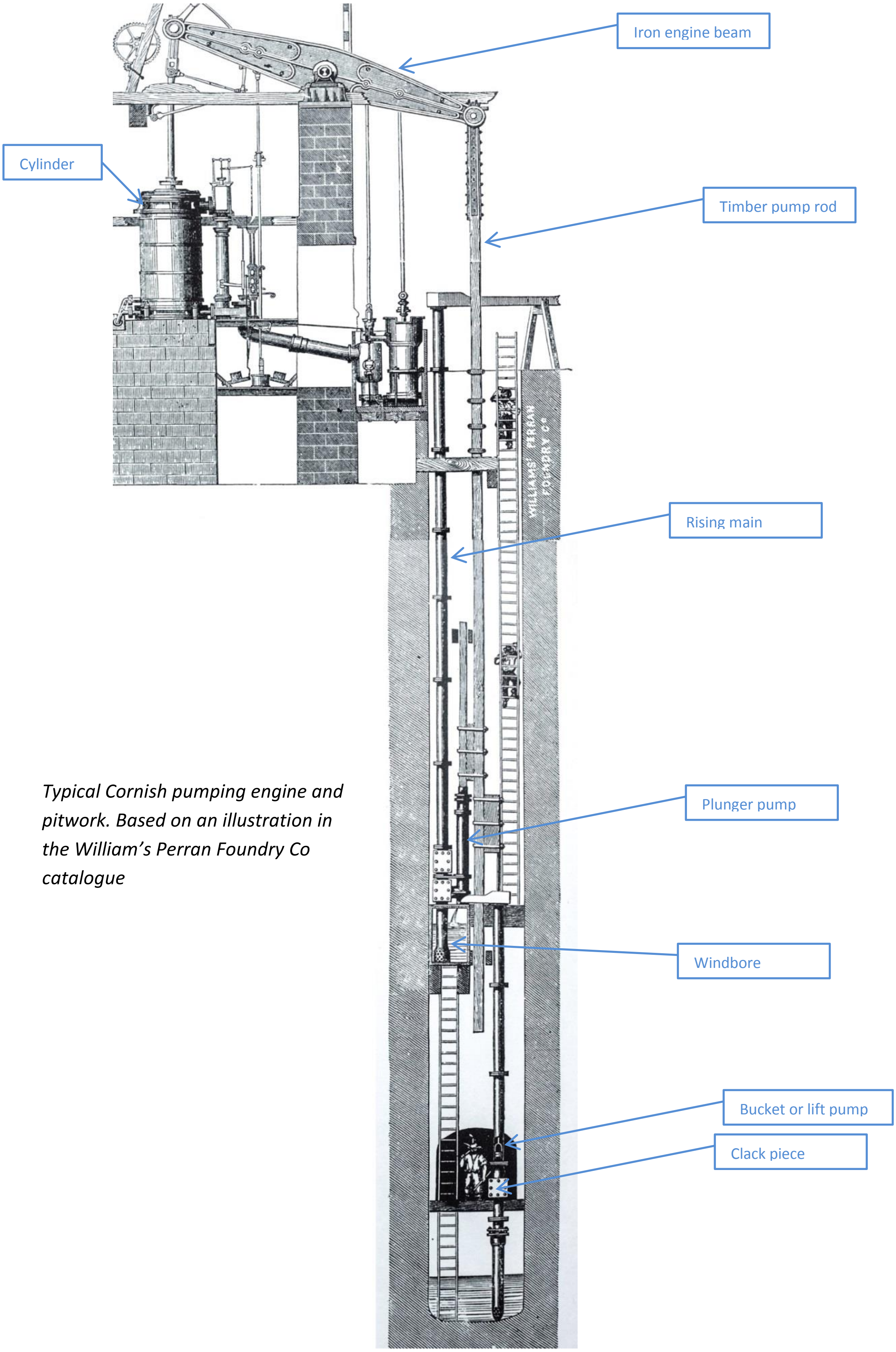
I Wheel Wreck, Heritage List for England, 1000086: https://historicengland.org.uk/listing/the-list/list-entry/1000086

Ii Kevin Camidge, e-mail correspondence with Serena Cant, 05.02.2018

iii The location of the Hats is described as follows: 'a sunken ledge, so called, which lies about half way between Sandy Bar, and one of the Eastern islands, called Great Ganinick, and likewise clear of the rocks that lie of Inazigan, on St. Mary's Shore'. Troutbeck, J, 1796: A Survey of the Ancient and Present State of the Scilly Islands Sherborne: Goadby and Lerpiniere, p98.

iv Interpreted as unlikely to be railway iron, from examination of cargo mound on cover photograph to Wheel Wreck Investigation 7698, Andrew Wyngard, pers.comm. to Serena Cant, 13.02.2018

Appendix IV – Cornish Pumping Engine & Pitwork



Typical Cornish pumping engine and pitwork. Based on an illustration in the William's Perran Foundry Co catalogue

Appendix V – Concordances by Tehmina Goskar

Cornish and South Wales foundries and their sources c1770-1830

Summary

- There is a lack of primary visual material relating to engineering and parts produced by Cornish and South Wales foundries with the exception of the engineering plans of **Neath Abbey Iron Company** at West Glamorgan Archives Service – these must be consulted in person owing to size and quantity; the 1870s catalogue of **Perran Foundry,** 1884 catalogue of **Harvey's of Hayle** and possibly the undated catalogue of the **Tuckingmill Foundry Company** remain the best visual sources for Cornish foundries (identified to date)
- Huge amount of detailed, descriptive information in the ledgers of various foundry business archives such as **Harveys of Hayle** (at Cornwall Record Office). These must also be methodically searched in person
- Based on the 3D still imagery of the wreck Pumping machinery experts from **Claverton Pumping Station** have confirmed our hunch that the Wheel Wreck's cargo strongly resembles the parts and machinery of a water pumping system such as used at Claverton (for managing waterflow for canals, in this case the Kennet and Avon Canal)
- Comparative evidence of pumping machinery used in non-mining scenarios suggest there was movement of **already old/secondhand** foundry material for new works/purposes. This means that there is no reason to assume that the Wheel Wreck's cargo must have originated in Cornwall or Wales so a search for visual material would need to be much broader in timespan and geography.

Aims of the research project

To identify the ship, its dates and the origin of the cargo of the Wheel Wreck. To create a brief concordance of primary sources that may lead to positive identification of the cargo of mining/water pumping machinery, and the ship that was carrying it.

Investigations

Primary documents, archives and contemporary periodicals, particularly those with visual material:

- British Newspaper Archive and selected indexes e.g. *The Cambrian*
- Cornwall Record Office
- Royal Institution of Cornwall (Courtney Library)
- Cornish Studies Library

Finds:

- Finds Research Group
- Social History Curators Group

Primary research question

- Which Cornish foundries were in operation in the supposed period of the wreck and what are their sources?

Related research questions

- From when do the glass and pottery finds date? (currently thought to be late 18th century and tentatively 1770-1830 resp.)
- What can be found out from any makers marks that are revealed?
- Are the iron artefacts mainly wrought or cast iron?
- Which reported shipwrecks have a documented cargo?
- Is it possible the ship survived the disgorging of the cargo?

Foundries in operation

Cornwall/West Devon		
Harveys of Hayle aka Harvey and Company	1779-1903	Prime candidate. Produced machinery for mining, town and canal water pumping and drainage
Perran Foundry, Perran-ar-Worthal aka Foxes & Perran Foundry (until 1858) Williams & Perran Foundry (until 1879)	1791-1879	Prime candidate. Produced machinery for mining, town and canal water pumping and drainage; catalogue forms best visual contemporary source to supposed date range of Wheal Wreck cargo.
Copperhouse Foundry, Copperhouse, Hayle *aka* Cornish Copper Company Sandys, Carne and Vivian	1820-1869 sold out to Harveys	Prime candidate. At height matched Harveys in scale of operation including winning contract to supply Kew (London) with water pumping engines. Pre-1840 main focus was mining machinery for Cornish, Welsh and Irish trade; also bridges, ships from 1850, marine engines and bellfounding. See also Pascoe, pp. 113-114 for contracts list 1855-64
Mount Foundry, Tavistock	1805-	Possible candidate. Most closely associated with the canal, as its proprietors were its promoters and principal shareholders; manufacturing plant and equipment for them in the form of wrought iron boats, water wheels, plate railways and a cast iron aqueduct.

Charlestown Foundry	c1827-	Possible candidate. Mainly produced for local china clay industry and some regional mines; old or little used mining machinery is attested to have been sold off for canal pumping works, for example for the Thames and Severn Canal in the 1850s (see below).
Vivian's/Tuckingmill Foundry	c1835-	?
Holmans, Camborne	1801-	Too late?
South Wales		
Neath Abbey Iron Works aka Neath Abbey Iron Company	c1785-1880	Prime candidate. Perran Foundry moved its boiler and machine manufacturing operations from Cornwall to Neath Abbey Ironworks by **1800**—Neath gets international reputation as supplier of machines and parts to mining and other industries; in 1812 supplied pipes to Claverton Pumping Station (complex for managing water for the Kennet and Avon Canal); made first harbourside crane for Falmouth Quay
Britannia Foundry, Newport	1854-	Capable of casting 20 tons of iron per day and large machinery

Archival sources

Foundry	**Dates**	**Sources**
Harveys of Hayle	1779-1903	Cornwall Record Office • H/1/1-42 – Incoming correspondence (letters and letterbooks),1829-1851 • H/2 – Outgoing correspondence 1791-1935 • H/3 – Ledgers 1809-1907 • H/15 – Stock inventories 1815-1899 • X475/10-12 – Inventory of stock, Hayle Foundry, Harvey and Company, Hayle, 1812-1848 • H/80 – List of names of ships and masters of Harvey and Company, 1800-1910 • H/1/185/33-36 – Contracts, removal of engine and supply of new engine, Kent Waterworks Company, 23 Jul 1880-26 Jan 1887 • AD225/27 – Letter from John Protheroe, metal broker, Nicholas Lane, London, seeking orders, 20 Jul

Foundry	Dates	Sources
		1844 • AD642/8 – Correspondence, regarding castings for Laity Mills, Redruth, 1834-1883 • AD2077/3/11 – Correspondence between John Harvey, Penzance and Mrs Pascoe, Apr-May 1843 • FS/3/1203 – Photocopy of patent specifications for valves for hydraulic machines by Richard Jenkyn, Hayle, 1841 • X578 – Engineering papers and plans, 1844-1977 • X725 – Harvey's of Hayle engineering drawings, 1819-1977
Perran Foundry, Perran-ar-Worthal aka Foxes & Perran Foundry (until 1858) Williams & Perran Foundry (until 1879)	1791-1879	Cornwall Record Office • AD1898/1 – Engine plans, Volume of engine plans, Perran Foundry, Mylor, 19th century • CF 4004-4010 – Accounting and misc records, 1842-83
Copperhouse Foundry, Copperhouse, Hayle *aka* Cornish Copper Company Sandys, Carne and Vivian	1820-1869 sold out to Harveys	Cornwall Record Office • J/1/780 – Valuation of stock of Cornish Copper Company and allied papers (Sir C. Hawkins had a financial interest), 1833.
Holman Brothers Limited, Camborne	C1875-	Cornwall Record Office • X542
Neath Abbey Iron Works aka Neath Abbey Iron Company	c1785-1880	West Glamorgan Archive Service • DD NAI/1- Administrative records • DD NAI/4 – Plans of machinery • DD NAI/22 – Pipes for conveying water, 1823 • DD NAI/25 – Steam pipes, 1823

Advice on using archival sources

West Glamorgan Archive Service:

- Contains visual material from this period
- The Neath Abbey Ironworks collection is very extensive (around 8000 plans), dating from 1792 onwards
- Beautifully drawn and include the small details as well as the overall nature of the piece, "so with a lot of work and a bit of luck, it should be possible to match engineered parts to the original drawing."
- Digitising the plans would be a monumental undertaking
- The series entitled 'Plans of machinery' (DD NAI/4) is the most sizeable, consisting of thousands of plans
- Costs of copies, £2.50 per plan
- To organise a visit contact: archives@swansea.gov.uk

Cornwall Record Office:

- Harveys of Hayle collection contains extensive ledgers 1809-1907 (H/3) which are extremely detailed records of what was being made, who for and costs
- No specific series of drawings within either of the Harveys or Perran collections; there might be small sketches within certain material in the collection which would require systematic searching
- CRO also has access to shipping registers, harbour masters' reports and log books of departures may be helpful after other research has narrowed down dates and location
- To organise a visit contact: cro@cornwall.gov.uk
- CRO will be closed to the public from **September 2018**

Newspaper sources

Top-level searches into the British Newspaper Archive and the index of *The Cambrian* (major South Wales newspaper) has not revealed any notable visual or descriptive information about these foundries in this period. A systematic (rather than search term-based) search *may* reveal more.

Nothing notable in shipping lists that describe cargoes, not already proposed regarding possible candidate ships.

Expertise from Claverton Pumping Station

Three volunteer engineers from Claverton Pumping Station looked at the wreck photography and 3D models on the website.

1. PD, leader of the Claverton Pumping Station Group.

“The pictures as you say clearly show a pile of engine and pump parts The **large ring is not dissimilar to our flywheel and the star shaped part next to it is most likely the center hub and spokes of the flywheel**.

There is no sign of a steam engine beam that I would have expected to be part of a pumping engine that required a flywheel. I expect that it could be there but **as a beam would be heavy it may have been loaded first and is therefore under the pile**. The **beam could also have been made of timber** so would not have survived like the rest of the ship. However this may also help dating as **cast iron beam were not used until 1800** or thereabouts.

As you say the ship may have left the South Wales coast from the Neath Iron Works or the Fox foundry. Have you looked at the archives held by the Swansea Museums I believe that the Fox archive is quite extensive. *Note: Yes this refers to the Neath Abbey Ironworks Collection, see above.*

We do not know exactly where our pump parts were cast despite a lot of research.

The design of the larger casting would suggest that they of Boulton & Watt manufacture. However the Bolton & Watt archives have no record of ours. It would seem that John Rennie probably produced our pump in his London Foundry they would have probably been shipped along the Kennet & Avon Canal Anything from Fox & co would have come across the Bristol Channel into Bristol and transferred to canal barges then on to Claverton.”

Note: According to Grace’s Guide the Claverton parts and machinery were made at Neath Abbey Iron Works around 1812.

<u>2. DH, volunteer at pumping station, SCUBA diver and amateur IA.</u>

“I have some thoughts on possible sources eg Railway & Canal Historical Society and their members, together with the various industrial archaeological societies around the UK. The Boulton & Watt archives are a useful source and the Think Tank in Birmingham has good displays of pumping engines.”

<u>3. JB, offshore technical engineer, wreck diver and volunteer at the pumping station.</u>

“it does indeed seem to be a collection of flanged piping which could be risers or flow lines, cable pulls/guides and what looks like a head gear which the central spider has broken from the rim. There are other **pipes which look socketed for running water**.”

Library sources

Pamphlets, small publications and periodicals in addition to some boxes of unpublished manuscripts at the **Cornish Studies Library, Redruth**. The search identified several pamphlets and publications relating to Cornish foundries in addition to a book about canal pumping (see references).

- The comparative size of the Wheel Wreck's cargo and descriptions of the output of minor foundries in Cornwall may suggest that this *could* have been the output of a smaller foundry rather than the larger players assumed so far
- The foundry cargo may also have been used/secondhand machinery bound for a new purpose and a new place as suggested by Michael Ware (1979, pl. 25) in the example of the **Thames and Severn Canal**:

    > "In 1853, the committee authorised him to go ahead, and in little over six months, Taunton had found, bought and installed a second-hand engine built in 1852 by Thomas and Company of the Charlestown Foundry for Wheal Tremar, near Liskeard, and scarcely used before the mine closed down… the parts were shipped from Looe on 8 February 1850."

- London and other Water Boards were significant customers of Cornish foundries such as the Copperhouse Foundry and Harvey's of Hayle for pumping machinery in mid decades of 19th century. Brentford, Battersea and Croydon pumping stations were all supplied by Cornish foundries; also East London Waterworks (pair of filter engines) and Leek in Staffordshire (Harris 1960, p.18)
- Manuscript files of T R Harris contain correspondence researching the destination of Cornish foundry machinery and parts for water boards including Staffordshire Potteries Water Board, Stoke on Trent; also notes on scrapping and reuse (see PDF, T. R. Harris Collection Box 7 Foundrys [sic] and Engineering)
- Contemporary issues of the *Journal of the Royal Cornwall Polytechnic Society* carried detailed drawings of machines but none were identified to resemble a single or part of a machine represented by the Wheel Wreck cargo
- Accounts of the foundries of Cornwall in the same periodical shed light on the kinds of parts and machinery each foundry produced, and specialised in outlined in summary above (see also PDFs).

Log

Date	Source	New information
29 May	John Allan, Exeter	Pottery evidence suggests 1770-1830
30 May	Finds Research Group	Query sent to bottle experts, awaiting photography
30 May	World Heritage Site	By 1840 Cornish engines and engineers were most distinguished in the world. Mine engines despatched to South America, Ireland, South Africa and Australia
31 May	Goskar, Made in Metal, p. 82	Perran Foundry moved its boiler and machine manufacturing operations from Cornwall to Neath Abbey Ironworks by 1800—Neath got international reputation as supplier of machines and parts to mining and other industries; Made first harbourside crane for Falmouth Quay
1 June	Video of pit wheels in action	Claverton Pumping Station on Kennet and Avon canal (supplied by Neath Abbey Iron Company 1812) machinery used for canals. Includes a pit wheel very similar to those on the Wheel Wreck. In 1844 Harvey's supplied parts, including Harvey and West double beat water valves, to Claverton Pumping Station
12 June	Photographs of bottle finds	Sent to Finds Research Group for identification.
12 June	Visual material in archives	Enquiries made to West Glam Archives and CRO.
12 June	Visual material relating to pumping stations	Enquiry made with Claverton Pumping Station for expertise in this machinery.
15 June	Visual and descriptive material in pamphlets, ephemera and periodicals including Journal of the Royal Polytechnic Society of Cornwall which carried many engineering articles and illustrations.	Evidence of older, second hand foundry pumping equipment bought and shipped to new destinations/sites (Michael Ware, *Britain's Lost Waterways*, vol. 2 Navigations to the sea, 1979), pl. 25. It is clear that a Cornish or South Wales foundry need not be obvious candidates to have produced the artefacts of the Wheel Wreck. It is also possible that this is not the machinery and parts of a massive water pumping complex and so the range of foundries that could have produced these materials is greatly increased. Research archive of engineering historian T R Harris contains a mix of original material and notes. No obvious relevant visual material.

References for Appendix V

Charles Barham 'Report by Charles Barham, Esq., M.D., on the employment of children and young persons in iron foundries in the West of England: and on the state, condition, and treatment of such children and young persons', *Children's Employment Commission*, Children's Employment Commission, 1842.

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Stephen Michell, Joseph Hambley Rowe ed., 'The Early History of Hayle Foundry, 1770-1833: Based on Material Collected by the Late Stephen Michell of Hayle', *Journal of the Royal Cornwall Polytechnic Society*, 1935 (offprint).

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(Pamphlet missing at Cornish Studies Library: 622.028)

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Claverton Pumping Station, Kennet and Avon Canal Trust, 2003.

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Robert Waterhouse, ‘Industrial Archaeology of the Tamar Valley’, Morwellham Archaeological Group, 2008 (accessed: http://www.tvia.org.uk/pages/ironfoundries.shtml).

Appendix VI – Chemical Analysis of the Bottles by Sarah Paynter and Florian Stroebele

Introduction

Project 7698 has investigated the Wheel Wreck site, in order to more accurately establish the date of the wreck. A large proportion of the cargo comprised cast iron, but this is difficult to date and often survives poorly in marine environments. In contrast the composition of glass changes quite rapidly in the post-medieval period due t developments in technology, which lends itself to dating, and glass often survives post-burial conditions in fairly good condition.

A number of visually similar cylindrical bottles were recovered from the wreck site, one from beneath the iron cargo, so at least that one, and probably all, can be associated with the wreck. Vast numbers of similar bottles were produced in Britain in the 18th and 19th centuries, and dispersed all over the world. Their typology is well studied (Jones 1986) and more recently data has been gathered on their composition too (Dungworth 2012). Here the composition of the Wheel Wreck bottles is used to estimate their possible date.

Material

Five fragments of glass were provided, listed in Table 1.

Table 1: the analysed finds

F1	Green bottle base, with kick and pontil mark, 1760s-1820s (Ian Scott)
F10	Green bottle base, neck and body 1770-1830 (John Allan, Jacqui Pearce)
F24	Green bottle base, with kick and pontil mark
F30	Green bottle shoulder
F46	Green bottle base and body

Typological study of the bottle fragments suggests that they date from about 1770 to 1820. They have a cylindrical shape, with a relatively straight neck. F10 has a slight bulge at the heel as well as a down-tooled lip and thick applied string rim (Figures 1 and 2) (Jones 1986). One bottle has been dated more closely, to the 1770s or 1780s (F31).

Figure 1: Photo of F10 by Kevin Camidge

Figure 2: Close up of neck and rim of F10 by Kevin Camidge

Another bottle from the wreck site, F31, was not sampled for analysis, but this fragment is from a green bottle neck, with a cracked-off, fire polished rim, and an up-tooled string, dated to around 1770-1780 by Ian Scott.

Method

X-ray fluorescence analysis (XRF) is a surface analysis technique that can rapidly provide quantitative data. The machine used was a Bruker Tornado M4. Freshly broken surfaces were selected for analysis to avoid glass that had been altered, either by weathering or due to deposits on the surface. Each fragment was analysed 5 times and the average and standard deviation are given in Table 2.

Results

Table 2: Average composition of bottles, determined by XRF, average of 5 analyses, normalised, with standard deviation in italics.

Bottle	Na_2O	MgO	Al_2O_3	SiO_2	SO_3	K_2O	CaO	TiO_2	MnO	Fe_2O_3	SrO	PbO	P_2O_5	BaO
F24	1.25	3.32	4.61	61.80	0.14	2.31	23.09	0.21	0.12	2.26	0.12	0.02	0.63	0.06
StDev	*0.23*	*0.21*	*0.07*	*1.21*	*0.01*	*0.09*	*0.63*	*0.01*	*0.00*	*0.06*	*0.02*	*0.00*	*0.02*	*0.00*
F1	1.78	3.06	3.03	61.68	0.31	2.12	24.57	0.16	0.12	1.85	0.14	0.08	1.04	0.03
Stdev	*0.25*	*0.12*	*0.04*	*0.30*	*0.01*	*0.01*	*0.08*	*0.00*	*0.00*	*0.04*	*0.01*	*0.00*	*0.03*	*0.00*
F10	2.20	2.23	4.51	62.25	0.28	0.90	24.72	0.26	0.12	1.96	0.13	0.02	0.42	0.02
StDev	*0.17*	*0.06*	*0.03*	*0.19*	*0.02*	*0.01*	*0.08*	*0.00*	*0.00*	*0.02*	*0.00*	*0.00*	*0.01*	*0.00*
F30	1.25	3.55	8.07	56.98	0.24	3.02	22.99	0.33	0.12	2.26	0.12	0.02	0.92	0.07
StDev	*0.13*	*0.05*	*0.05*	*0.24*	*0.01*	*0.01*	*0.19*	*0.00*	*0.00*	*0.04*	*0.00*	*0.00*	*0.02*	*0.00*
F46	1.16	3.29	4.58	62.50	0.14	2.27	22.69	0.20	0.12	2.20	0.10	0.02	0.62	0.06
StDev	*0.13*	*0.06*	*0.02*	*0.33*	*0.00*	*0.02*	*0.13*	*0.00*	*0.00*	*0.03*	*0.01*	*0.00*	*0.02*	*0.00*

Discussion

The chemical composition of the glass used for bottles changes over this period, largely due to different types of plant ashes being added to the batch (Dungworth 2012); in particular the strontium content increases sharply, probably due to kelp ashes being added instead of other ashes, resulting in a decrease in the phosphorus content at about the same time.

Figures 3 and 4 show the phosphorus and strontium contents of the Wheel Wreck bottles against plots of the changing composition of English bottles over the past four centuries. The Wheel Wreck bottles have strontium and phosphorus contents coinciding broadly with bottles dated from around 1740 to 1780. They are therefore more likely to have been made earlier in the date range suggested by their typology, so in the later 18th century rather than in the early 19th century. Therefore on Figures 3 and 4, the Wheel Wreck data have been shown at a date of 1770 for illustrative purposes, although the actual date is unknown.

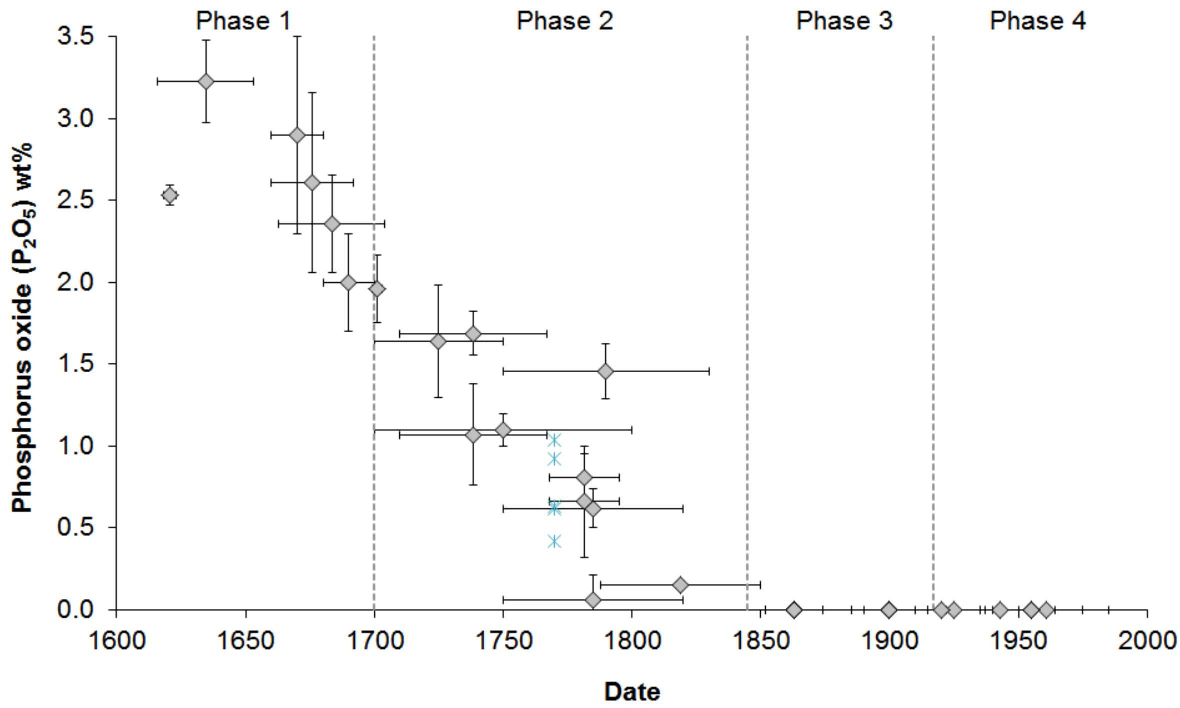

Figure 3: The Wheel Wreck bottles (blue star datapoints) shown against a plot of changing phosphorus content over time for dated English bottles (from Dungworth 2012)

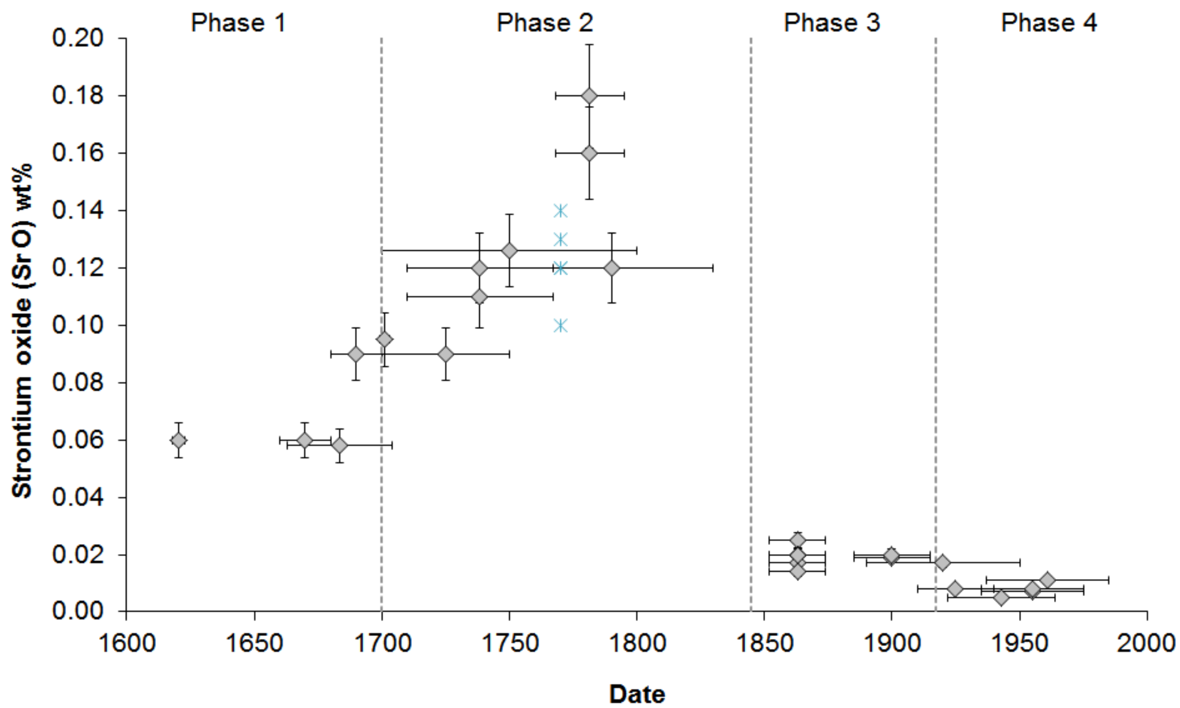

Figure 4: The Wheel Wreck bottles (blue star datapoints) shown against a plot of changing strontium content over time for dated English bottles (from Dungworth 2012)

Conclusions

Using chemical composition to estimate the date of bottles is a novel technique, and tentative at this stage until such time as more chemical data for securely dated bottles can be obtained. The Wheel Wreck bottles have fairly consistent compositions however, with relatively high strontium contents, which are consistent with a manufacturing date of towards the end of the 18th century (1770 to 1800), rather than the beginning of the 19th century. This agrees with the date of the 1770s / 1780s suggested for bottle F31 on typological grounds (although this was not analysed), and the spot dates for some of the pottery (17th/ 18th century), which increases confidence in the tentative date proposed for the bottles and by association the wreck itself.

References for Appendix VI

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Appendix VII – The Bottle Glass by Ian R Scott

The small bottle glass assemblage provides some limited dating evidence, but the reliability is restricted in part because the assemblage is very small, and also because there are no complete bottles and only one potentially near complete bottle, and there are only two rims (finishes) to help dating. Broadly the bottles can be confidently dated to the period from about the mid-18th century to the about 1820.

The problems come with trying to narrow down the dating. Late 18th and early 19th century beer and wine bottles were very similar and made of the similar glass. Beer quarts tended to be shorter and broader than contemporary wine quarts, but the complicating factors are that different quart measures were in use (Jones 1986, 29-32, 73-82) and that both beer and wine bottles tended to become taller and slimmer during the 18th century and into early 19th century. To be able date with any confidence it is necessary to be able to measure both body diameter and body height (base to bottom of shoulder) to distinguish wine bottles from beer bottles.

1 **Wine or beer bottle**. Base of dip-moulded cylindrical bottle with pronounced basal sag, and deep domed pushup. No clear pontil mark. Two refitting sherds. Dark green glass. D: 95mm x 94mm. Context F1.
The diameter suggests this could be either a beer bottle or a wine bottle; which it was cannot be confirmed without the body height. It could be a later 18th century wine bottle, beer bottles being a little broader generally at that date, or an early 19th century beer bottle. Late 18th to early 19th century

2 **Wine or beer bottle.** Two refitting sherds from shoulder neck junction. No diagnostic features. Dark green glass. Not measured. Context F1.

3 **Wine or beer bottle**. Sherd from the body of cylindrical bottle. Not diagnostic. Dark green glass. Not measured. Context F6

4 **Wine bottle**. Shoulder, neck and finish from a cylindrical wine bottle. It has a bulged neck, and a hand-tooled finish probably formed from the cracked-off rim by fire polishing and down-tooling. There is a thick down-tooled string immediately below. Dark green glass. Extant Ht: 120mm. Context F10.
Potentially could date from 1760–1800, but if it is the same bottle as No. 5 also from context F10, then it is probably a late 18th century wine bottle dating c 1780-1790.

5 **Wine bottle**. Most of the body of dip-moulded cylindrical wine bottle with pronounced basal sag and domed kick. No clear pontil mark. Dark green glass. Ht extant: 134mm; D: 90mm x 90mm. Context F10.
Possibly from the same bottle as No. 4. Diameter and extant body height would suggest that this is probably a wine bottle dating c 1780-1790.

6 **Wine or beer bottle**. Body sherd from a cylindrical bottle. No diagnostic features. Dark green glass. Not measured. Context F10

7 **Beer bottle.** Lower body of a dip-moulded cylindrical bottle with pronounced basal sag. Domed kick. No clear pontil mark but it is possibly square. Dark green glass. Ht extant: 77mm. D: 100mm x 105mm. Context F24
The diameter of this bottle indicates that it was a quart beer bottle rather than wine bottle. It probably dates to 1760 - 1790.

8 **Wine bottle.** Neck fragment from bottle with tapered rather than bulged neck. Dark green glass. Not measured. Context F30

9 **Wine or beer bottle.** Upper portion of a tapered neck with cracked-off finish and applied string rim, possibly up-tooled. The sherd is eroded especially around the rim and string rim, but the simple finish is unmistakable. Dark green glass. Ht extant: 51mm. Context F31
Dating 1750-1770, but could be as late as 1780.

10 **Wine or beer bottle**. Part of the base of dip-moulded cylindrical bottle, with slight basal sag and deep pushup. Dark green glass. D: c 100mm. Context F46
Could be a beer or wine quart.

11 **Wine or beer bottle**. Two refitting sherds from shoulder neck junction of a cylindrical bottle. No diagnostic features. Dark green glass. Not measured. Context F46

Reference

Jones, Olive R, 1986 *Cylindrical English Wine and Beer Bottles 1735-1850*, Studies in Archaeology Architecture and History, National Historic Parks and Sites Branch, Parks Canada