AGGREGATE LEVY SUSTAINABILITY FUND
MARINE AGGREGATES AND THE HISTORIC ENVIRONMENT

WRECKS ON THE SEABED:
ASSESSMENT, EVALUATION AND RECORDING

MULTIBEAM SONAR ON WRECKS

Variations to include:

GEOPHYSICAL SURVEY OF DESIGNATED HISTORIC WRECKS:
HMS *A1*, *HAZARDOUS*, *INVINCIBLE* AND *MARY ROSE*

TECHNICAL REPORT
Report Ref: 51536.05

Prepared for:

English Heritage

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Paul Baggaley undertook the geophysical interpretation. This report was compiled by Jens Auer and Paul Baggaley, and edited by Mark Lawrence. Mark Lawrence managed the project for Wessex Archaeology.

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1. INTRODUCTION

1.1.1. Wessex Archaeology was commissioned by English Heritage to undertake a geophysical survey of the following Designated Historic Wrecks: The *A1* submarine, the *Hazardous*, the *Invincible* and the *Mary Rose*.

1.1.2. In this report the general survey methodology employed on all sites and the post processing techniques will be described briefly. A detailed description of all methodologies can be found in the Year Two report for the Wrecks on the Seabed: Assessment, Evaluation and Recording project (51536.04). A separate chapter outlines the survey results and contains a brief description of the data collected.

2. GEOPHYSICAL SURVEY METHODOLOGY

2.1. GENERAL SURVEY METHODOLOGY

2.1.1. On each of the four designated sites a magnetometer survey, a multibeam sonar survey and a sub bottom profiler survey was undertaken.

2.1.2. To place the wrecks in their environmental context, extended areas around the sites were surveyed. This method served to provide baseline data relating to environmental processes on and around the targets.

2.2. MULTIBEAM SONAR

Introduction

2.2.1. Multibeam sonar ensonifies the seabed in the form of a swath beneath and to either side of the survey vessel deriving continuous and well positioned 'spot heights' for many thousands of points on the seabed as the vessel moves forward. Multibeam sonar is a development from using single beam sonar systems (i.e. ordinary echosounders) which gather more widely spaced single point depths in a line beneath

the survey vessel as it moves along.

2.2.2. Unlike sidescan sonar, multibeam sonar provides full bathymetric (depth sounding) data for every patch of seabed that is ensonified, allowing three dimensional digital terrain models to be created very easily. As with sidescan sonar depressions and features projecting from the seabed can be displayed.

System components, installation and calibration

2.2.3. The multibeam service provider Netsurvey Ltd. was commissioned to set up and carry out the multibeam sonar survey. The sonar was set up on board the 12.5 m Aquastar survey vessel EMU Surveyor belonging to EMU Ltd.

2.2.4. The sonar system used was a Reson SeaBat 8125 multibeam echosounder system with 240 dynamically focussed 0.5º beams, a swath coverage of 120º and a reported depth resolution of 6mm.

2.2.5. Components of the system comprised the sonar head itself, a sonar processor unit, sound velocity probes and a dual processor PC with increased hard disk capacity running Reson 6042 acquisition and survey software.

2.2.6. The vessel movement was compensated for with an Applanix POS MV (Position Orientation System for Marine Vessels), utilising two Novatel GPS antennas mounted on the A frame of the vessel at the stern, to deliver heading and motion information, a gyrocompass for heading information, and a motion reference unit to correct heave, pitch and roll.

2.2.7. Positioning was provided by a LEICA SR530 24-channel dual-frequency survey receiver with on-board RTK. A GSM compatible mobile phone was used to receive differential corrections from a base station placed at surveyed locations ashore.

2.2.8. The sonar head was attached over the starboard side of the survey vessel on a rigid pole arrangement around the midship point. The pole arrangement had to be such that no free movement of the head was possible relative to the vessel. The pole was therefore secured fore and aft with stays. An additional belly strap was used which ran from the base plate of the pole on which the head was mounted underneath the hull to a cleat on the port side. Subsequent problems with some of the data gathered indicated that some pole movement independent to the vessel hull was occurring.

2.2.9. One sound velocity probe was attached near the sonar head on the pole. The probe provided continuous measurements for the purposes of the beam forming process employed by the system.

2.2.10. A second sound velocity probe was present as a separate unit for the purposes of obtaining sound velocity profiles through the entire water column at regular intervals during the survey.

2.2.11. A separate sonar control unit (known as the sonar processor) to control the acoustic parameters of the sonar head was placed inside the wheelhouse alongside the system PC. Constant alterations using this processor unit were required during the survey, aided by a visual display of the raw sonar data. Various settings for range, gain and ping rate limited the number of bad soundings acquired during the survey.

2.2.12. Reson 6042 survey and acquisition software running on the PC was used to control the survey with a navigational chart backdrop for the positioning of survey grids and the provision of detailed navigational information (which could be displayed on a separate helm screen) to aid the vessel skipper during the running of survey lines.

2.2.13. Reson 6042 software co-ordinated a database of all aspects of the system setup which included all offset measurements between the various components and also relevant tidal data and water column sound velocity profile data. The software also created appropriate file folders during data acquisition to aid data file management.

2.2.14. The data collected by the system comprises Reson 6042 database files for each individual survey line, and optional point files (as XYZ ASCII text). The point files could be imported immediately into other visualisation software (such as Terramodel Visualiser or Fledermaus) to view the data just collected in three dimensions during or immediately after the survey. This was very useful in determining whether any problems existed with the data during the survey.

Survey Planning

2.2.15. The number of survey lines needed to obtain complete coverage of a wreck varied for each site due to water depth. Also it was sometimes necessary to run a survey line in a different orientation to the main survey direction to ensure complete coverage of the site notwithstanding acoustic shadows. Table 1 shows the multibeam survey details for each wreck site including the total number of pings recorded at each site.

Site	Number of survey lines and orientation	Number of soundings / pings
A1	2 lines NE-SW 2 lines NW-SE	963,000
Hazardous	9 lines E-W	7,731,500
Invincible	22 lines NE-SW	11,672,500
Mary Rose	8 lines E-W	7,703,500

Table 1. Summary of multibeam survey for each wreck site.

Post Processing

2.2.16. The first stage of post processing was conducted by Netsurvey Ltd using CARIS HIPS software to further clean the data by inspecting it swathe by swathe and deleting any erroneous or 'bad' soundings.

2.2.17. WA reviewed the resulting data using Fledermaus IVS. In the course of this review, some 'bad' soundings were re-incorporated into the results as although anomalous in terms of the overall seabed bathymetry, they were considered likely to represent archaeological features. Other soundings in the dataset were 'ignored', where, as a result of line to line overlays, they were detracting (by blurring and rounding) from the survey. The datasets as a whole were optimised for archaeological interpretation.

2.3. MAGNETOMETER

Introduction

2.3.1. Marine magnetometers are instruments that detect variations in the earth's total magnetic field. These variations may be caused by the presence of ferrous material

on or under the seabed, geological features or diurnal variations in the earth's magnetic field due to solar activity. Marine magnetic surveying has become a standard technique for mapping the location of ferrous material on the seabed.

2.3.2. Magnetometers are usually deployed within a towed fish arrangement at a sufficient distance behind the survey vessel to avoid any magnetic disturbances caused by the survey vessel itself. The magnetometer is typically towed near to the bottom along survey lines that are closely spaced.

2.3.3. Caesium vapour magnetometers, of the type used in this project, measure differences in energy caused by changing the orientation of a caesium atom's electron orientation to determine the strength of the ambient magnetic field. The important considerations here though are that caesium magnetometers offer a high signal to noise ratio, rapid sampling rates and small heading errors allowing subtle anomalies in the earth's magnetic field to be detected and therefore effectively allow detection of small amounts of ferrous material on the seabed.

2.3.4. Magnetometer data can easily be output in XYZ form i.e. geographical co-ordinates of the towfish (having corrected for its position relative to the survey vessel) and field strength at this position usually measured in nanoteslas (nT). It is then possible to plot the magnetic field and all the disturbances or anomalies that exist either as a series of points, contours or as a surface.

Magnetometer Components and Installation

2.3.5. The magnetometer and sub bottom profiler surveys were carried out by the marine survey company Emu Ltd. Both surveys were conducted simultaneously from the survey vessel *Emu Surveyor*.

2.3.6. A Geometrics G-881 caesium vapour magnetometer was used for the magnetometer survey. The G-881 is especially well suited for shallow water surveys from smaller boats.

2.3.7. Positioning was provided by the boats LEICA 420MX differential GPS. For data logging and display the Geometrics software package MagLog was used. This software allowed to control the sensor depth and provided the possibility to calculate the sensor position using a "dragging" algorithm.

Survey Planning

2.3.8. The following lines were run:

Site	Number of survey lines and orientation	Survey linespacing
A1	11 lines NE-SW	10m-20m
Hazardous	22 lines E-W	10m
Invincible	7 lines N-S	20m
Mary Rose	3 lines E-W 3 lines N-S	10m

Table 2: Summary of magnetic survey lines for each wreck site

Post Processing

2.3.9. The first stage of post processing of the data was to calculate and apply the layback positions to the data. This stage of post processing was carried out by Emu Survey Ltd.

2.3.10. The total magnetic field values as detected by the magnetometer were plotted as a series of points over the multibeam data.

2.4. SUB-BOTTOM-PROFILER

Introduction

2.4.1. Sub bottom profilers work on the same principles as a simple echosounder but make use of much lower frequency acoustic energy. Low frequency acoustic pulses penetrate below the seabed and into the sediment. Returning echoes from sub-bottom features such as underlying bedrock (geological strata) or buried material such as stone, metal or wood from a buried wreck site can be imaged.

2.4.2. Sub bottom profilers are usually deployed as a towed arrangement behind the survey vessel. The equipment is categorised by two of its principal operating parameters: penetration and resolution. To some degree both of these characteristics depend on the frequency content and bandwidth of transmitted pulses. The frequency content of acoustic signals generated by various types of sub-bottom profiling equipment ranges from several tens of Hz to several tens of kHz.

Sub Bottom Profiler Components and Installation

2.4.3. As with the magnetometer survey, the sub bottom profiler survey was carried out by Emu Ltd. from *Emu Surveyor*.

2.4.4. For sound emission, an Applied Acoustics AA200 boomer plate was used mounted on a CAT200 catamaran. An AA Capacitor Charging Unit CSP1500 provided the energy for the boomer plate.

2.4.5. An Octopus 360 recording unit received all data from the hydrophone and annotated positioning information in the form of fixes every 10m along the line rather than a unique position for each sounding.

2.4.6. The boat's LEICA MX 240 differential GPS was used in conjunction with a navigation software package for survey grid definition and positioning.

Survey Planning

2.4.7. The aims of the sub-bottom profiler survey were to try and determine the geological setting of the wreck sites and the presence of any significant pieces of wreckage which were covered by sediment and therefore unable to be detected by the sidescan sonar or multibeam systems.

2.4.8. As the sub bottom profiler only provided a narrow profile of data along the survey line, the number and orientation of the lines was governed by the requirements of the magnetometer survey which was recorded at the same time. This normally ensured that at least one survey line went over the wreck itself while the other lines provided

information on the surrounding geology.

Site	Number of survey lines and orientation	Survey linespacing
A1	11 lines NE-SW	10m-20m
Hazardous	22 lines E-W 9 lines N-S	10m
Invincible	17 lines E-W 3 lines N-S	20m
Mary Rose	4 lines E-W 12 lines N-S	10m

Table 3 Summary of seismic survey lines for each wreck site

Post Processing

2.4.9. As with the magnetometer data the first stage of post processing was to calculate and apply the layback positions to the data. This stage of post processing was carried out by Emu Survey Ltd.

2.4.10. Then a unique position for each sounding was calculated by interpolating between the fix marks in the data. This meant that any point of interest on the seismic trace could be accurately located and correlated with the multibeam and magnetic data.

2.4.11. Each line of the seismic data was interpreted to delineate boundaries such as the seafloor and other geological layers. The upper few metres of sediment were also examined for any short, strong reflectors that might indicate buried wreckage.

3. SURVEY RESULTS

3.1. INTRODUCTION

3.1.1. In the following section the results of the geophysical survey undertaken by Wessex Archaeology in 2003 are presented for each of the four sites.

3.2. HMS *A1* SUBMARINE (FIG. 1)

Site Location and Environment

3.2.1. The wreck of the *A1* Submarine is situated SW of Wittering on the South coast. The Wreck position is 50° 44.5511' N, 00° 55.2792' W (WGS 84, DDM). The general depth on site is 10m (CD). HMS *A1* was the first British designed and built submarine. She was commissioned in 1903 and lost with all hands off the Nab light ship in 1904 in a collision. The submarine was raised in 1904 and then mainly used for training and experimental purposes. In 1911 she disappeared during an unmanned exercise, when the tow broke. Despite of extensive searches the Royal Navy was unable to locate *A1*. The wreck was finally rediscovered by a fisherman in 1989 and designated as historic wreck in 1998.

Magnetometer Survey

3.2.2. The magnetometer survey took place on the 21st June 2003 in moderate sea state and south easterly winds force 3-4. Due to buoys in the area the survey vessel had difficulties to stay on track. A second attempt was made on the 26th June in a smooth sea state.

3.2.3. Altogether the site was covered by 11 NE-SW lines, with a centre line over the wreck and lines at 10m – 20m spacing to both sides.

3.2.4. The wreck is acting as one large magnetic dipole anomaly of 236,340nT, caused by the metal hull of the submarine.

Sub Bottom Profiler Survey

3.2.5. The boomer survey was conducted on the 26th June 2003 in smooth sea state. The survey was made very difficult by the high number of buoys and lobster pots in the area, and the sub bottom profiler snagged once. The wreck site was covered by 11 NE-SW survey lines, two of which (lines 6 and 7) went over the submarine.

3.2.6. While the upstanding hull is visible on both lines, it is impossible to detect buried wreckage. The seismic section in Figure 1 plate 5 shows approximately 10m of sediment before the appearance of the seafloor multiple. There are a number of strong, consistent reflectors between the seafloor and the seafloor multiple which indicate that the local geology underlying the wreck site was a conformable sequence of layers dipping towards the south. The BGS solid geology chart for the area shows that the bedrock underlying the site is part of the Headon Hill Formation (Late Eocene) which consists of soft marls, clays and sands. The BGS seabed sediments chart shows the area to be covered by sand deposits.

Multibeam Sonar Survey

3.2.7. The multibeam sonar survey was conducted on the 11th June 2003. A total of four survey lines were run, two NE-SW lines and two NW-SE lines, but only a single line was chosen for reprocessing.

3.2.8. The *A1* submarine is clearly visible on the seabed. It is resting on even keel at a slight angle but inclined from stern to bow. The stern is buried, while the bow is standing proud of the seabed. The hull lies in NE-SW orientation.

3.2.9. The visible part of the wreck measures 25m x 3.8m. The conning tower is situated about 12m aft of the bow. It stands 2m proud of the hull. About 8.5m aft of the bow, two apertures are visible. These represent the torpedo loading hatches. The remains of one of the submarine's lifting rings are visible between the hatches and the bow.

3.3. *HAZARDOUS* (FIG. 2)

Site Location and Environment

3.3.1. The site of the *Hazardous* lies in Bracklesham Bay, West Sussex in 7m of water. The wreck position is 50° 45.1311' N, 00° 51.5596' W (WGS 84 DDM).

3.3.2. *Hazardous* was built in Port Louis in 1698 as *'Le Hazardeux'*, a French 3rd rate with 50 guns. She was captured by the Royal Navy in 1703 and converted to an English 4th rate of 54 guns in Portsmouth.

3.3.3. The ship was lost in November 1706, when she was run aground in Bracklesham Bay. The site was discovered by divers in 1977, and designated in 1986, after partial exposure caused by sediment changes in 1984.

Magnetometer Survey

3.3.4. The magnetometer survey took place on the 26th June 2003 in light winds and a

moderate sea state.

3.3.5. The site was covered by 22 E-W survey lines. They had a centre line over the wreck site and then lines spaced 10 m north and south of the centre line. The survey lines orientated N-S had a centre line over the wreck site and then lines 10m east and west of the centre line.

3.3.6. A number of magnetic anomalies were noted on the wrecksite. On four survey lines magnetic hits correspond with the conglomerate of guns in the centre of the site visible in the multibeam data. Further anomalies were noted north of the main site, towards a single obstruction on the seabed, and even further north outside of the area covered by multibeam sonar.

Sub Bottom Profiler Survey

3.3.7. The boomer survey was conducted simultaneously with the magnetometer survey. In addition to the E-W lines the site was covered by nine N-S lines.

3.3.8. The seismic sections in Figure 2 plate 5 and 6 are oriented N-S and E-W respectively. The N-S seismic line shows strong, consistent reflectors between the seafloor and the seafloor multiple which indicate that the local geology underlying the area was a conformable sequence of layers dipping towards the south. The BGS solid geology chart for the area shows that the bedrock underlying the site is part of the Headon Hill Formation (Late Eocene) consisting of soft marls, clays and sands. The BGS seabed sediments chart indicates that this area is covered by a slightly gravelly sand unit and the reflectors underneath the wreck site itself are high amplitude and discontinuous suggesting a coarse grained deposit. This type of reflector is seen in part of plate 5 and across the entire length of the seismic section shown in plate 6 indicating that this seismic unit is part of the southwards dipping conformable sequence.

Multibeam Sonar Survey

3.3.9. The multibeam sonar survey was conducted on the 4th June 2003. Altogether 9 E-W lines were run over the site. The survey covered an area of 328m x 111m from which an area of approximately 174m x 84m was selected for reprocessing.

3.3.10. The main site shows on the multibeam data as a slight depression in the seabed, measuring approximately 86m x 61m. A number of features are visible in the depression, the most prominent ones probably being guns.

3.3.11. A 11m x 5m depression with a number of upstanding features in it is visible to the west of the main site. A small mound, measuring 2.5m x 3.5m is situated just north of the main depression. The magnetometer data indicates the presence of ferrous objects in the area of the mound.

3.4. *INVINCIBLE* (FIG. 3)

Site Location and Environment

3.4.1. The wreck of the *Invincible* lies in 7m of water on Dean Sands, about 1 ½ miles south-east of Horse Sand Fort at the entrance to Spithead. The wreck position is 50° 44.18' N 01° 02.12' W (WGS 84 DDM)

3.4.2. The *Invincible* was a 3rd rate 74 gun ship of the line, built in Rochefort in 1744. She

was captured by Admiral Anson in the Battle of Finistere in 1747.

3.4.3. Due to her superior design she was purchased by the Royal Navy and commissioned as a 3rd rate ship of the line. Her lines were taken off, and two new 74 gun ships, the *Valiant* and the *Triumph* were built after her design in 1757.

3.4.4. In 1758 a jammed rudder caused the ship to run aground on Dean Sand. Despite several efforts the Invincible could not be made free. All guns and the crew were taken off, but the hull remained on Dean Sand.

3.4.5. The wreck of the *Invincible* was discovered when a fisherman caught his nets in 1979. The site was designated in 1980.

Magnetometer Survey

3.4.6. The magnetometer survey took place on the 27th June in light south-westerly winds and slight sea state.

3.4.7. The site was covered by 7 N-S survey lines, three and 17 E-W lines. The survey lines had a centre line over the wreck site and then lines 20m east and west of the centre line.

3.4.8. A number of magnetic hits can be observed around the site. By overlaying the magnetic data with the multibeam survey and the existing site plan (Wessex Archaeology 2004), it was found that the two westernmost anomalies correspond with concreted iron feature such as knees etc. observed on the seabed (range of 48,197nT – 48,394nT). An anomaly in the south of the main site is probably caused by the sternpost assembly in this area (range of 48,053nT – 48,293nT). A fairly big anomaly was noted just east of the main site towards a newly discovered feature (Wessex Archaeology 2004). This magnetic hit, ranging from 48,062nT – 48,427nT, indicates that a number of ferrous objects could be buried in the area.

Sub Bottom Profiler Survey

3.4.9. The boomer survey was conducted simultaneously with the magnetometer survey. Due to the shallow water, the multiple is visible at a very early stage. This means that the underlying geology of the site cannot be discussed.

3.4.10. Reflections above the site area, visible in line 24 could have been caused by upstanding features on the seabed, e.g. hull structure. In line 70, the newly discovered anomaly south-east of the main site is clearly visible as a depression in the seabed.

3.4.11. The seismic sections in Figure 3 plate 5 and 6 shows approximately 5m of bedrock before the appearance of the seafloor multiple. The seismic data shows that the wreck site is situated towards the base of a slope and that the raised area of seafloor is composed of a seismic unit with no strong internal reflectors. This unit is over 1m thick in places and is probably a sandy sediment, indicated on the BGS seafloor sediment chart as a sandy mud. This sandy unit is covering an earlier seafloor marked by a strong sub-horizontal reflector. The reflectors below this are gently dipping towards the south except for two areas where the seismic reflectors are high amplitude and steeply dipping suggesting an area of coarse grained or shelly deposits. The BGS solid geology chart for the area shows that the bedrock underlying

the site is part of the Headon Hill Formation (Late Eocene) consisting of soft marls, clays and sands.

3.4.12. Diver surveys conducted by WA in 2003 revealed that the seafloor was covered by sand containing shells and gravels (Wessex Archaeology 2003). The Licensee for the site is of the opinion that sediment is slowly covering the wreck. This appears to be in agreement with the seismic data which shows the recent sandy unit covering the bedrock towards the north of the wreck site.

Multibeam Sonar Survey

3.4.13. The multibeam survey took place on the 11.06.03 in good weather. A total of 22 NE-SW lines were run over the site. From a total survey area of 213m x 368m, 143m x 154m were selected for further processing.

3.4.14. The multibeam data clearly shows the main body of the site and an anomaly in a depression SE of the main site. Detailed discussion of the site and diver observation points as well as existing site plans displayed over the multibeam data can be found in the Wessex Archaeology Full Report for the *Invincible* (Wessex Archaeology 2003).

3.5. MARY ROSE *(FIG. 4)*

Site Location and Environment

3.5.1. The *Mary Rose* lies in 12m deep water 1.5 nautical miles off the Portsmouth harbour entrance in the Solent. The Wreck position is 50° 45.8309' N, 01° 06.2549' W (WGS 84 DDM).

3.5.2. Built in 1509, the *Mary Rose* was one of the bigger warships in Henry VIII fleet. She was rebuilt in 1536 and sank in 1545 during an engagement with the French fleet in the Solent. The site was discovered by Alexander McKee in 1971, designated in 1974, and then excavated and partly raised. The main part of the hull is now being conserved in the Portsmouth Historic Dockyard, but the bow section was not raised during the main excavation and there is high potential for the survival of artefacts and features outside of the excavation area.

Magnetometer Survey

3.5.3. The magnetometer survey took place on the 27th June 2003 in light south-westerly winds and moderate sea state.

3.5.4. The site was covered by six survey lines, three N-S lines and three E-W lines. The centre of the lines is south-east of the excavation area. The general linespacing was 10m.

3.5.5. A number of magnetic anomalies were detected on site, the biggest of which are over the main excavation area and the diving platform to the east. Another very large magnetic dipole was located south-west of the excavation area. This anomaly does not correspond to any features visible in the multibeam data.

3.5.6. An object on the seabed SSE of the main site caused another magnetic dipole.

Sub Bottom Profiler Survey

3.5.7. The boomer survey was conducted on the same day as the magnetometer survey. Altogether, 12 N-S survey lines and four E-W lines were run over the site at a linespacing of ca. 10m.

3.5.8. The seismic sections in Figure 4 plate 5 and 6 show a complicated sequence of reflectors, dipping towards the south. These sediments are described as horizontal/sub horizontal intercalated muds, clays and sands (Quinn et al, 1997). The BGS seafloor sediments chart indicate that the area is covered by a sandy mud. The most obvious feature on plate 5 is the excavation hole which is approximately 4m deep. The BGS solid geology chart for the area shows that the bedrock underlying the site is part of the Headon Hill Formation (Late Eocene) consisting of soft marls, clays and sands.

Multibeam Sonar Survey

3.5.9. The multibeam sonar survey was conducted on the 11th June 2003. Altogether eight E-W lines were run over the site. An area of 246m x 284m was surveyed and also reprocessed.

3.5.10. The main excavation area is clearly visible in the data as a 45m x 40m large and 4m deep depression. A number of smaller features can be seen on the sides and in the bottom of the excavation area.

3.5.11. To the north and east around the original *Mary Rose* site three further depressions are visible. In the north-eastern depression, a pattern of grooves can be observed. This depression is caused by the sinker and the chain of the wreck marker buoy.

3.5.12. The eastern depression formed around the wreck of a dive platform or boat, which is clearly visible (Fig. 4, plate 3 inset). Further depressions could have been caused by the legs of the lifting platform employed to raise the remains of the hull.

3.5.13. A single, according to the magnetometer data ferrous object is lying on the seabed ca. 57m SSE of the main excavation area (Fig. 4, plate 3, inset). This object remains unidentified.

BIBLIOGRAPHY

British Geological Survey (1995) Wight, 1:250 000. Solid Geology, Second Edition.

British Geological Survey (1989) Wight, 1:250 000. Seabed sediments and Quaternary Geology.

Fenwick, V. and Gale, A. (1998). *Historic Shipwrecks. Discovered, Protected & Investigated.* Stroud: Tempus Publishing.

Lavery, B. (1983). *The Ship of the Line. Volume I: The development of the battlefleet 1650-1850*. London: Conway Maritime Press.

Quinn, R., Bull, J.M. and Dix, J.K., 1997. Buried scour marks as indicators of palaeo-current direction at the Mary Rose wreck site. Marine Geology, 140: 405-413.

Wessex Archaeology (2003). *Archaeological Services in Relation to the Protection of Wrecks Act (1973). Invincible, Solent, Hampshire. Designated Site Assessment: Full Report*. Unpublished