The use of remote sensing techniques for the location and investigation of heritage wreck sites

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Abstract

The investigation of wreck sites is of great interest to archaeologists, however site investigation often needs to be conducted within a limited budget. They can often be time consuming as the result of the wreck being poorly defined, or buried in the sediment with little surface indication of their location.

The majority of true wreck investigation, archaeological appraisal and recording is conducted and will likely continue to be conducted by marine divers. This is often essential for the precise recording of artefacts; however, there is often an initial need to locate the wreck site and/or its subsequent extent. Additionally, visibility and available bottom-time may severely hamper the diver in the detection of all seabed evidence.

Within the paper, it is intended to look at the relative value of magnetometers, sidescan sonar, sub-bottom profilers and swathe bathymetric systems in offering assistance to the diver within their initial searches and within an appraisal of the extent of the heritage site. This will be achieved by examining activities over two wreck sites; those of the Earl of Abergavenny (1805), where magnetometer and sonar surveys were compared against the known location of artefacts; and secondly, an investigation of an area of seabed, believed to be the site of the Bellona (1779), using magnetometer, sidescan sonar and sub-bottom profiler.

Conclusions are drawn on the effectiveness of the sensors used, the benefits of an integrated approach and reviews the potential offered by alternatives, such as the emerging technologies offered by swathe bathymetry systems.

Keywords: hydrography, sidescan sonar, sub-bottom profiling, magnetic surveys, swathe bathymetry, marine archaeology, seabed mapping.
1 Introduction

Traditionally marine archaeological surveys were conducted throughout all stages by the diver archaeologist using invasive excavation techniques, although, as they have become available, remote techniques have been used to detect and map the heritage site. Increasingly there has also been a preference for the greater use of the non-invasive remote sensing tools to not only discover the site, but to image the undisturbed site before any excavations begin. This has been based on the use of magnetometers, sidescan sonars and sub-bottom profilers, but should also include the use of swathe bathymetry systems. Use of these systems is also dramatically reducing the time taken for site inspection, evaluation of the spatial distribution of artefacts and the logging of their respective positions.

2 Survey techniques

2.1 Diver

As stated, surveys have historically been conducted by divers, who have either been the archaeologists themselves, or have acquired investigative skills, through self-learning, or completion of a limited number of training courses.

They have commonly been achieved by constructing a taped grid over the projected survey area and meticulously observing and measuring two-dimensional taped offsets to ‘target’ artefacts, within the grid.

Accordingly, survey progress has not only been slow, but has been further restricted by the restraints placed upon the diver by available bottom time, the ability to dive only at times of slack water, not to mention bottom visibility, surface weather conditions, dive safety and budgetary restraints.

Dive seasons over a site of interest are often limited to only a few months, or even a few weeks per year, with the additional needs to both uncover the ‘wreck’ from perhaps a protective plastic membrane and sand-bagged area, left from the previous dive season, and to render a new level of protection before abandoning the site, again.

The techniques described will probably continue to be observed, to a degree, in documenting a site, however such an approach during initial field assessment may not reveal the full extent of the site, which may be outside of the visibility of the diver, either as a result of turbidity or an overburdening layer of sediment, which is hiding a proportion of the site.

2.2 Magnetic surveys

Magnetic surveys, along with sidescan sonar surveys, have long been used within marine archaeology in order to detect the precise location of a vessel that has previously been ‘lost at sea’. In order to detect a site, however, there is a need for a good initial assessment of the wreck site, and very close line running, say at 10–20 metre line separation, in order to detect magnetic signatures.
emanating from the wreck, or any artefacts. Even then the survey may be frustrating, since early wrecks will have been of wooden vessels, with limited ferromagnetic material onboard; whilst inshore, or even in offshore waters, the seabed has increasingly been fouled by debris of human origin, such as discarded wires, lost anchors, sunken containers or even just scrap metal or munitions. Such is then the case that the archaeologist could spend many fruitless hours investigating human detritus, of little value or archaeological interest. Never-the-less, the magnetometer remains a useful tool, with current Overhauser and proton precession magnetometers offering sensitivities of 0.1 nanoTeslas, offering the capability to detect both seabed and sub-seabed artefacts.

2.3 Sidescan sonar

Sidescan sonar has also, historically, been used as a search tool for the initial detection of seabed artefacts although, unfortunately, detection is limited to that of exposed evidence. As researchers are fully aware, many small, or ancient, artefacts are hidden beneath an overlying layer of silt, or sediment. Close examination of sonar records may often provide evidence of seabed anomalies, as in humps or hollows, indicative of variability in the substrate and the presence of hidden objects.

In the past, the use of sidescan sonar has often been considered as subjective, being aspect dependent, whilst resolution has also been variable, particularly when using 100 kilohertz (kHz) systems and paper recorders. In recent years, detection capability has been enhanced by the introduction of higher frequencies of between 300 and 500 kHz, digital signal processing and digital recording.

2.4 Sub-bottom profiler

Once a site has been detected, it will often be found that part of the site and the artefacts therein are buried. Indeed it may often be that an initial sidescan sonar survey has revealed no seabed evidence of disturbance, however, the site may show significant magnetic anomalies. A subsequent survey with a sub-bottom profiler may well serve to provide indicators of subsurface point or planar reflectors, as the source. Analysis can also be made of the depth of the reflector, such that subsequent dive excavation and/or investigation could be more effectively conducted.

2.5 Swathe bathymetry surveys

Whilst primarily designed with a vision of usage for bathymetric surveying and depth investigation, swathe systems conveniently lend themselves to area mapping of potential wreck and archaeological sites.

Development of systems have followed one of two pathways; either the development of multiple sounding beams, typically numbering the order of 150 across a lateral swathe of seabed, equivalent to between four and seven times the water depth, or a development based on the sidescan sonar and use of multiple receiving transducers, so as to receive bathymetric depths of 3 millimetre slant
range resolution and across track resolution to 12 millimetres, for a 250 kHz system, across a swath of up to twelve times the water depth and irrespective of actual water depth.

Such systems also have the ability to portray the acoustic backscatter imagery – the swath equivalent of sidescan sonar imagery – with the interferometric systems, or those based on sonar technology, giving the higher resolute imagery.

3 Case studies

3.1 Earl of Abergavenny (1805)

Lying in 18 metres of water, in Weymouth Bay, the Earl of Abergavenny is a historic wreck, which has been extensively worked by the Weymouth Underwater Archaeological Group, an amateur dive team, since 1979 [1]. Since that time a number of artefacts, comprising anchors and cannons have been recovered from the seabed, to leave a relatively level seabed exhibiting only fifteen or so iron ‘knees’ as visual clues to the wreck’s location, which has also been meticulously subjected to a professional one metre gridded survey. This has provided local control over an area of several hundred square metres, within which there is believed to be an extensive debris field, central to which lies the remaining parts of the hull, lying flat and partially buried within the sediment.

Being a site that had been extensively surveyed by divers, it was chosen as a prime location to conduct an evaluation of the effectiveness of magnetometer and sidescan sonar, as remote sensing tools and as aids for marine archaeological investigations. Thus, using an Aquascan AX2000 proton precession magnetometer and a GeoAcoustic dual frequency sidescan sonar, operating at 410kHz, a 25 metre grid was ran, using both sensors over a 200 metre square area centred on the known position of the wreck.

The results of the sonar survey were somewhat disappointing to the survey team in that it was difficult to ascertain the position of the wreck, simply by observing the sonar records. This was in part due to the return of a mottled portrayal of the seabed, which showed areas of mud interspersed with patches of shell and stone. Intuitive knowledge however allowed the wreck to be determined as a reoccurring area of higher acoustic intensity, measuring approximately 28 metres in length (see fig.1), which also appeared as a slight rise in the seabed. A further low intensity area of approximately 8 x 8 metres was also repeatedly identified, and was identified as that of an area of disturbance, the result of diver excavations. No evidence of any of the knees were detected, however the largest of these was only of 1.5 metres, as opposed to a predetermined system resolution of 0.75 to 1.15 metres, making target detection difficult in the first instance.

The magnetometer survey, by contrast, appeared to produce more ‘contacts’, with 18 anomalies recorded. Of these, however, an analysis of results resolved that two contacts were potentially false returns, whilst a further three may have been duplicate contacts, offset by possible 4 metre positional errors. Of the remainder, 8 targets were considered to represent significant targets, having
attained 4 ‘hits’, whilst 7 were of lower magnitude and of only 2 or 3 ‘hits’. Figures 2 and 3 show the distribution of these anomalies, which whilst centred on the wreck site were also indicative of five further contact points across the site. Four of these were of low magnitude and were thought as unlikely to be associated to the wreck, but more likely to be of miscellaneous debris of naval or fishing origin.

Figure 1: Annotated sonar record highlighting the centre of the *Earl of Abergavenny* wreck site and showing a low intensity return over an excavation area, 50m to the south (R. Cumming).

Figure 2: Sample annotated magnetometer survey traces across the wreck of the *Earl of Abergavenny* (R. Cumming).
3.2 Bellona (1779)

The history of the Bellona, a late 18th century privateer, is less well known. However, the 96 foot (29.3 metre) brig was lost off the coast of Devon in tragic but well documented circumstances, in a water depth of 12 metres. Over the years occasional artefacts had been recovered from the locality including, in 1966, a cannon muzzle, capable of 4lb shots. The site was also known as a ‘hitch’ by local fishermen, but despite a magnetic survey over the site, by the Archaeological Diving Unit, which showed a dispersed but significant anomaly (see fig. 4), dive surveys and excavations were unable to detect any surface, or near surface evidence of the wreck.

Assistance was subsequently sought through the University of Plymouth, in order to complete further surveys, in an attempt to substantiate the magnetic findings. Accordingly, in 2004, a sidescan sonar and sub-bottom profiler survey of the site was conducted, using the GeoAcoustic dual frequency sidescan and a GeoChirp sub-bottom profiler. Operating at 410 kHz, the sidescan sonar was used to run survey lines at 50 metre line separation, whilst the GeoChirp was operated within a 0.5-13 kHz sweep, at 20 metre line separation, and set to high resolution, the equivalent of 6 cm resolution.

Results of the survey were for the detection of four linear artefacts (identified as targets A1-A4), upon an otherwise featureless seabed, of between 1.8 and 7.6 metres and of two depressions close to the extremities of the search area; and 27 ‘sub-bottom’ contacts, ranging in size from point sources to a maximum length of 73 metres, and at depths of 0.8-1.4 metre sub-seabed (see figures 5 and 6).
Whilst the depressions upon the seabed were considered to be away from the primary magnetic anomaly, the remaining contacts were clustered around the central area, with the linear seabed contacts also displaying an interesting arrangement, which bears for future dive investigation. The sub-bottom contacts were also deemed of interest, occurring as a number did, as linear arrangements which showed a trend 180 degrees opposed to that of the geological stratification.
4 Discussion

The survey team upon the *Earl of Abergavenny* survey expressed disappointment upon the results obtained from the sidescan sonar survey over the wreck site but, in hindsight, were asking a lot of the sidescan sonar with respect to its detection capability – ‘knees’ of dimension of less than 1.5 metres. Other results were also compromised by a variable seabed, with the areas of mud, interspersed with shell and stone providing variable returns in the first instance. Within the *Bellona* survey, seabed artefacts are far more prominent, the smallest artefact detected being a 1.8 x 1.8 metre contact that appeared to stand proud of the seabed and which was near coincidental with one of the largest magnetic deviations. The other three artefacts, linear and measuring between 4.6 and 7.6 metres in length, did not correlate to any magnetic anomaly, but then they could be of wooden origin.

When reviewing the sub-bottom data from the *Bellona* survey, parallels were drawn from the likely decay and break-up of the vessel and survey results upon other wreck sites. Dive surveys upon the *Earl of Abergavenny* [1] have revealed that the vessel has generally collapsed and appears to remain as only a small ‘arc’ of hull, shallowly buried within the sediment. Such is also the case of further remains of the *Mary Rose* [2] and the *Invincible* [3]. Indeed the sub-bottom profile records obtained from the *Bellona* are very comparable in displaying artefacts to those produced by Bull et al [3].

Both sites investigated have also been surveyed with magnetometer, however following a magnetic survey alone, upon the *Bellona* site, divers were unable to locate any artefacts or features that might have been contributing to the anomalous signatures. Upon the *Earl of Abergavenny* site, minor anomalies were not considered to be associated with the wreck and discarded as someone’s debris.
Both surveys conducted have shown that magnetometer, sidescan sonar and sub-bottom profilers can contribute to knowledge, but have also concluded that no one set alone can substantiate a ‘find’ and that all are best used in conjunction, within an integrated survey approach.

5 Alternative technologies

Upon the sites discussed, use has been made of three remote sensors to develop a picture of the potential site, via integration. The sites have not however been subjected to swathe survey, as is emerging as a newer technology in seabed mapping.

It is interesting to note that within both the *Earl of Abergavenny* and the *Bellona* surveys, depressions and mounds have been detected, and indeed in the case of the *Earl*, that a mound appears in conjunction with a change in acoustic return. Thus it can be taken that bathymetric data may prove an important addition to the data set. This may be more so if variations in acoustic backscatter can be draped over the bathymetry, as may be achievable within digital ground modelling type packages and associated Geographical Information Systems. This may be illustrated within figure 7, which shows two wrecks lying off Balls Head, in Sydney Harbour.

![Figure 7: Acoustic backscatter imagery draped over bathymetry, showing two scuttled wrecks, off Balls Head, Sydney Harbour Australia (GeoAcoustics Ltd).](image)

It has already been stated that systems such as GeoAcoustic’s Geoswath, which was used to produce the images in Sydney Harbour (fig. 7 and 8), offer high resolution [4]. This facility not only allows for imaging of any wrecks, but also associated scouring around the wrecks and discrete targets upon the seabed.
6 Conclusions

Discussions have shown that there is a range of remote sensing tools, which can be used to assist divers in wreck investigations, and techniques, which can also lend themselves to submerged heritage and landscape sites of interest. These tools offer rapid data acquisition and assimilation, for what would previously have taken divers weeks or months. Observations do, however, conclude that integrated survey approaches are, however, better than the reliance on a single technology.

References