DIGITALLY RECORDING A SUBMERGED NAVAL BATTLEFIELD FROM THE FIRST PUNIC WAR

Interim report on the 2013 season for the Honor Frost Foundation

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Introduction

The 3rd century BC site located off the Egadi Islands in Sicily is the first submerged naval battlefield yet to be located from Antiquity. Due to this distinction as a highly unique site, the authors have endeavoured to record the site and its artefacts using the highest calibre scientific methods currently available. As outlined in the grant proposal, the goal of this research was to digitally record the Egadi Islands site and the rams recovered from it. This report details the highly successful field season in which survey was carried out on the seabed and nine warship rams and three helmets were scanned and sampled.

Fieldwork

Fieldwork was conducted from June to July 2013. On site remote sensing, using a cutting edge acoustic sonar, and artefact recovery, through ROV operations, took place from the RPM research vessel *Hercules*. In addition 3D scanning and metal sampling of the bronze rams recovered from the site was carried out at museums and conservation labs in Trapani and Palermo (in Sicily), Pisa, and Rome.

Scanning the Egadi 8 ram in Rome.

In total, nine of the Egadi rams were available for metal sampling and eight were 3D scanned. Two more rams were discovered toward the end of the season, but remain on the seafloor at this time. This brings the total number of discovered rams to eleven. This sample size is the largest dataset of ancient rams ever assembled and, at the completion of this project, they will be the most rigorously analysed examples to date.

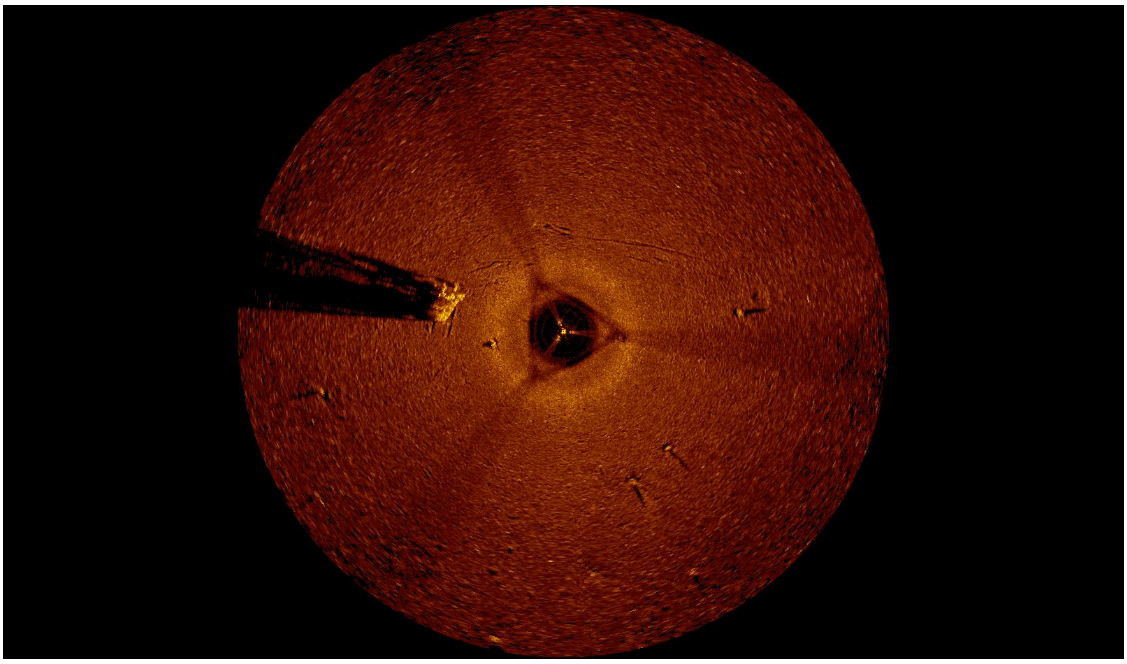
Site recording

One of the aims of the project is to use cutting edge technologies to record the battle site itself. In 2013 trial survey was carried out using a Kongsberg-Mesotech MS 1000 sector scan sonar, a device that generates high quality metrically accurate images of the underwater environment, and as such has great potential for underwater archaeological survey.

Side-scan sonar has been traditionally used in maritime archaeology to locate archaeological sites and map areas of seabed. Specifications and models of side-scan sonar vary but all must either be hull-mounted to a vessel or towed behind one. For side-scan to operate the survey vessel must be in constant motion through the water. As the sector scan sonar operates from a fixed position on the seabed it is better suited to planning individual sites in detail as the location of areas being scanned can be more tightly controlled. It is relatively simple to redeploy the sector scan sonar over known points, to revisit and rescan important areas, and as a result build up a more detailed record of a site over time.

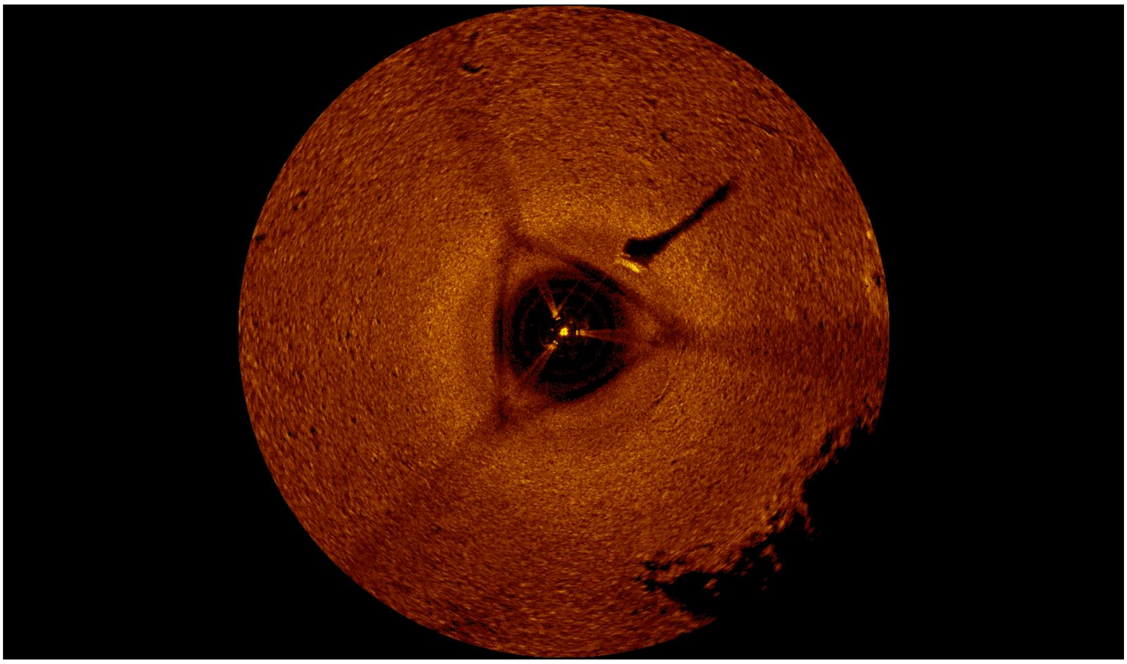
Dr Henderson explains the workings of the sector scan sonar to the public during an open day on the Hercules

The system consists of a sonar operating computer housed on the research vessel which directly connects through a high tensile weight cable to a sonar head unit hung from a movable stainless steel tripod in the water. The in-water sonar unit can be accurately positioned on the seabed using GPS position fixing to within +/- 50mm. The sonar head transmits a very narrow acoustic beam which is swept vertically so that the returning echoes indicate the distance and angle of depression to the many reflectors. Since the position of the transmitter is fixed, it can obtain higher levels of resolution of acoustic data than conventional side scan or echo sounder units. The sonar head incorporates a stepped motor which allows full 360^o scan coverage of the area surrounding the unit, with successive high resolution pulses. A high frequency (675 KHz) acoustic ping is transmitted from the sonar head and the system waits to receive the echoed returns. Once the return is received the motor steps the transducer in parts of a degree to a new azimuth angle, and the process is repeated. This is done until a full 360^o circular sweep is carried out. The scan radius is set by the operator and may range in distance from 5m to 1000m. It normally takes between 2 and 5 minutes to complete an individual scan once the head is deployed on the seabed. As the distance from the scanning head increases, the quality of the image decreases.



30m diameter scan of Egadi seabed – the centre triangle is the sector scan unit itself, to the left of the unit the ROV can clearly be seen, the other upstanding features are amphora targets on the seabed

Typical scan radii used for the Egadi battle site ranged from 100 metre scans (covering a total sea floor area of 31,000 sq metres) down to very high resolution 5m scans of individual rams. The unit was used at a depth of 80 to 100 metres.



15m scan with the clear profile and acoustic shadow of a new bronze ram (Egadi 11) as located on the seabed

The ability to visualise submerged archaeological features and produce measured scans of them in a matter of minutes has obvious advantages to the practice of underwater archaeology. The MS 1000 sector scan sonar provides instantaneous high resolution seafloor scans which consist of three dimensional point cloud data comparable to that produced by terrestrial laser scanners. The data produced by the sector scan sonar can be manipulated in 3D environments to produce isometric images of the features on the seabed. Over the coming year the sector scanning data will be mosaiked together and geo-referenced using the existing multi-beam data from the site, as well as AUV imagery obtained in 2012, to create geometrically accurate plans of the remains on the seabed.

3D Scanning

Breuckmann GmbH provided an academic loan grant of a structured light scanner for 3D documentation of the rams. This partnership with industry provided one the highest accuracy 3D scanners currently available on the market for only the cost of training. The latest Breuckmann SmartSCAN model used this research has a rapid collection setting with an average accuracy of 25 microns. Eight rams and three helmets were scanned using the Breuckmann scanner.

Scanning the Egadi 4 ram in Palermo.

While scanning and sampling two rams on display in Rome, under a permit from Dr Sebastiano Tusa (Soprintenza del Mare), key elements of the Tiber Island monument were also scanned. Built in either the 3rd or 2nd century BC, the monument is located on an island in the Tiber near the ancient forum. It depicts a Roman *polyreme* and the monument is the closest surviving example of a warship from this period. This 3D data will be used for reconstructing Roman warships and conducting Finite Element Analysis for determining the size of these vessels.

Scanning the Tiber Island Monument in Rome.

Metal Sampling

Metal sampling was conducted on nine rams for analysis at the National Oceanographic Centre. Professor Croudace travelled to Italy to conduct the sampling based on a methodology he developed while analysing the Belgammel Ram in 2010. Two sawn samples and two drilled samples were taken from each ram. At the time of writing, these samples are currently being analysed at the National Oceanographic Centre. Preliminary results show the rams to be composed of a similar bronze mixture to the Belgammel Ram (Adams et al. 2012) and different from the Athlit Ram (Oron 2006), which has interesting consequences for our understanding of ancient rams. These two rams, along with the currently unpublished Acqualadroni Ram and Piraeus Ram, are the only known waterline rams besides the Egadi assemblage. Since so few rams are available for analysis, comparing the compositions of these rams may reveal differences across time and geography.

Professor Ian Croudace sampling the Egadi 4 ram.

Beyond elemental composition, the metal samples will be examined using a Scanning Electron Microscope (SEM) and lead isotope analysis. SEM reveals the crystalline structure of the bronze, which helps researchers to understand how the original cast cooled and how impacts affected the casting during combat. As the largest single cast bronze objects in Antiquity together with statues, there is still a scholarly debate as to how the rams were manufactured and SEM offers further information.

Lead isotope analysis reveals where lead ore originated. Preliminary results reveal the Egadi rams to be leaded bronze and ample lead is present to conduct isotope analysis. Difference in lead origin between the Egadi 3 (Punic) ram and the other Roman rams may provide interesting commentary on Mediterranean trade and politics during the 3rd century BC.

Other Methods

Reflectance Transform Imaging (RTI) was conducted on four rams that have inscriptions, as opposed to reliefs. Reliefs stand out from the surface, making them easy to read; however, inscriptions are more delicate and often erode much easier. Indeed, these four heavily weathered Egadi rams are difficult to read. RTI uses photographs with a moving light sources to create an image of a surface with only depth information. By removing colour and other superfluous data, it is possible to focus on the surface data and see things that would otherwise be hidden to the human eye. RTI of the Egadi rams allowed for reading of known inscriptions, as well as the discovery of a new inscription. The rams' inscriptions are a critical source of information and are currently the oldest known evidence of Quaestors (Professor Jonathan Prag, pers. comm.), an important political position in Rome for quality control that was thought to have originated later than the 3rd century BC.

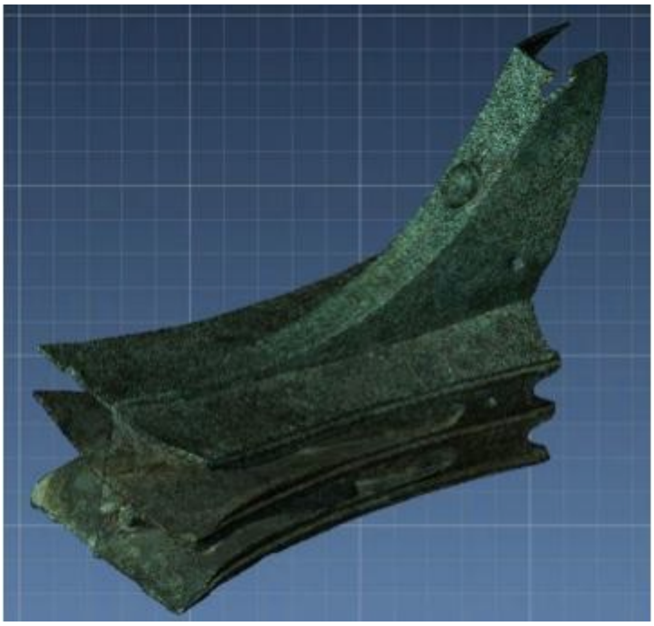
Photograph of the Egadi 1 ram (left) and RTI of the same area with colour data removed, as well as highlighted writing (right).

Analysis

3D and elemental data has been collected, but how will it be used in a meaningful way? The next stage of research gets to the crux of current questions about ancient warships relating to construction and use.

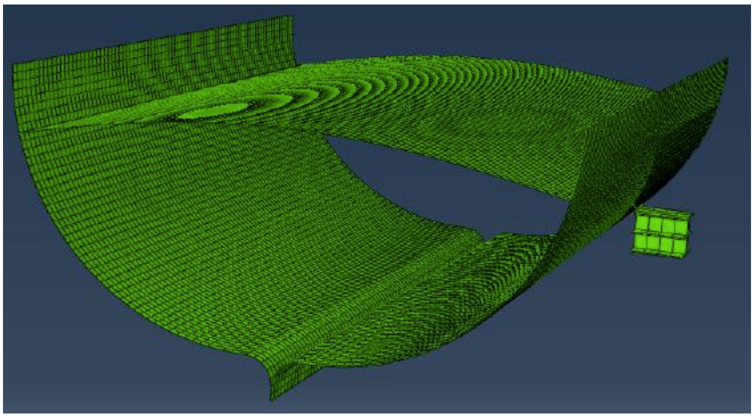
High resolutions models of the rams and the Tiber Island monument are currently being produced from the scan data. These 3D models act as digital records of the rams, should anything in future damage or destroy the original artefacts. The models are also tools for understanding ship construction, bronze casting, and warship use. To address these issues, the authors are preparing to reverse engineering of two rams in the next phase of research.

The research aim for conducting the 3D scanning and elemental analysis is to reproduce exact scale replicas for quantitative testing. The Egadi 3 and Egadi 7 rams are to be 3D printed at ¼ scale and then a lost wax mould created. A bronze mixture matching their elemental composition will then be poured into the mould to create a reverse engineered replica. These reconstructions will undergo strenuous scientific testing that we could not ethically submit the original rams to, allowing for digital quantitative feedback on how rams performed under certain conditions. When Honor Frost began hypothesizing about ancient naval tactics and the functionality of rams, she could not have imagined the technology today to accurately provide an exact scale replica for impact testing.



3D model of the Egadi 8 ram in OptoCat software.

The digital data retrieved from the impact testing will supplement a Finite Element Analysis (FEA) recently conducted by University of Southampton's Ship Science department. Professor Stephen Turnock and Dr Dominic Hudson (University of Southampton) led a research regimen focused on testing the impact of a ram with several variables, such as speeds between 1-12 knots and ship sizes between 25-35 tons. Also, rams of different shapes beyond the Egadi's three-finned design were tested. Adding variables from the actual impact testing of the bronze replicas should provide further constraints for understanding how 3rd century bronze casting and wooden hulls behaved when impacting each other.



FEA image of a model ram head impacting a ship's hull.

This summer's fieldwork offers insight into where the bronze artefacts were manufactured through lead isotope analysis, as well as creates a digital record of the artefacts. More importantly, it forms a foundation for further research that can address several of the major questions related to warship construction and use.

Project spend (actual)

National Oceanographic Centre metal analysis: £6,800
Breuckmann Structured Light Scanner Loan: £769
Field Recording Expenses: £2,356
Sector Scan Sonar shipping: £1,446

Total: £11,358 (£1358 overspend)

Conclusion

The authors would like to thank the Honor Frost Foundation and its trustees, as this research would not have been possible without the generous grant provided. The Egadi Islands Survey Project will continue in 2014, expanding the search area with more sophisticated equipment with the hope that more intact warship may be located. Analysis using the data collected during the 2013 field season will also continue, using quantitative methods to ascertain precisely how large-scale bronze pieces were cast and how warships functioned. Ongoing research both on site and in the lab is re-writing understanding of ancient warships and naval combat, much of it building upon Honor Frost's pioneering research.