Report Prepared for the Honor Frost Foundation
Reconstruction and Quantitative Analysis of the Egadi Islands Warship Rams

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Introduction
The second Honor Frost Foundation grant awarded to the authors has extended the Egadi Islands Survey Project from recording and analysis to innovative analytical methods and reverse engineering of the rams. While the experimental recasting process has taken longer than expected, the results funded through both grant awards are in the process of being prepared for scholarly publication.

Research
Analysis of the Battle of the Egadi Islands artifacts is revealing a considerable amount regarding the manufacture of large, single cast objects in Antiquities, as well as the function of rams. The first Honor Frost Foundation grant allowed for the critical recording of basic quantitative measurements of the warship rams such as weight and dimensions, metal analysis, and provenance data. This research provided high-resolution three-dimensional models and elemental composition that allowed for the second grant's experimental inquiry.

Figure 1. 3D model of the Egadi 8 Ram that is being reverse engineered (Authors).

Eight of the Egadi rams were scanned using a Breuckmann GmbH SmartSCAN structured light scanner during the first year of funding. Partnering with Breuckmann, the authors

were able to use the latest and highest accuracy 3D scanner currently available on the market. The scanner was high resolution and the authors settled on a rapid setting that offered an average accuracy of 25 microns. The Egadi 3 and 8 rams were chosen as representative of the Carthaginian and Roman weapons, respectively, to be 3D printed at the Department of Engineering at the University of Southampton, using an experimental mixed-composition printer.

Analysis

The previous round of funding examined the rams for their metallurgical properties. Samples from each ram were analysed at the National Oceanography Centre (UK) using a range of analytical procedures, including an EAGLE III micro X-ray fluorescence spectrometer for elemental content and a Thermo NEPTUNE MC-ICPMS mass spectrometer for lead isotope analysis. This analysis continued using a LEO scanning electron microscope to investigate elemental and metallurgical textures, necessary to understand the casting process. An experimental copper isotope analysis was also attempted, the first time this has been used in archaeology. The results are still being interpreted, but it is hoped that this may reveal further information about the ore sources that supplied the metal for the rams.

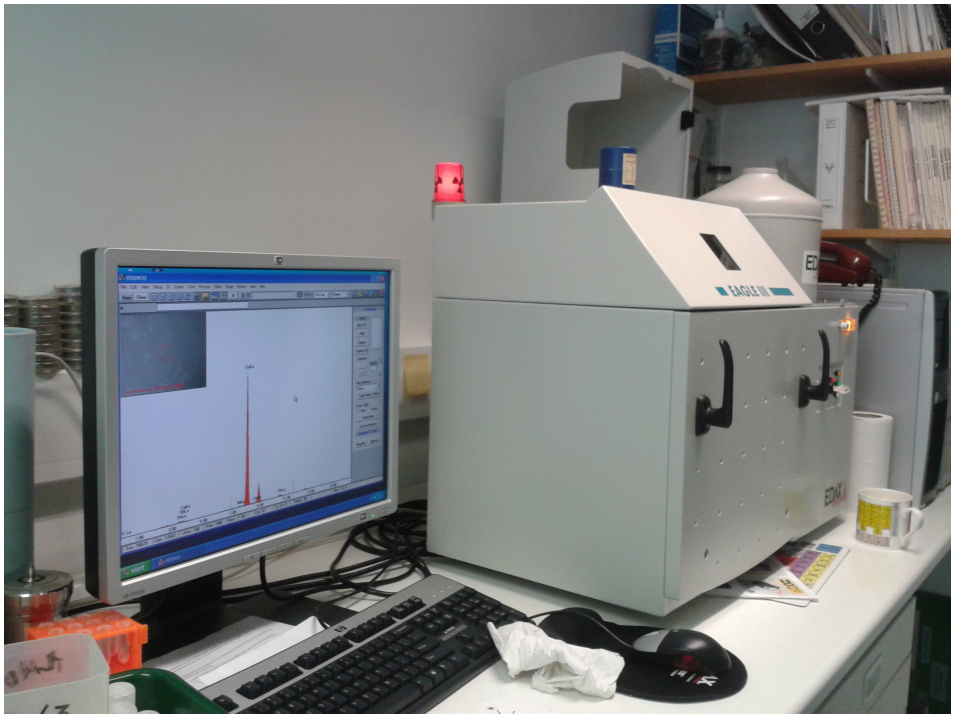

Figure 2. Analysis of the bronze in the x-ray fluorescence spectrometer prior to recasting (Authors).

A bronze fragment from the Egadi 2 Ram was analysed using a new innovative method. The sample was placed in the most powerful Mu-VIS 3D x-ray tomography available in the UK. The system builds 3D internal models using a complex series of x-ray images. The fragment was the densest artifact ever recorded by the unit, but the results were impressive. The analysis provides insight into metal alloy and its cooling structure, which is being

studied to determine the orientation of the ram when it was being cast. It is hoped that the findings will be published in the Journal of Archaeological Science.

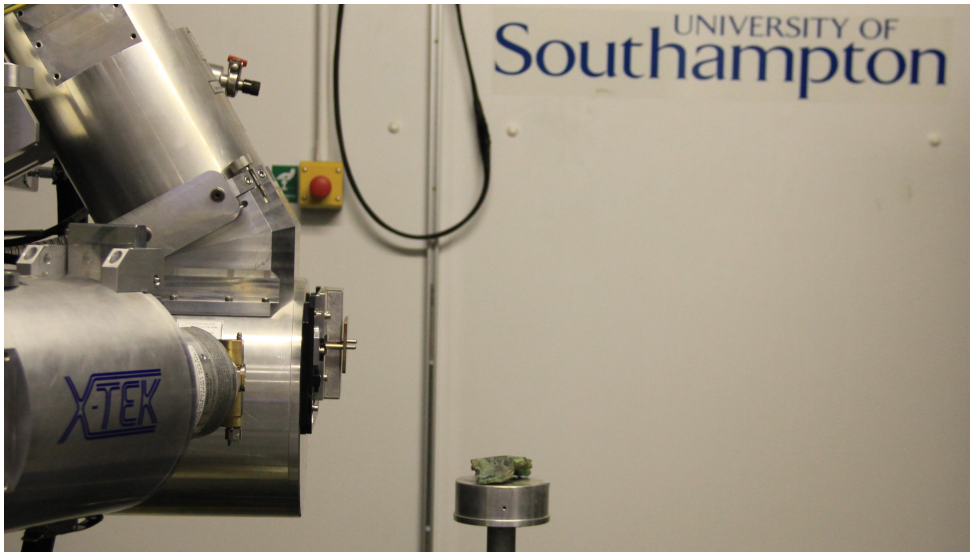

Figure 3. The Egadi 2 Ram fragment inside the x-ray chamber at the Mu-VIS facility (Authors).

A partnership with the Winchester School of Art and its bronze foundry provides the facilities for the recasting of the rams. The recasting of the rams has been a slow process due to the regulations surrounding the use of lead in university facilities. However, permission has been cleared and the recasting of ¼ scale rams is expected to commence either during the Easter or summer break when fewer individuals are working in the facility. The process begins with mixing the bronze composition into ingots several days prior to the casting of the rams. A bonze casting mould will then be prepared around the 3D printed models, in preparation for the Lost Wax technique of bronze casting. It is expected that the rams will be recast over a two-day period.

Conclusion

This research has pushed the analytical side of archaeology into the experimental, in a manner previously only attempted by the *Olympias* reconstruction experiment. The initial Honor Frost Foundation grant allowed for high quality analysis and upcoming articles are prepared for the Journal of Roman Archaeology (September 2015) and the Journal of Analytical Chemistry (late 2015/2016) regarding the findings. This second grant allowed for the reverse engineering of the rams, providing new information on the source of ores in the Roman Period and methods of ancient Lost Wax casting. The third step of the research will be the impact analysis, which is being planned for the fall. The authors would like to thank the Honor Frost Foundation for their continued support in the pursuit of innovative research that pushes the boundaries of archaeological inquiry.