SURVEY OF A GREEK SHIPWRECK OFF KYRENIA, CYPRUS

BY J. N. GREEN*, E. T. HALL* and M. L. KATZEV**

* *Research Laboratory for Archaeology and the History of Art, Oxford University*
** *Department of Underwater Archaeology, University Museum, Pennsylvania*

INTRODUCTION

A shipwreck of the fourth century B.C. was located off the north coast of Cyprus, near the harbour town of Kyrenia, by a joint team from the University Museum of the University of Pennsylvania[1] and the Research Laboratory for Archaeology and the History of Art, Oxford. This discovery was made while conducting a search for ancient shipwrecks during the summer of 1967[2]. Lying at a depth of 30 metres on a flat, muddy sand bottom, the visible wreck consists of a mound of approximately one hundred amphorae. The amphorae are stacked in a regular pattern, indicating that the mound is the site of a sunken cargo, and not merely jettison. A remarkable feature of the amphora mound is its small size, only an area 3 x 5 metres was visible to the divers.

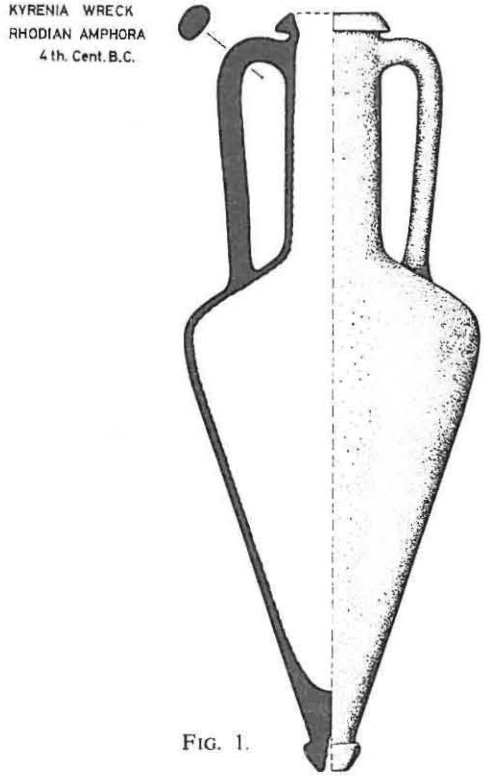

FIG. 1.

1 Sponsoring the University Museum expedition were: The Cyprus Mines Corporation, the National Geographical Society, the Dietrich Foundation, Inc., and the Houghton-Carpenter Foundation.

2 The group was shown the wreck site by Mr. Adreas Cariolou of Kyrenia.

Three distinct types of amphorae lie within the wreck. The type which predominates (figure 1) has been identified by Miss Virginia Grace of the American School of Classical Studies at Athens, Agora Excavation, as the earliest type of Rhodian amphora. The origin of the other two types is at present unknown.

THE PRELIMINARY SURVEY

The object of the preliminary survey was to devise and test a method of surveying for metal on an archaeological wreck. It was hoped that it would be possible to locate the extent of the metal objects in and around the area, without having to disturb the wreck. With this information subsequent excavation can more profitably be attempted.

The two instruments available for the survey were the Proton Magnetometer (Aitken 1958, Hall 1966), and the Underwater Metal Detector which was developed from a land based version (Colani 1966), by the Oxford Archaeology Research Laboratory. The wreck was first surveyed with the magnetometer to indicate the broad distribution of ferrous metal. The metal detector was subsequently used for a more precise location of both ferrous and non-ferrous metals.

METHOD OF MAGNETOMETER SURVEY

So as not to cause spurious magnetic anomalies from the diver's aqualung cylinders, the diver has to be at least 10 metres from the detector when a reading is being taken. To inform the surface operator when divers were clear of the

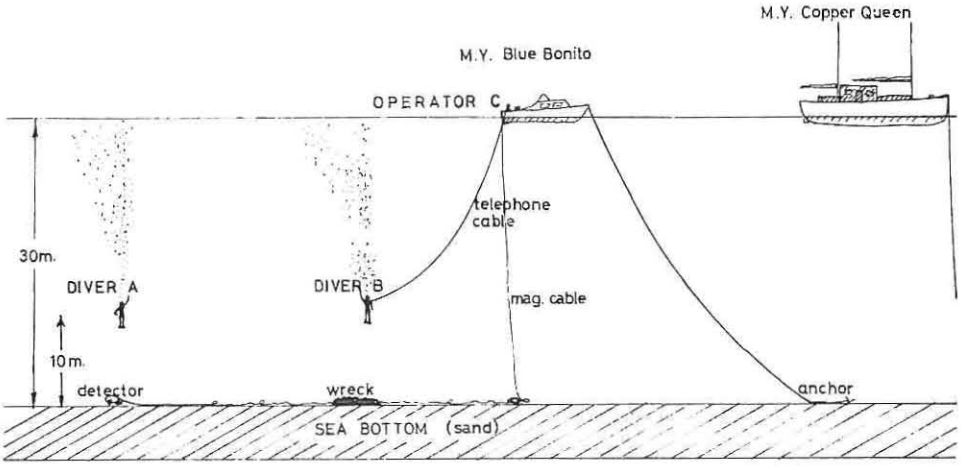

FIG 2. Survey method for magnetometer.

detector, companion diver B communicated with the operator by underwater telephone (see figure 2). The magnetometer detector was always placed horizontally on the sea-bed, with its axis pointing in the same east-west direction.

Two surveys were made with the magnetometer, the first, a preliminary survey to assess the extent of the anomalies. This was done, first in the east-west direction and then in the north-south. The axes of this first survey were used for the alignment of a grid used in the detailed magnetometer survey. The grid used was 28 metres long by 10 metres wide, with squares every two metres (see figure 3).

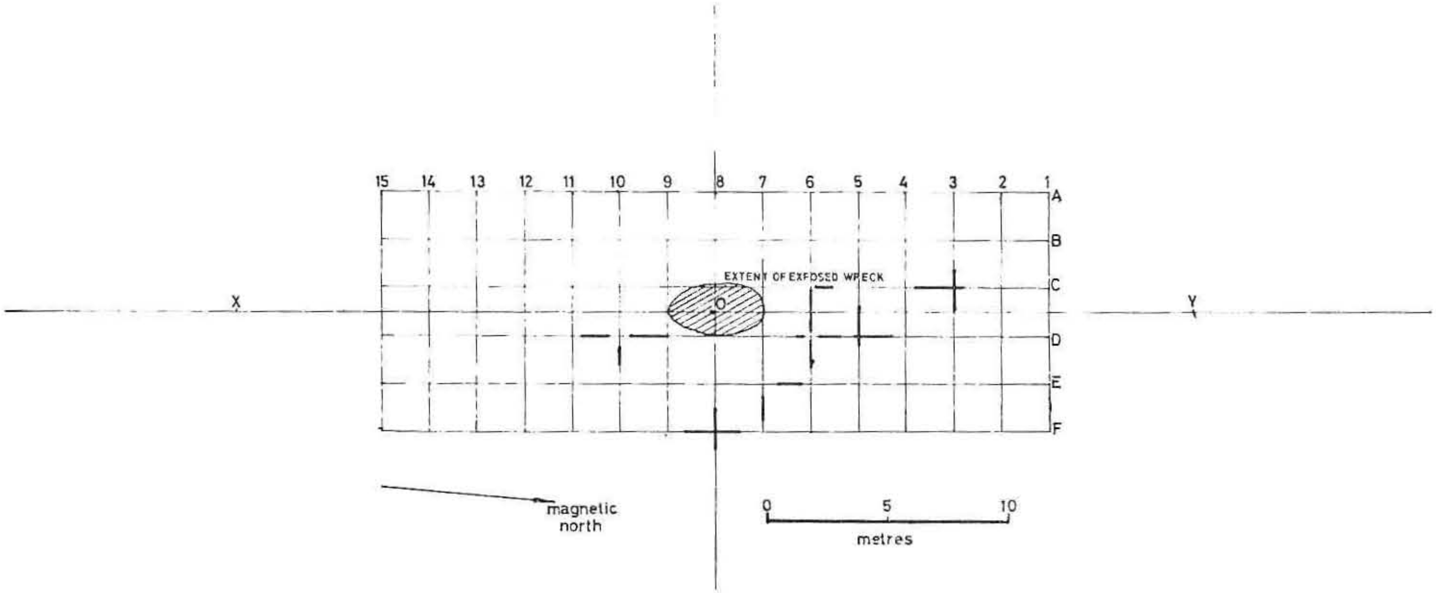

FIG. 3. Grid showing preliminary metal detector survey.

The detailed survey was made by placing the detector on each intersection of the grid lines, so that a total of 75 readings were taken. A careful estimate of the background diurnal variation was calculated for the duration of the dive, and for the period between the dives. This was done by standardising the measurements at the beginning and end of each dive by placing the detector on a fixed point, X or Y (see figure 3).

After the survey of the grid, an estimate of the mass of metal causing the anomalies, and its depth was made. To do this, readings were taken with the detector positioned at 0, 1, 2, 3, 5 and 10 metres above the bottom.

METHOD OF METAL DETECTOR SURVEY

It was found that the metal detector could not at first be used on the wreck because of the large signal reading on the meter. This reading which varies with depth, is caused by the conductivity of the sea water, and only becomes significant in water deeper than 10 metres.

On land a similar effect, although less pronounced, can be annulled by placing small metal objects between the coils. This method was tried under water using strips of lead; by careful positioning of the lead, it was possible to reduce the $25\mu A$ full scale deflection to between 0 and $5\mu A$.

With the metal detector set on the high sensitivity and the water reading annulled, a preliminary survey was made. This was done by moving the detector coils along the lines of the grid. Where objects were indicated, their coordinates were marked on an underwater slate. From this survey (see figure 3), the approximate positions of the main objects were found.

The main targets determined, a more detailed survey was then started. Stakes were placed in the ground where the signal reached $25\mu A$ on the high sensitivity. Thus a $25\mu A$ equipotential line could be constructed around each target. The position of each stake was measured from two of the fixed points, A, B and C, on the wreck and an accurate map of the stakes was drawn (see figure 6).

THE PROBE SURVEY

During the progress of the survey, a question that arose was how would it be possible to determine the extent of the non-metallic buried wreck. The remarkably simple but effective idea was suggested by Claude Duthuit that a thin metal rod could be used to probe the soft bottom. Thus it was possible to determine the extent of the buried wreck (see figure 4).

RESULTS OF THE SURVEY

The results of the survey of the magnetic field intensities around the wreck, show a complex distribution of peaks. The variation of their intensities is shown as a contour map in figure 5. Figure 6 shows in graphical form the changes of intensity along line D in figure 5. This graph shows two reverse peaks, M1 and M3, and two normal peaks, M2 and M4. Comparing this graph with the theoretical curve (see figure 7), drawn for a small spherical ferrous object in a magnetic declination of 50 degrees (as found in Cyprus), it is seen that the shape of the peaks M1 and M2 in figure 6 are similar to the theoretical in figure 7. The ratio of the peak values is lower than the theoretical value of 3.2; this could be due to the

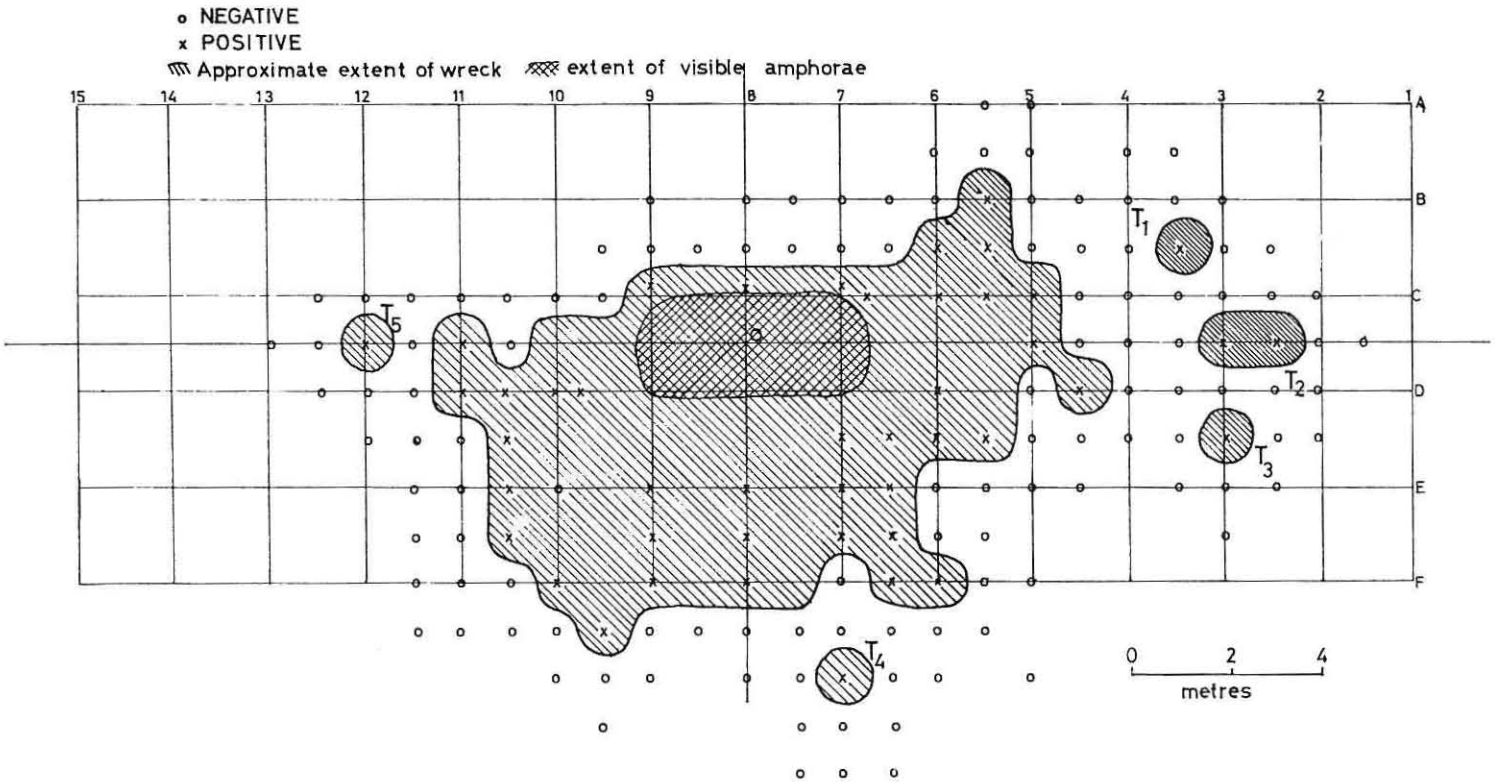

FIG. 4. Probe survey.

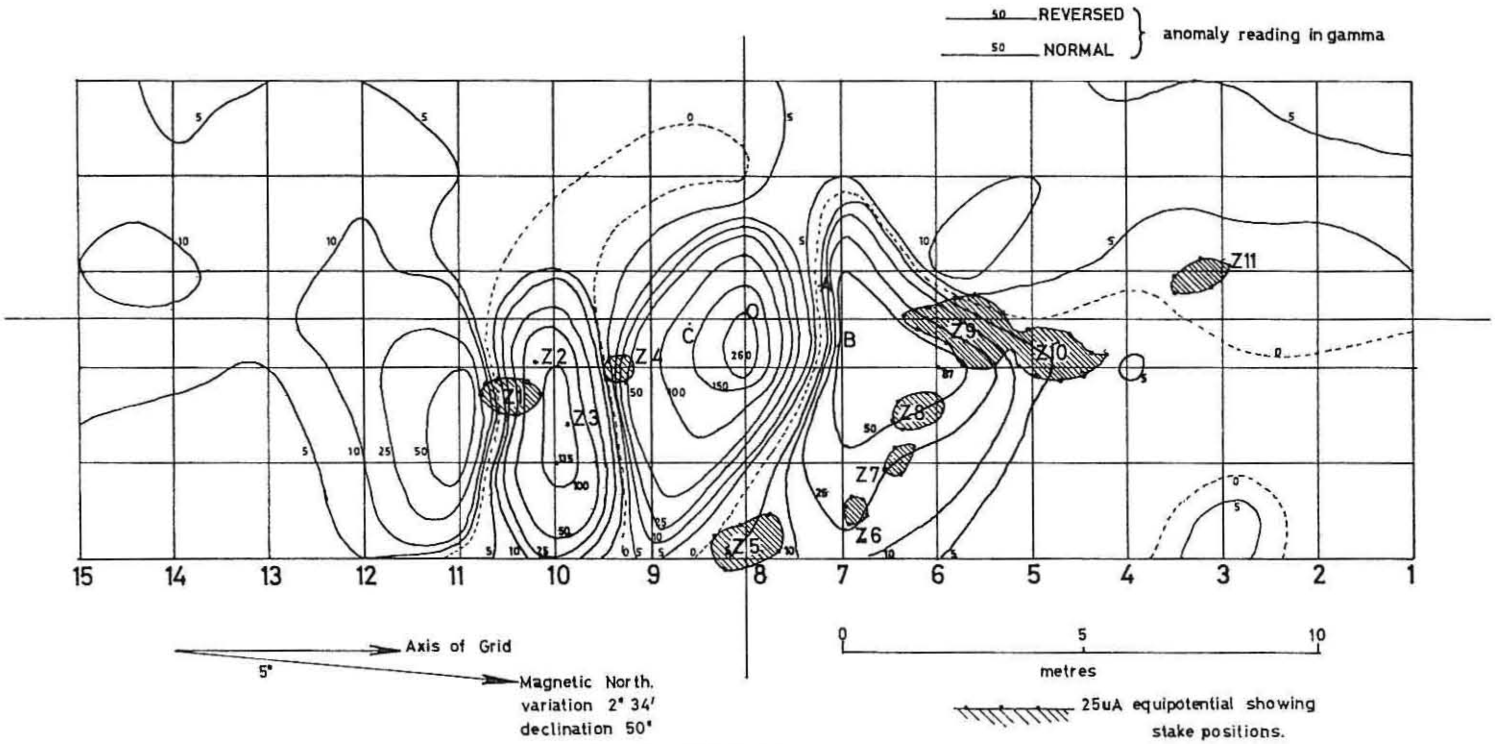

FIG. 5. Metal detector survey.

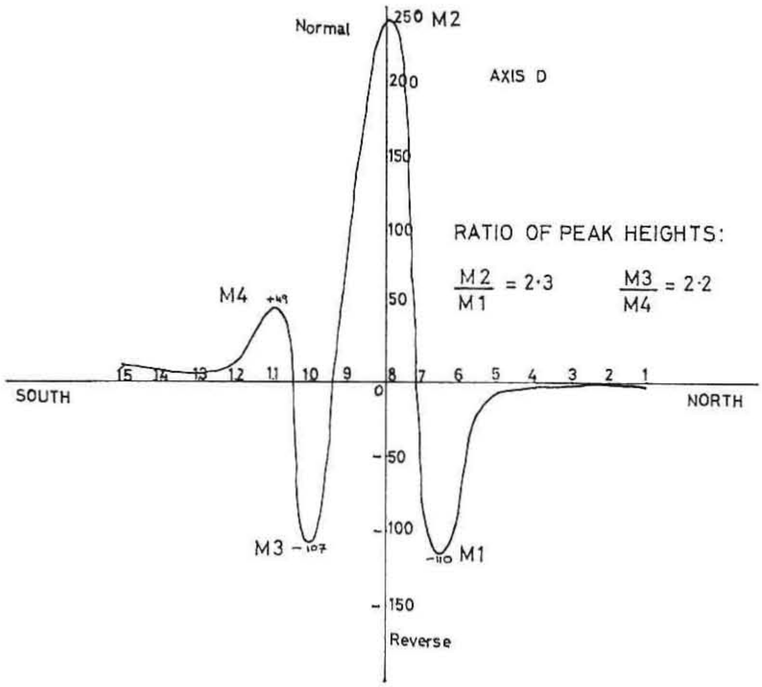

FIG. 6. Magnetometer survey of line D.

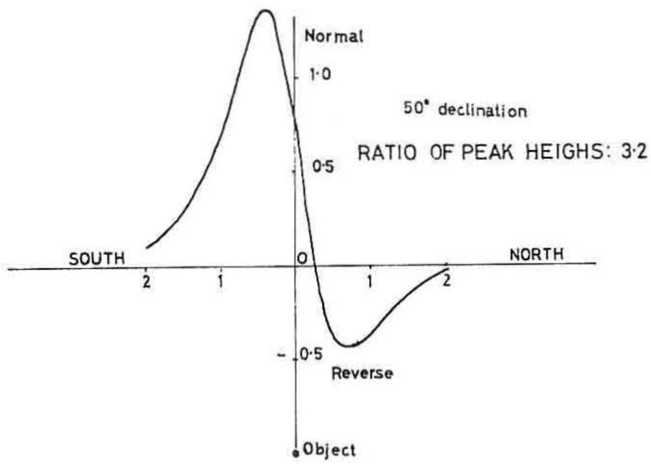

FIG. 7. Theoretical distribution for a small spherical ferrous object.

object not being an ideal sphere. It is significant that the metal detector survey showed no metal object between the peaks M1 and M2, as would be expected theoretically. It is possible that some or all of the amphorae were responsible for this anomaly.

The peak system M3, M4 is in the reverse direction to the usual, i.e. with the reverse peak larger than the normal peak. This may be due to a magnetic object whose axis of magnetization is orientated in the opposite direction to the Earth's magnetic field. A further point of interest is that the ratio M3/M4 is within 5% of the ratio M2/M1. The metal target in figure 5 marked Z1 was located in exactly the position an object would be expected from consideration of the magnetometer survey.

The relationship between the other metal targets and the magnetometer survey is not conclusive. Target Z4 may have some influence on the M2, M3 peaks but this is not certain. Target Z11 appears to have no obvious influence on the magnetometer gradients, and can tentatively be said to be non-ferrous.

Calculation of the depth of an ideal small spherical object, which would give the same magnitude of disturbance can be made from the formula:

$$\triangle H = M/d^3$$

where $\triangle H$ is the anomaly in the total magnetic field intensity, M is the magnetic moment of the dipole and d is height above dipole.

The value of d may be calculated from:

$$\triangle H_1/\triangle H_2 = (d_2/d_1)^3$$

where $\triangle H_1 = 131\gamma$ and $\triangle H_2 = 14\gamma$. Substituting $d + 1$ for d_2, and d for d_1, gives $d = 0.91$ metres, and from this the mass can be calculated. The mass M in kilogrammes may be calculated from the formula:

$$M = d^3\triangle H/10$$

where d is in metres and $\triangle H$ in gamma. Substituting $\triangle H = 131\gamma$ and $d = 0.91$ metres gives:

$$M = 10\text{Kg}.$$

As the magnetometer reading decreases from 131γ to 14γ at 1 metre above the wreck, the magnetometer would not be effective in locating this wreck if towed in the usual way behind a survey boat. If an archaeological wreck has more ferrous metal present, there would be a greater probability of location.

Comparing the metal detector survey and the probe survey one sees that all the metal targets with the exception of Z11, lie within the limits of the main wreck. The target Z11 may be associated with the complex T1, T2. It is interesting to note that the buried cargo does not extend evenly from the centre of the visible wreck. Its extent is 1 metre to the west of O (see figure 4), and 5 metres to the east. The reason for this is not clear, but it is significant that the amphorae lie stacked in a general east-west direction, with their pointed bottoms to the east.

The probe survey also showed that the extent of the amphorae cargo was approximately 10 x 19 metres, suggesting a cargo of over 500 amphorae. The actual orientation of this cargo was found to be at a considerable angle to the visible amphora mound.

CONCLUSIONS OF THE SURVEY

Until the wreck has been excavated, no definite conclusions can be made. There appear to be several metal objects buried around the wreck, but until more is known about the contribution of the amphorae to the magnetic anomalies, these cannot definitely be said to be ferrous or non-ferrous. The metal detector appears to be effective in locating metal objects in such an environment, and it will be of great interest and value to find the depth and size of the objects from the excavation. The instrument should also be useful at the end of an excavation to determine if all the metal has been found, and also could be used for the same purpose on wrecks that have already been excavated.

The most important considerations of technique are concerned with the co-ordinate system. The grid in future should be made of either thick nylon rope securely fixed to the bottom, or better still plastic rods. The size of the squares is important, and would depend on the conditions experienced—on this wreck the squares could have been made smaller. This would have given a more accurate location of position, and a far more detailed magnetometer survey. With more experience of use of the metal detector, it should be possible to assess the value of making a contour map of the survey area. The efficiency of the magnetometer survey could be greatly improved by the use of non magnetic aqualung cylinders.

This survey in its three aspects represents a new approach towards inspecting a wreck site preliminary to excavation. It has provided clues to approach this wreck which will eliminate much of the initial guesswork usually required. For example, a system of permanent reference grids is normally laid over a wreck before excavation begins. Hitherto, the placement of such grids has followed the axis of the visible cargo, often leading to an incomplete coverage. The metal and probe surveys indicate that the real axis runs at a considerable angle to the apparent axis suggested by the amphora mound. In addition the survey provides the approximate dimensions of the wreck lying beneath the sand. Thus, with the axis and dimensions of the site already known, a grid system can be designed and positioned, which will cover the entire wreck and will require no later positioning.

This development of a workable system for surveying wrecks is a procedure which could become standard for all wreck sites preliminary to excavation.

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