Final-report- Omis Croatia

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Authors: Peter Seinen and
Joost van den Besselaar

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Photograph by Eric van Hoof.

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Mailing list
Members Mergor in Mosam
Tino Mrcelic
Tea Katunaric

Summary

In the Adriatic sea near Omis in Croatia a merchant vessel of the late Roman Republican era sank with its cargo of amphora's. Wreckage sites of ancient merchant ships may contain invaluable information about shipbuilding techniques, navigation, the daily life of the crew on board and ancient trading routes. The location known as Stanici-Celina was, however, discovered in the fifties by sponge divers, who salvaged a large number of amphora's and possibly other objects, leaving a pile of shards that were useless to them. Because the area is easily accessible for scuba divers and is known to be subjected to looters, it is necessary to determine the present archaeological value. The first step is to locate the original position of the wreck after its descent two millennia ago.
During a week's project, members of the Dutch foundation Mergor in Mosam (underwater archaeology) made all preparations to find the location.
After mapping and surveying the site, it was decided to excavate a small area. In this excavation, broken amphora's were uncovered that showed a clear coherence and orientation, relating to their position in the wreck, being clear that the wreck is close by. The survey also yielded some interesting ex-situ artifacts, like an intact amphora, a stamped amphora rim fragment and two metal sheets.

1. Introduction
In the summer of 2009, Joost van den Besselaar chairman of Mergor in Mosam, a Dutch foundation for diving amateur archaeologists, joined a couple of diving tours organized by the diving-school of Tino Mrcelic in Omis, Croatia. One tour led to an area covered with pottery shards, which aroused his interest. Discussions following this tour led to involvement of archaeologist Tea Katunaric of the Arts Academy Split, and eventually led to a one-week investigation of ten members of Mergor in Mosam. This report provides an overview of all activities, observation & measurements and discusses the results of this short investigation.

2. History of the site
The site is presently known as Stanici-Celina, near Omis, close to Split. The presence of the site is known since the fifties and sixties, when it was discovered by sponge fishermen. Allegedly at that time the bottom was covered with pottery remains, mostly amphora's of the Roman late-republican era (2^{nd} to 1^{st} BC). The intact amphora's are being harvested ever since, first by fishermen and now by looters. The number of amphora's being removed is reflected by a remark of a fisherman: "It is like shopping" [1]. Most were sold and a part is still in possession of inhabitants of Omis [2]. Intact amphora's are still found today and sold by looters.

3. Goal of the project
Besides the commercial value of the amphora's, the site may have a major archaeological value for the information it may provide on ships construction techniques, the life of the merchants and crews as well as the trading-routes they used.
The major goal of the project was to determine the archaeological potential of the site with respect to its uniqueness and state of preservation. This requires knowledge about the original and present size, its capacity and the cargo on board of the ship. This in turn requires information about its location and orientation. Thus the derived goal is to find the original location and boundaries of the wreck-site [2]. Given the limited time, men power and depth of the site, it was not likely that this goal would be fully met.

4. The project plan
The project plan consisted of the logical steps usually followed in underwater archaeological projects [3,4]. The techniques used have been thoroughly described in alphabetical order in Appendix 2.

The project plan:

- Pre-disturbance mapping of the site:
  - Determining the geographical and geological context of the site.
  - Estimating roughly the size and shape of the area of archaeological interest.
  - Photographing each section of the area, to be stitched into a photo mosaic.
  - Mounting a reference gridline-network around and over this area (a rectangle).
  - Mounting permanent reference points.
  - Determining the coordinates of the corner points of the gridline-network, with respect to the permanent reference points:
    - Measuring the distances between all points, both corner points and reference points.

        - Calculating the coordinates of all corner points, taking one reference point as origin.
    - Determining the (magnetic) orientation.
    - Determining the absolute geographical location of the reference points (GPS).
- Surveying the area:
    - Determining the types and number of artifacts.
    - Determining the distribution of artifacts.
    - Metal detecting.
    - Surveying the surrounding area.
    - Selecting a suitable area for starting the excavation.
- Excavating the selected area:
    - Marking the area.
    - Installing a mammoth water-pump.
    - Removing and collecting loose (ex-situ) artifacts by hand.
    - Removing sediment from the selected area using the mammoth pump.
    - Documenting the progress:
        - Tagging artifacts
        - Measuring the tagged artifacts with respect to the gridline-network.
        - Taking photographs of the artifact in-situ.
- Salvaging artifacts that require protection (looters, erosion or corrosion)
- Closing-up the excavation area.
- Summarizing the project documentation into day reports.
- Making the final report.

5. Results

The results will be presented and discussed according to the sequence of the project plan, which will not necessarily be the chronological order of the activities in the project. All figures are shown in Appendix 1. All dive data is given in Appendix 4.

<u>Pre-disturbance mapping of the site.</u>

The geographical location of the area with respect to coastal features is shown in Figure 1. Its shortest distance from the shore is 200m. Figure 2 shows a tentative plot of the bottom profile from the shore to the area at 24m depth.

The coastal region of this part of Croatia consists of Mesozoic Dinaric Karst (limestone, dolomite and limestone-breccia) [5]. This sharp brittle bedrock material forms a dented surface with sharp peaks and depressions, partly covered-up with sediment. The area therefore looks like a fairly flat plain with occasional bedrock peaks emerging from it. Figure 3 shows the area and the distribution of the rocky peaks over the area. The colored dots represent a depth classification for the sediment level. Figure 4 shows the calculated depth-profile lines. From the shore to the deep the area is fairly flat with a slope of 10- 20% and 1- 5% at right angles.

The sediment (at location A11) consists of a very thin surface layer (1- 3cm) of very fine sediment covering a thicker layer (10- 15cm) that consists of a mixture of course coral fragments and sand, covering a thicker layer (30- 40cm) of fairly stiff marine clay, covering a layer of hard and sturdy coral concretion of unknown thickness.

The area that confines 99% of the (visible) amphora shards measured about 10x20m^2. This area was marked by a rectangular gridline-network supported by four large steel pins on each corner with a numbered tag (401- 404). Right in between the two 20m lines, a third line was mounted. All lines were tagged at regular distances of 2m. Figure 5 shows the locations of the pins, the names of the gridlines and the tag-number sequences. Because the steel pins were only for temporary use, two small steel reference pins (405 and 406) were mounted permanently (and retraceable) into a bedrock feature at some distance from the gridline-network. These reference points were used to measure and calculate the spatial lay-out of all pin-positions. Figure 6 shows this calculated lay-out. The way of calculating the coordinates is explained in Appendix 2. Finally a coordinate system was calculated, choosing reference pin 406 as the origin and choosing the X-axis running through reference pins 406 and 405. The location of all positions (artifacts and features) will be expressed with respect to this coordinate system and are summarized in Table a of Appendix 3. The techniques used will be explained in Appendix 2.

Finally the magnetic orientation (direction 403 to 404) was determined: 207^0 +/- 3^0.

Determination of the GPS coordinates, to link the coordinate system of the site to the Croatian national system was not followed through (see Appendix 2)

<u>Surveying the area.</u>

The (gridline) area was surveyed in three ways

- By making a photo mosaic (see Appendix 2) to determine the distribution of the shards over the area and to monitor changes of the area in future.
- By systematic close observation of the area.
- By means of metal detection (see Appendix 2).

The photo mosaic without any additions is shown in Figure 7a. Figure 7b shows the same mosaic with the gridlines and tags highlighted in red. The major shard concentration, containing over 90% of the shards on the surface, is shown in yellow. The excavated area is shown in green. M1- to M3 denote the locations of the metal artifacts found within the area.

The systematic close observation showed a vast variety of amphora parts that seem to represent all parts of a single amphora type [2]. The parts like rims, which may be imprinted with stamps, were all checked, but no stamps were found. It should be noted that, due to extensive concretion, recognition of stamps is often impossible.

Two pieces of metal sheet were discovered. One fairly large sheet (M3), completely free on the bottom (Figure 8) and a sheet (M2) of unknown dimensions, partly buried in the sediment (Figure 9). Investigation with the metal detector, using non-ferro discrimination, showed the sheets to be made of a non-ferro alloy, like lead- or bronze-based (based on its density, most likely a lead-based metal). The coordinates of both sheets were measured and the large plate (M3) was salvaged later.

The haphazard search by means of metal detection, using non-ferro discrimination, provided signals at almost every square decimeter. Some could be determined as contemporary fishermen’s lead, on the surface. One small piece (M1), which was heavily concreted. Its coordinates were measured and later on salvaged.

Outside the gridline-area, an almost completely buried amphora (A11) was discovered, its foot sticking out off the sediment. Figure 10 shows the amphora prior to excavation.

Below Amphora A11, at a depth of 30cm, the rim of another amphora became visible. Figure 11 shows the first picture of amphora A12.

The selection of an area to be excavated in search of undisturbed remains of the ship was based on three criteria:

- Highest probability of success.
    - Knowledge of previous illegal activity.
- Accessibility of the area.
    - Working space for the mammoth-pump.
- Least disturbance of the area.
    - Concentration of shards on the surface.

A preferable location would be somewhere near the perimeter of the gridline-area. A 2x2m^2 area, between tags 01-16 and 01-18, running 2m into the gridline-area, as shown in Figure 7b met all requirements:

- In the near past it had once shown signs of digging, according to Tino Mrcelic [6].
- It was poor in shards on the surface.
- It was easily accessible without much risk of seriously disturbing the site.

Later on, the local expert, Marinko Petric, claimed that a good part of the amphora's that were looted in the sixties, were found in an area to the north of the gridline-area, at lower depth [1]. This information, however, could not be used by the time it was shared.

<u>Excavating the selected area.</u>

Figure 12 shows the area to be excavated with boundary lines highlighted for clarification. The surface is clean, except for a few loose shards that were removed shortly.

Figure 13 shows the progress in the area after two shifts of working with the mammoth-pump. The first amphora shards are being uncovered. Removing the sediment, revealed the same types of materials as described previously: a thin layer of very fine sediment covering a thicker layer of a mixture of course coral fragments mixed with sand, covering a thicker layer of fairly stiff marine clay, covering a layer of hard and sturdy coral concretion. At this point, it was decided to shift the area a bit to the right side. The new boundaries were marked with yellow cow-ear marks with black numbers (423- 426).

Figure 14 shows a photo-mosaic of the progress in the area at the final stage after two more shifts. A total of 10 amphora shards belonging to 10 separate amphora's could be identified. The approximate centers of these amphora's were tagged (see Appendix 2). The photographs were highlighted with colored lines, circles and text boxes for clarification. The coordinates of the shard-tags were measured with respect to the gridline-tags (0-1-2 and 0-1-4) by using tie-lines (see Appendix 2). Table a (Appendix 3) shows the coordinates with respect to 405 and 406. Figure 15 shows a close-up of the concentration of the shards at the centre of the selected area.

Finally, shard A7 was planned to be excavated completely and to be removed in order to investigate the layers below. After removal of all obtrusive sediment it turned out to be fixed to the deepest layer of coral concretion. Unfortunately, there was no time left to remove any of the other shards instead.

<u>Excavating amphora A11.</u>

Prior to excavation, the orientation and coordinates of the amphora were determined. The amphora stuck into the sediment at an angle of approximately 30^0 (+/- 10^0) with respect to the bottom, foot-up. The foot pointed in the magnetic direction of 230^0 (+/- 3^0) [10]. The coordinates of the amphora were determined by means of trilateration measurements with respect to reference points 405 and 406, processed by Site-Recorder™ (see Appendix 2). The results are given in Table a (Appendix 3).
For this excavation, a second mammoth-pump was installed.

<u>Excavating amphora A12.</u>
Closer inspection of the visible part of amphora A12 made suspicion rouse that it might not be complete and intact. Removal of only a small part of the sediment also by using the second mammoth-pump showed that it consisted only of a part of the rim, the neck and a part of the handles.

<u>Salvaging of artifacts.</u>
Four artifacts were salvaged in order to avoid the risk of them being looted.

The complete intact amphora (A11) was carefully freed from the sediment (Figure 16a), lifted and strapped on a steel grid. The grid, with the amphora, was lifted to the surface by means of a balloon (Figure 16b) and transported to the shore and further to the base-camp. The amphora (Figure 17) was cleaned on the outside and inspected for hidden cracks. When none were found its content was removed and sieved over a $2x2mm^2$ sieve. The sieve residue was collected in large plastic bags with tags. No material other than of marine origin was found, suggesting it had been open and exposed to the environment for a long time. Its characteristic dimensions were:

- Overall length: 95cm,
- Outer-diameter body: 38cm,
- Outer-diameter rim: 17cm.

The amphora shard (A12) was transported in a shopping net to the base-camp. The shard (Figure 18a) was cleaned and it turned out to have a stamp on the rim (Figure 18b). Later, after careful cleaning, the stamp read AROHELA, indicating Italian origin [2].

The metal sheet M3 (Figure 19) was transported in a shopping net to the base-camp. It was provisionally cleaned and tagged. Its typical dimensions were:

- Overal length: 80cm
- Overall width: 60cm,
- Thickness: 4- 8mm.

The concreted metal M1 (Figure 20) was also salvaged,
It was treated in the same way as M3. Its characteristic dimensions were:

- Overall length: 7cm,
- Average width: 2- 6cm.

All salvaged artifacts have been packed in water-tight plastic bags and shipped-off to the Arts Academy in Split for further treatment (amongst others: cleaning and desalination), investigation and conservation.

<u>Closing the excavation.</u>

According to Croatian law on antiquities, the excavation area should be secured against decay and looters. This should be done by covering-up the area with geo-textile, kept in place by a course steal grid, covered with local sediment.

6. Discussion

To find the location and orientation of the wreck three clues may be followed:

- The location and distribution of the shards. After the descent of the ship, it came to rest on the bottom close to the present shard area. The bottom was very likely covered with a much thinner layer of sediment and therefore would look a lot rockier. At this point amphora’s could roll down from the wreck and spread over the bottom. The formation of coral concretion bonded the amphora’s to their neighbors and the bedrock (as amphora A11), thus limiting their movements during the decay and collapse of the wooden wreck. The deposition of the sediment layers confined their positions even better. Since the discovery of the site by the sponge divers and looters, the amphora’s have been removed top down, starting with the ones on top, working their way down. Besides the amphora’s that were broken already in antiquity, some will be broken during the removal. It is unlikely that these useless shards have been moved far from their original location. Also unlikely is movement of the amphora’s due to strong currents or rolling down the slope. At the depth of over 20 meters close to the Adriatic coast, water currents are not sufficiently strong to move large amphora’s. The slope of 20% in north-to-north-west can only cause movement on a fairly smooth bottom and not on soft marine clay. The slopes at right angles of 1- 5% would cause even smaller movement.

  The distribution (Figure 7b), defined as the area that encloses 90% of all shards, although fairly arbitrary, suggests the shape of a ship. Even the width-to-length ratio of 1:4 [15] seems to be in line. Its hypothetical size of 20m would easily fit in the range of merchant vessels Roman in the late Republican era, ranging from 70 to 500 metric tons, corresponding to 15 to 45m. A famous example is the Madrague de Giens (Roman, late Republican), carrying amphora’s as well, which measured over 40m and could carry about 8000 amphora’s. A ship of 20m length could carry about 2000 amphora’s [16]. It should be kept in mind that this is only the visible distribution after significant disturbances.
- The discovery of two metal sheets. Both metal sheets show significant corrosion which suggests ancient origin. Both sheets are made of a non-ferro metal or alloy, possibly lead-based. One sheet may be still in-situ. Lead sheets are known to have served as cladding the ship’s hull through-out the Roman era, thus providing water-tightness and / or deterioration of the wooden structure by Teredo navalis, an organism that feasts on wood [17]. Archaeological data shows that cladding was very often applied to merchant ships from early antiquity throughout the Republican era, eventually dying out in the early Empire era. The thickness of the plate, in its present state, seems to be fairly thick (3- 5mm) compared to the claddings used in antiquity (1- 2mm [17]). It should be kept in mind that a part of the thickness consists of voluminous corrosion products, so the original sheet may have been much thinner. Additional investigation should provide a rough dating. At present, the best technique for dating ancient lead is by determining the lead/lead-corrosion ratio [18]. Attempts to find a laboratory that employs the required techniques are in progress. The metal detection survey, although hampered by the presence of modern metal, does not rule-out the presence of more ancient metal.

- <u>The results of the excavation.</u> Figure 16 shows the final result of the excavation. The amphora shards uncovered were clearly part of 10 individual amphora's that although displaced after the decent of the ship, still show signs of coherence and orientation. Moreover, attempts to remove one of the shards A7, showed it to be bonded by coral concretion to underlying bedrock. As it is unlikely that this solid bonding has been formed in the past 60 years, this indicates that these shards have not been moved since antiquity. Either it was crushed by amphora layers on top of it or by looters trying to free it from the rock-bottom.

The ellipsoidal shaped area is very likely very near to the location of the wreck, although it may be much larger than the area with visible shards suggests. The location of deeply buried shards, like A12, at a large distance from the area makes one wonder how this shard got there. Considering the considerable layer of marine clay that covered it, was not likely to be deposited the in the last 60 years.

7. Conclusions

- The distribution of the amphora shards is not random: over 99% of the shards lie in an area of 20m x 10m and already 90% lie in an area of 16m x 6m.
- The distribution is very likely related to their original position for the past 2000 years.
- The layout of the shards revealed in the excavation area indicates that the wreck-site is close by.

8. Recommendations

- Trying to date samples of the lead sheet.
- Follow-through with the excavation in a larger number of locations (and smaller pits) around the area with largest shard concentration, thus narrowing down the wreck-area.

9. Lessons learned

As this survey was the first project for Mergor in Mosam under these conditions (depth, severely limiting the useful bottom-time) and scale (an area of over 200m^2), many lessons on organizational and technical level could be learned. A brief summary of the major lessons is given.

Organizational level:

- Very thorough briefing of all assignments for the entire group that needs to fulfill this assignment.
- Not assigning buddy pairs with specific tasks, they have to fulfill during a couple of subsequent dives, but assign a group with these tasks. All tasks must be written on an A4-size underwater tablet, which is filled-in or updated by each buddy pair during their dive and is handed over to the next pair with a brief explanation. The next pair starts where the previous pair stopped their task.

Technical level:

- This site is ideal for Nitrox-diving, almost doubling the bottom time.
- The daily transport of the mammoth-water-pump, followed by anchoring and installation is cumbersome. Moreover, the suction power of a mammoth-water-pump cannot easily be regulated at the working place on the bottom. An airlift (operated with compressed air) does not have these shortcomings: The compressor can be installed on the shore has to be installed only once and the suction-power can be regulated from zero to maximum by a simple valve near the mouth of the suction-pipe.
- For taking photographs it would be helpful to make the gridline somewhat more dense (blocks of 2x2m^2) and / or increase the object distance, when the brightness and visibility conditions allow of course. This would reduce the effort for correcting differences in scale and deviations of the correct perspective significantly.
- Taking more photographs of artifacts in-situ, with a measuring-stick

10. Follow-up

Actions for follow-up will be defined after careful consideration what the goals should be.

References:

[1] Marinko Petric, private communication, 2010.
[2] Tea Katunaric, private communication, 2010.
[3] J. Green, Maritime Archaeology,
A Technical Handbook, Elsevier Academic Press, 2004.
[4] A. Bowens, Underwater Archaeology,
The NAS Guide to Principles and Practice, Blackwell, 2009.
[5] S. Grandic, Italian Geological Society, **2**, 2008
[6] Tino Mrcelic, private communication, 2010.
[7] P.A. Seinen, Omis-Kroatia-day-report-16-9-2010.
[8] P.A. Seinen, Omis-Kroatia-day-report-17-9-2010.
[9] P.A. Seinen, Omis-Kroatia-day-report-18-9-2010.
[10] P.A. Seinen, Omis-Kroatia-day-report-19-9-2010.
[11] P.A. Seinen, Omis-Kroatia-day-report-20-9-2010.
[12] P.A. Seinen, Omis-Kroatia-day-report-21-9-2010.
[13] P.A. Seinen, Omis-Kroatia-day-report-22-9-2010.
[14] P.A. Seinen, Omis-Kroatia-day-report-23-9-2010.
[15] F. Meijer, Sail Rome, De koopvaardij in de Romeinse tijd,
Athenaeum Polak & Van Gennep, 2010.
[16] F.M.Hocker, The Philiosphy of shipbuilding, A&M Texas University Press, 2004.
[17] L. Casson, Ships and Seamanship in the ancient World,
Princeton University Press, 1971.
[18] S. Reich, Measurement of corrosion content of archaeological lead artifacts by their Meissner response in the superconduxtive state,
New Journal of Physics, **5**, 99-1 to 99-9, 2003.

Appendix 1 Pictures and graphs.

Figure 1 Geographical location of Stanici Celina (approximately).

Figure 2 Tentative bottom profile between the shore and the site (pin 403).

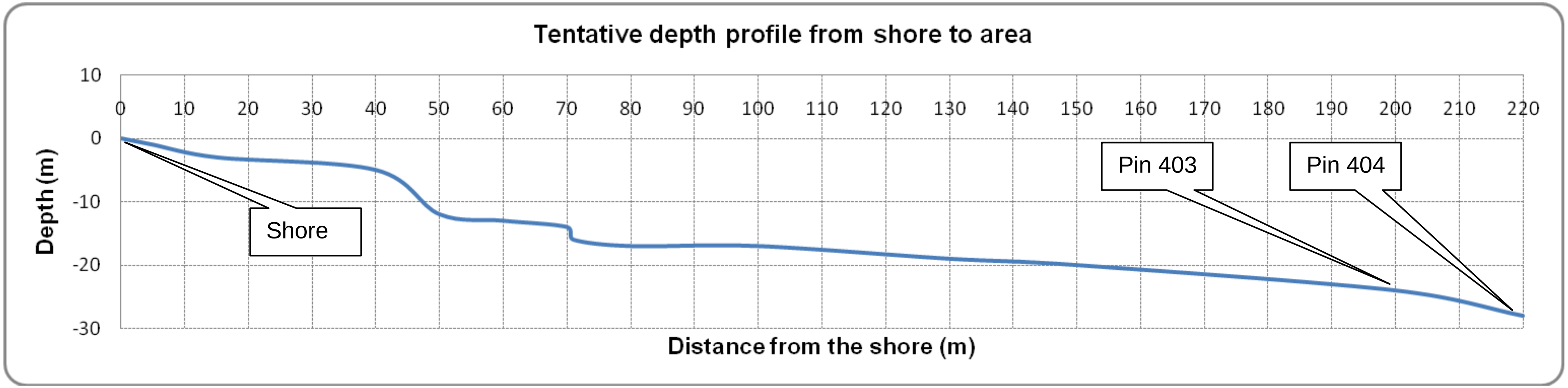


Figure 3 Depth measurements and locations of bedrock peaks. The colored dots represent classes of depth.

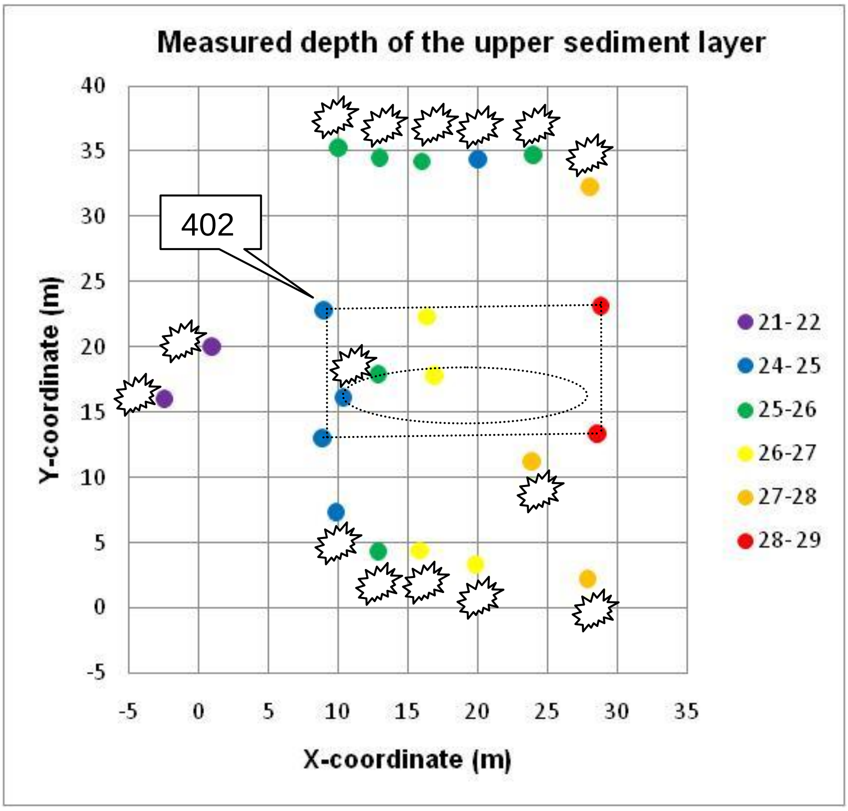


Figure 4 Calculated (MiniTab^{TM}) iso-depth lines.

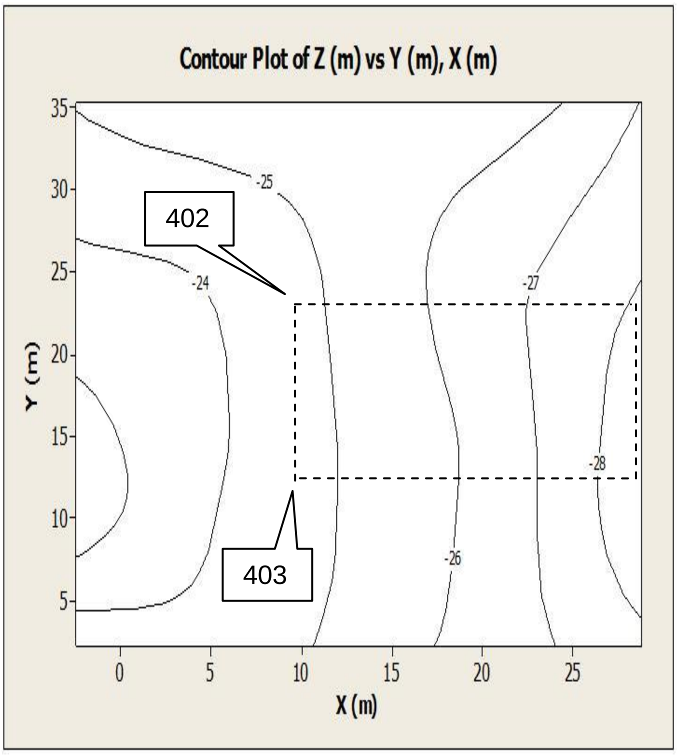


Figure 5 Codes and lay-out of the gridline area: sequence of the numbering.

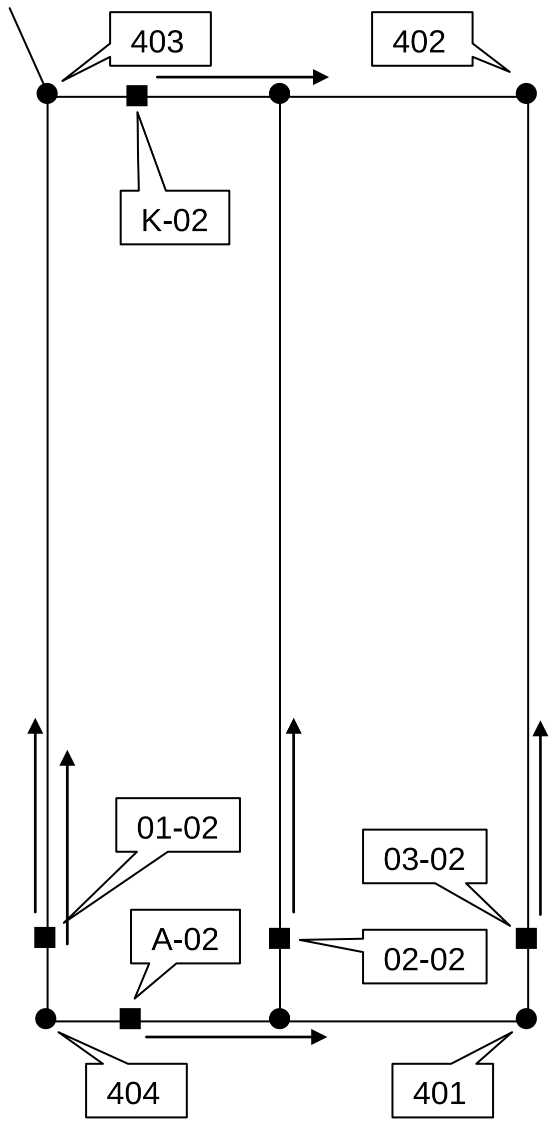


Figure 6 Site Recorder™ map of the calculated coordinates of all positions (reference points and pins).

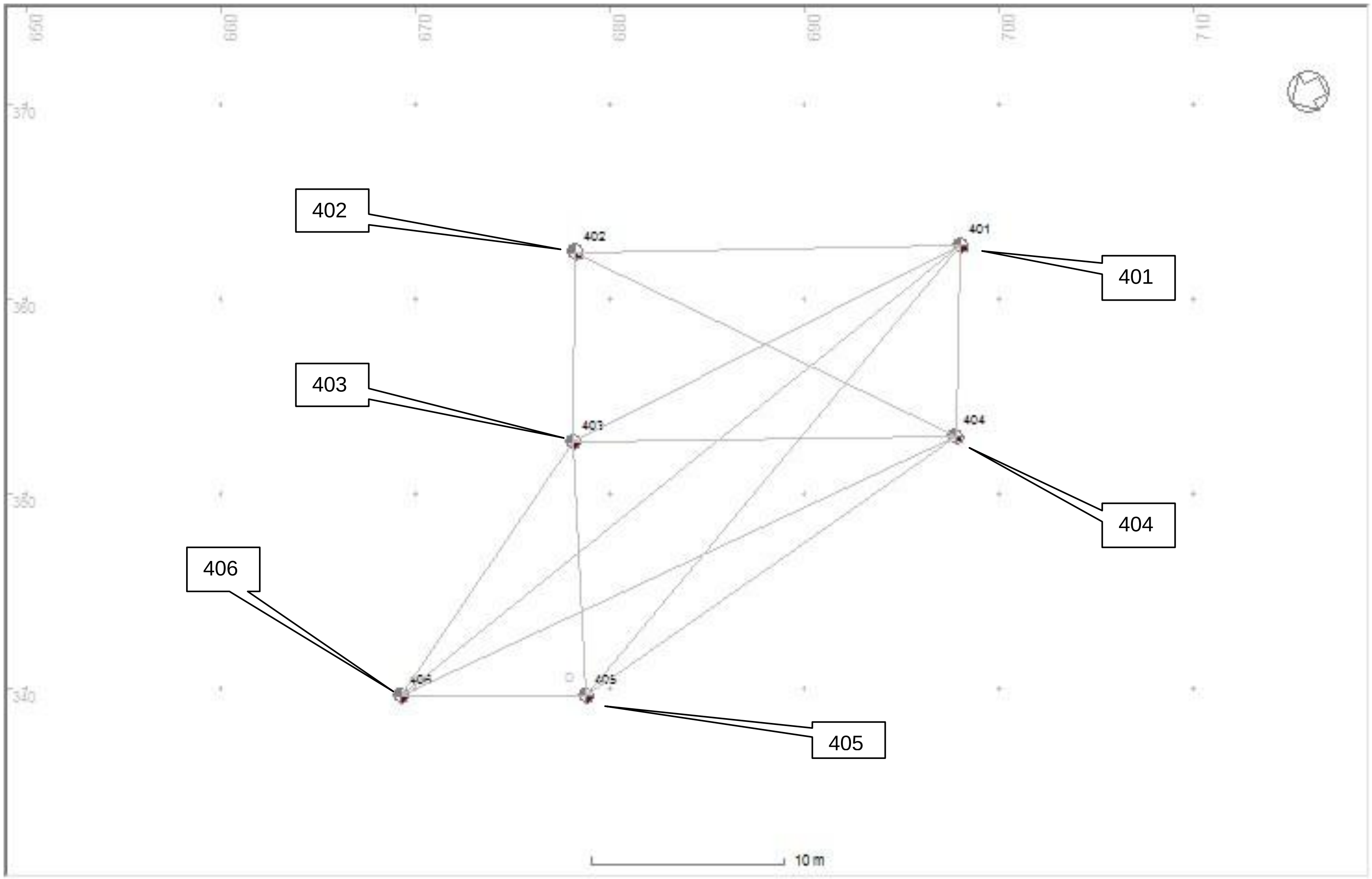


Figure 7a Photo mosaic in its basic state

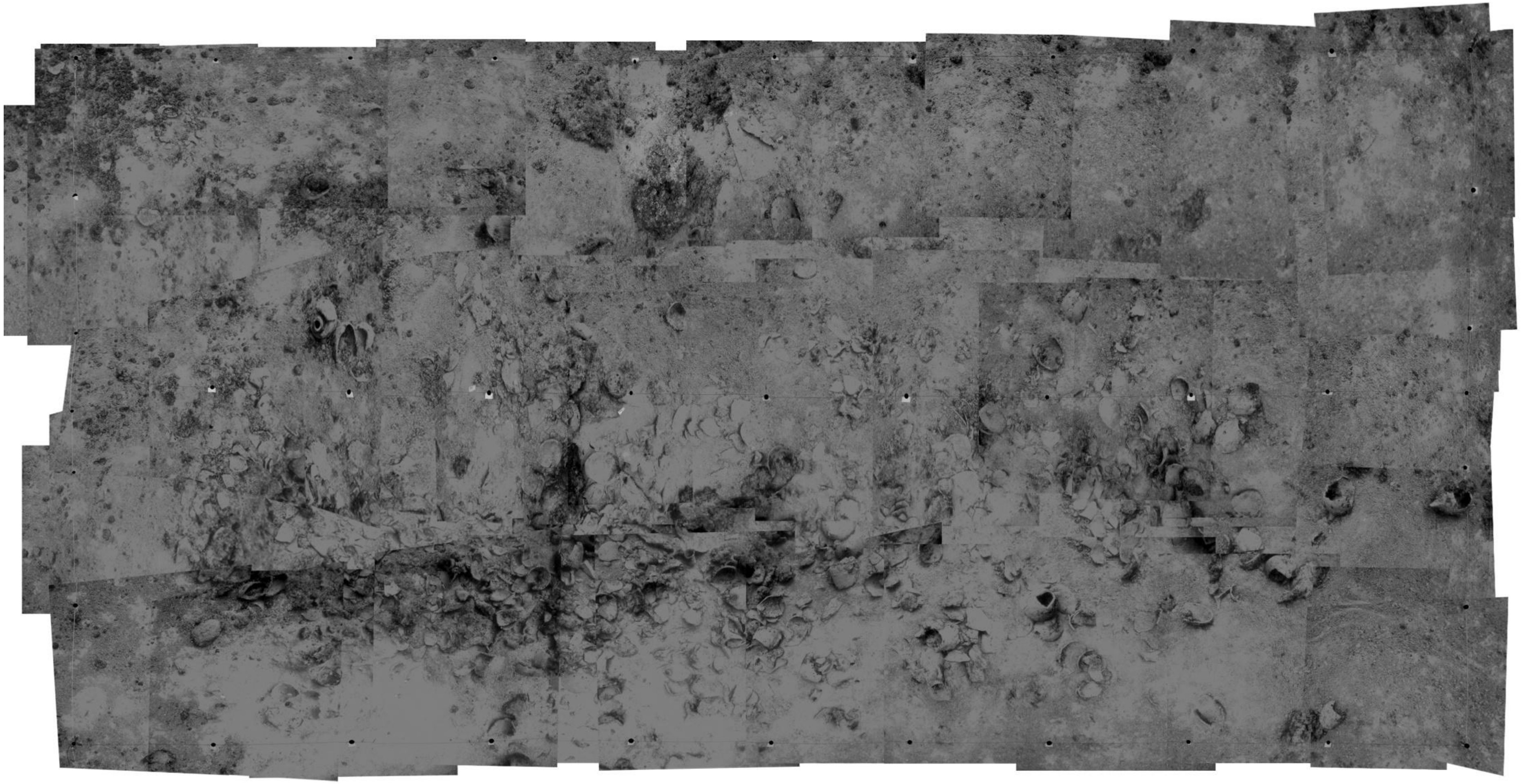


Figure 7b Photo mosaic with highlights of the gridlines, the amphora shard distribution and the excavation area.

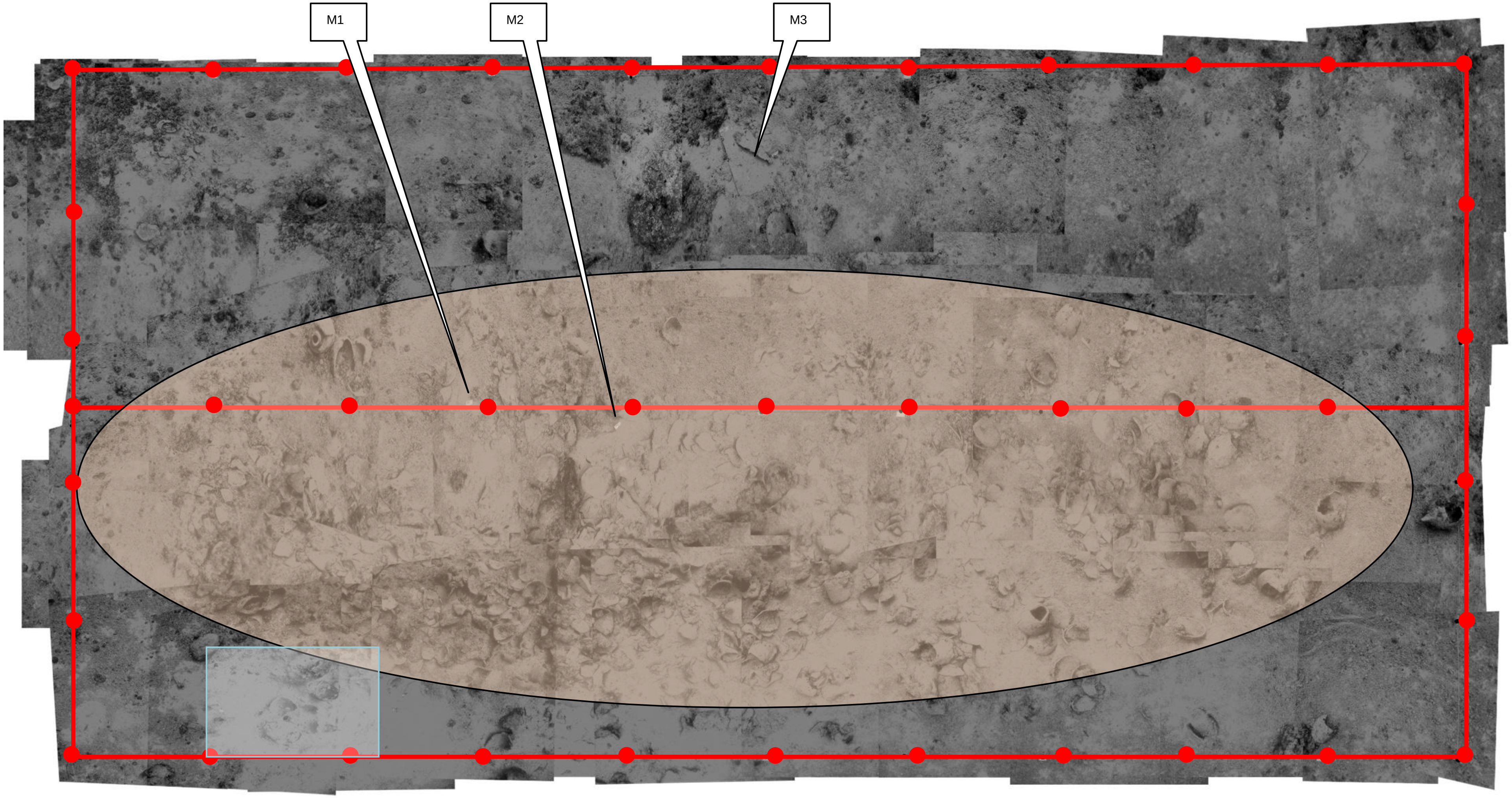


Figure 8 Metal sheet M3 at its underwater location.

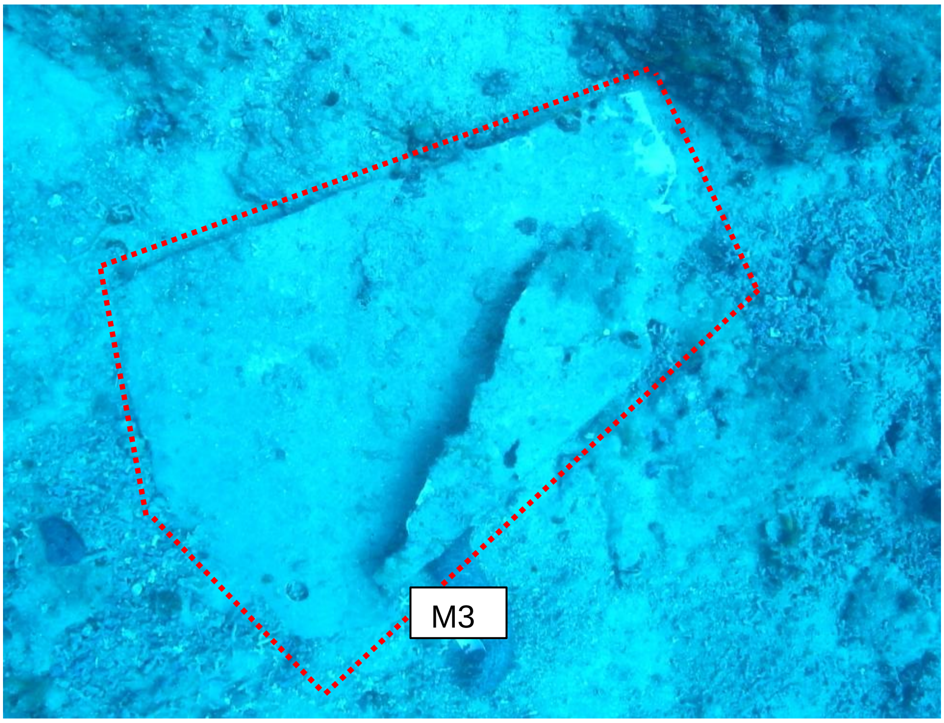


Figure 9 Metal sheet M2 at its underwater location.

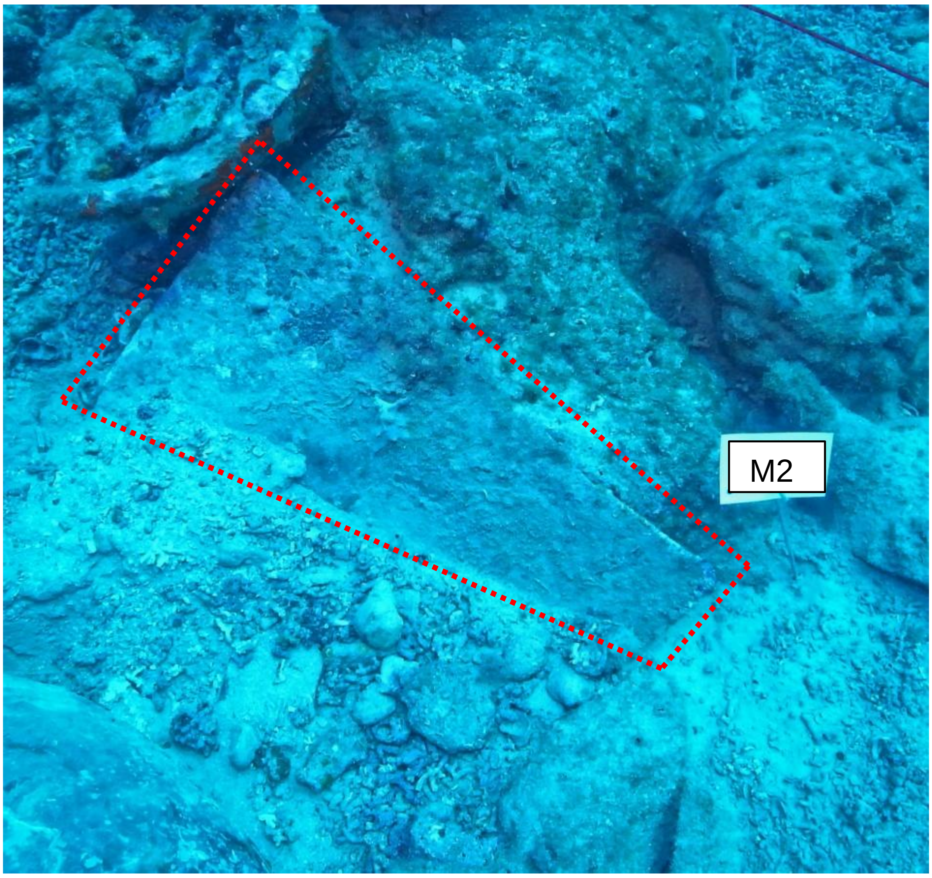


Figure 10 Amphora A11 in-situ.

Figure 11 Amphora A12 in-situ.

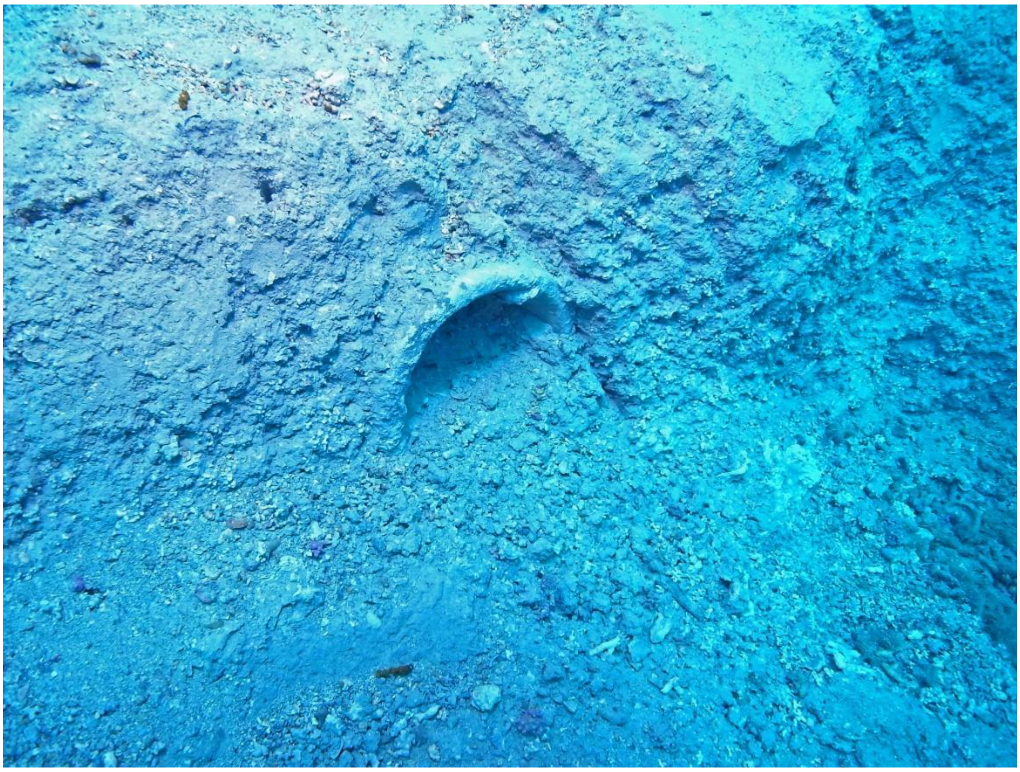


Figure 12 Birds view of the excavation area prior to excavation.

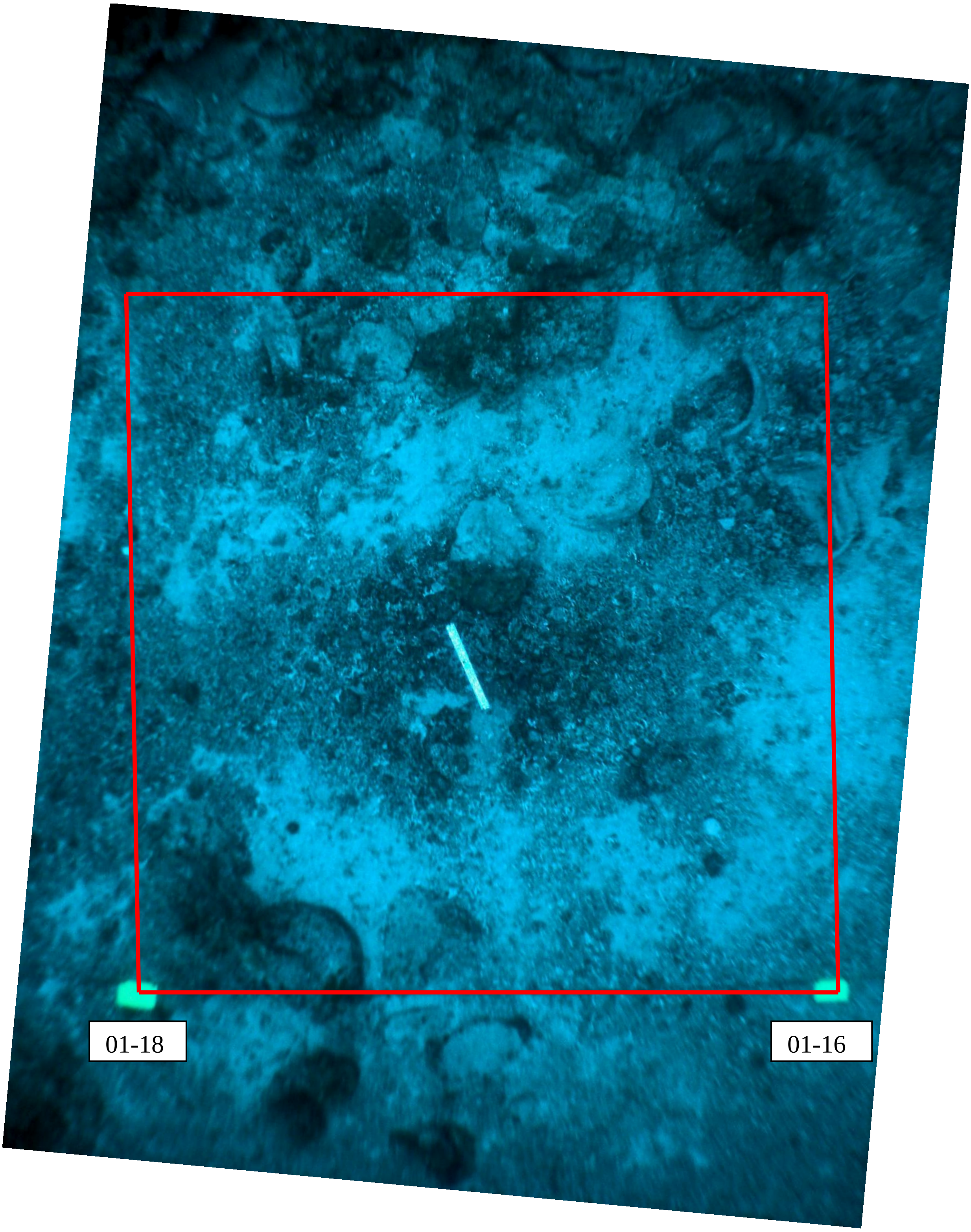


Figure 13 Birds view of the excavation area after excavating of two teams.

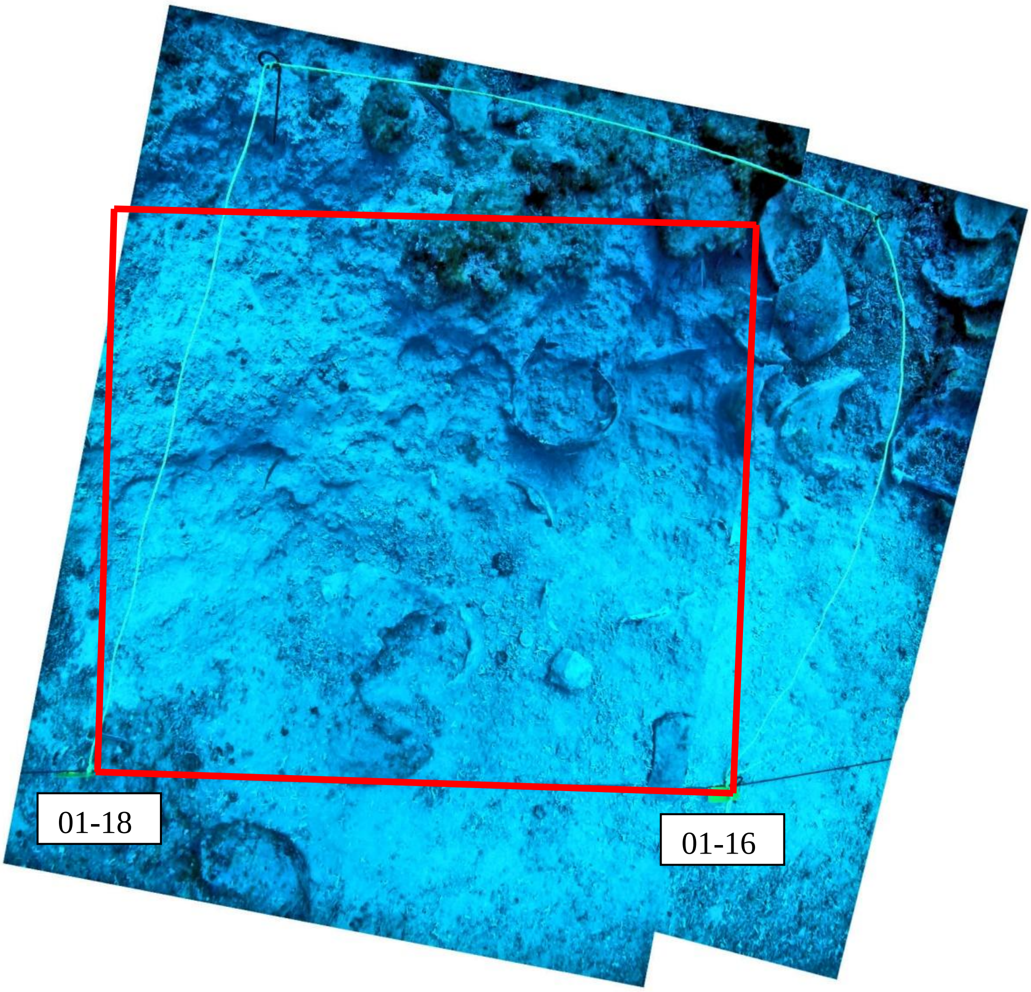


Figure 14 Photo mosaic birds view of the excavation area at its final stage.

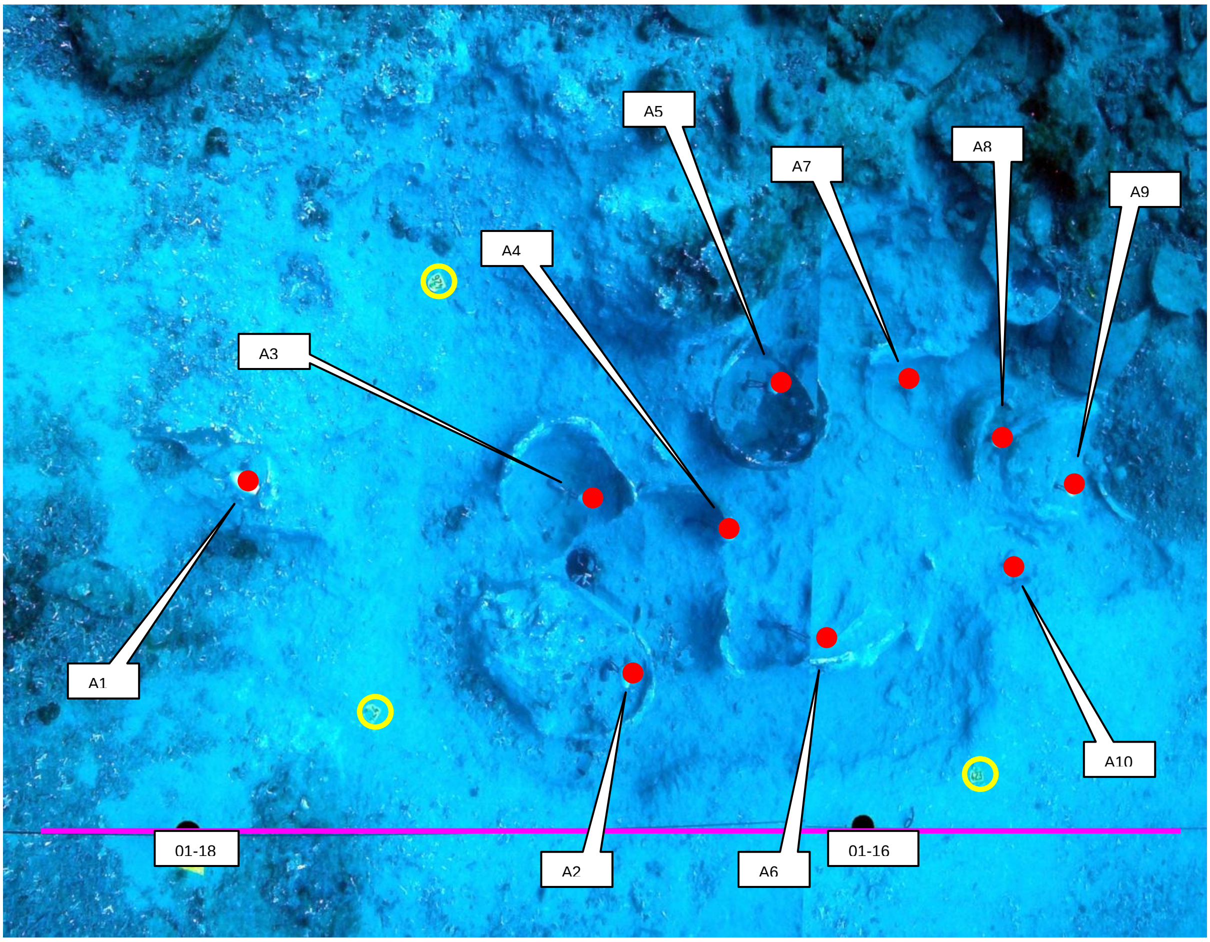


Figure 15 Panoramic close-up of the excavation area.

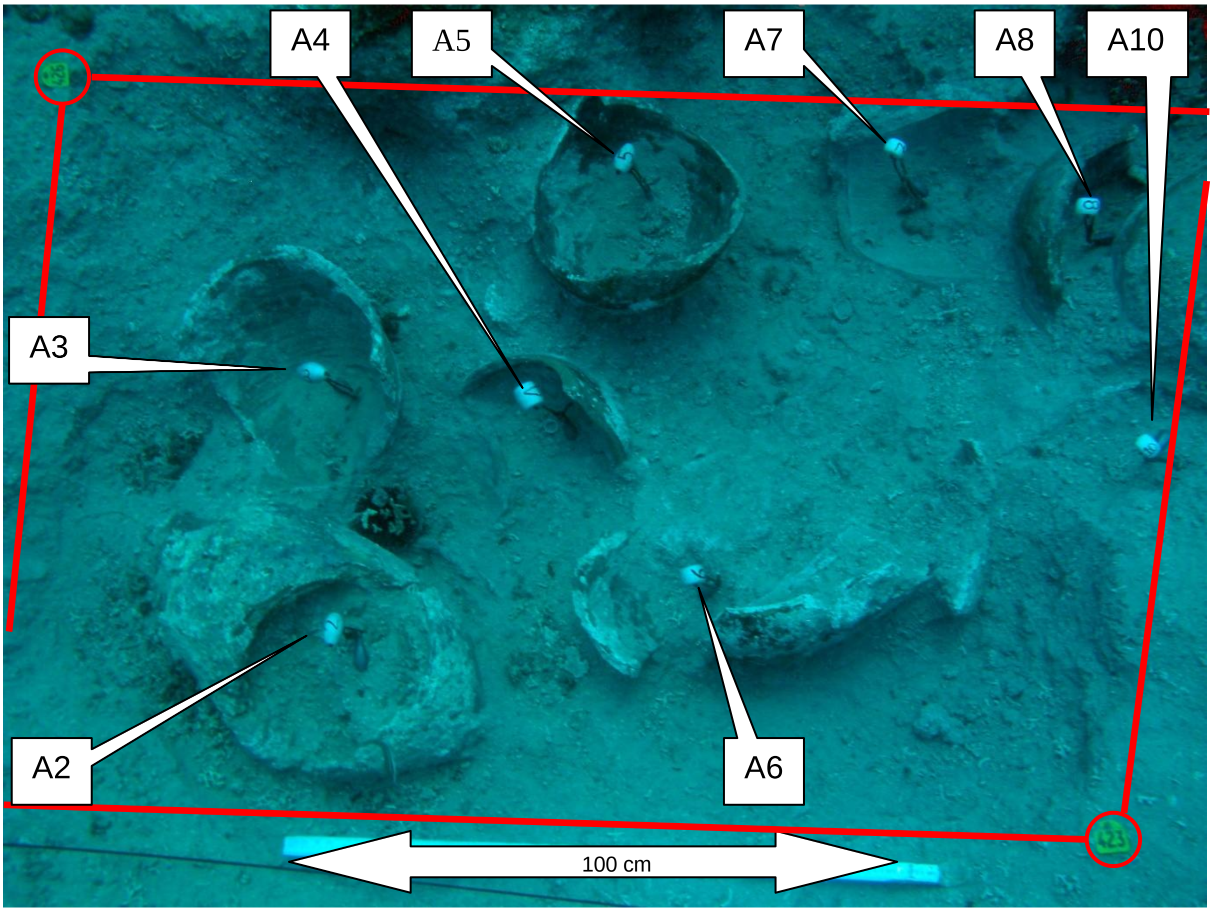


Figure 16a Excavated amphora A11, prior to salvation.

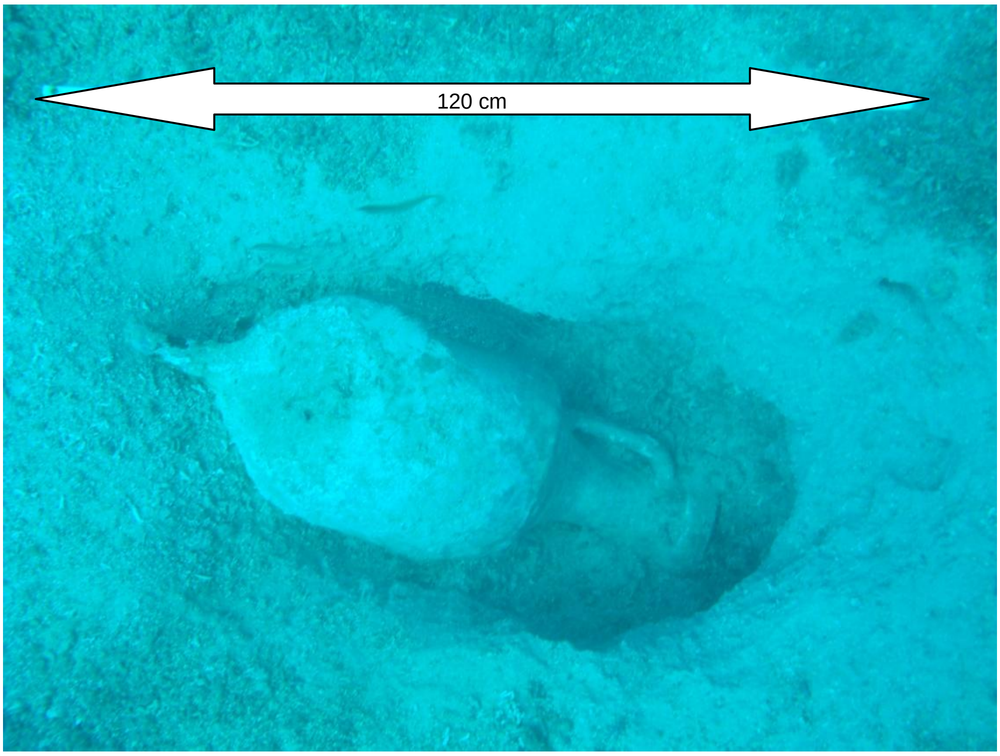


Figure 16b Amphora A11 prior to transport by means of lifting balloon.

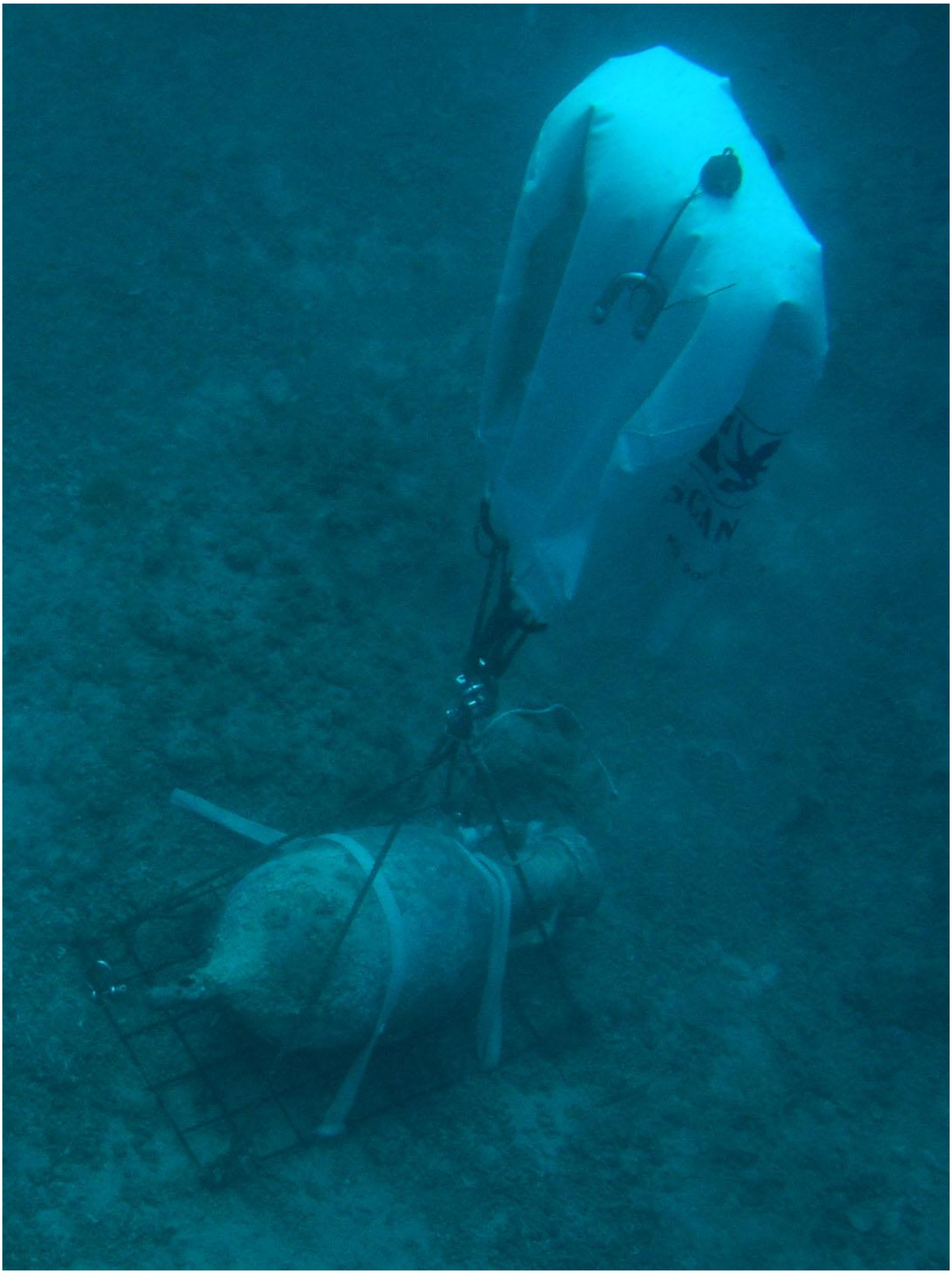


Figure 17 Amphora A11 after salvation.

Figure 18a Shard of amphora A12.

Figure 18b Detail of the stamp (AROHELA) on Amphora A12.

Figure 19 The salvaged metal plate M3.

Figure 20 The salvaged metallic concretion.

Appendix 2 Description of all techniques used.

This Appendix describes all techniques used in alphabetical order.

Coordinates, calculation of

Coordinates of data-points have been calculated using various mathematical routines embedded in the computer application Site Recorder™. Three routines have been used:

- The webbing-routine. For using the webbing routine all distances between all data-points must be measured, by fixing the measuring tape to a datum-point and measure all distances to the remaining data-points. This must be repeated for all data-points. The mathematical routine (iteration) than calculates all coordinates relative to each other. The coordinates can then be translated to a useful coordinate system, by choosing a specific datum-point as a reference.
  This routine was used to establish the coordinates of gridline-pins and de permanent reference point.
  This routine is often used for determining the coordinates of complex lay-outs of large (> 10m) dimensions. Depth data can be included.
- Trilateration. For using trilateration two (or preferably more) distances between the datum point and two (or more) other data-points with known coordinates must be measured. The routine then calculates the coordinates with respect to the reference points. Depth data can be included.
  Trilateration is specifically useful in cases when distances are too long to measure with the measuring stick.
- Tie-lines at right angles. Tie-lines at right angles hardly requires a mathematical routine. For using this routine, the shortest distance between de datum point and a (grid)line and the position on this line must be measured. Simple calculation provides the coordinates, provided the position of the line with respect to the reference coordinates is known.
  Tie-lines are specifically useful in cases when datum-points are close (<1m) to (grid)lines.

Excavating

For removing the sediment, a so-called mammoth-pump was used. A mammoth water-pump consists of a tube with a length between 2- 4m and an inner diameter between 10- 15cm. At the front-end, an inlet tube provides a water-jet into the tube at an angle of about 45^0. This jet causes a Venturi-effect which starts a water-flow to the other end of the tube. The water jet is provided by a water-pump (3bar / 50 dm^3min^{-1}), operated on a surface vessel. The water flow is very mild, so there was no need for a valve to regulate the water-jet and thus the suction of the mammoth.

Removing sediment, by using the mammoth water pump was done by loosening and stirring-up sediment by hand followed by sucking it up.

GPS coordinates, determination of

Because GPS receivers cannot receive signals under water, simple determination of GPS coordinates cannot be done. For shallow (and calm) waters (0- 5m) a boat and sufficiently long poles that are kept upright can be used. For deeper waters, these poles can be replaced by a buoy line and a buoy. This method provides results within 10- 50cm accuracy at most, often sufficient for our purposes. This requires perfect conditions with absence of wind and water current. Unfortunately conditions above the site were far from ideal, resulting in offsets of several meters.

<u>Gridlines, mounting of</u>
The pins (4 large ones and 2 smaller ones) as well as the lines were prepared ashore. The large pins (80x1.5cm) were equipped with (cow-ear) tags and hooks to fix the lines. The lines were cut in 2 sections of a little over 10m and 3 sections of a little over 20m. At one end of each line, metal clamps (widow-makers) were fixed. Starting at these sides of all lines, the lines were tagged with white/yellow plastic tags (10x6.5cm) at intervals of 2m. Each tag was given a number, designating the line (01, 02, 03 for the long and A and K for the short lines) followed by a bar and the distance from one pin. Figure a shows the complete lay-out of the gridline.

Figure a The lay-out of the gridline. The arrows show the increasing numbers.

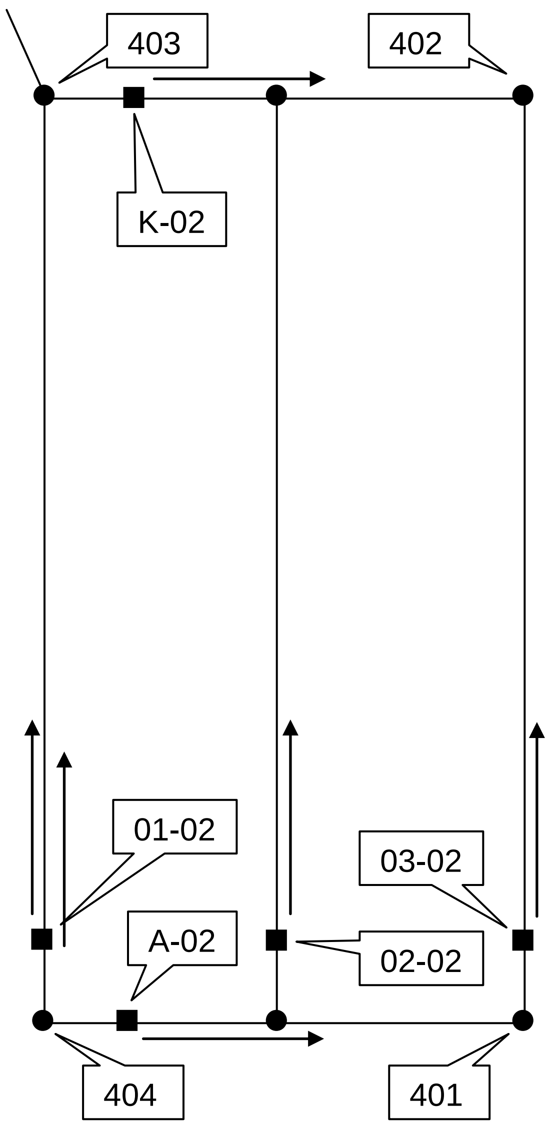
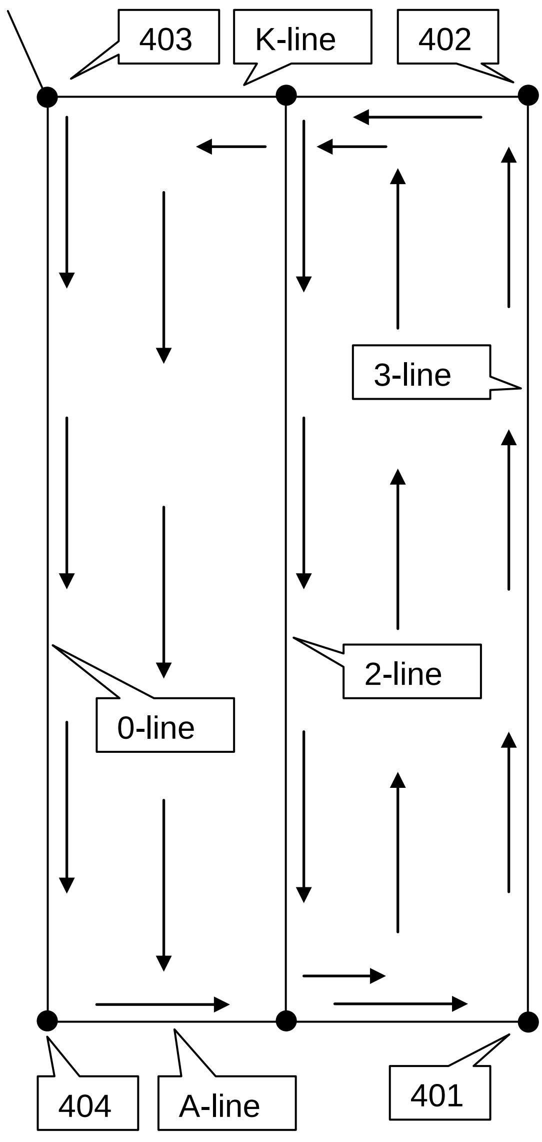


Figure b The sequence of the photographs for the photo mosaic.



Measuring distances and dimensions

Distances were measured using:

- Measuring tape (error approximately 0.3%, caused by stretching and sagging). The measuring tape was hooked-up to the metal pins. This causes an off-set of 2.5cm, which was subtracted from the value read from the tape.
- Measuring stick (error approximately 0.1%, but in most cases significantly more, caused parallax or perspective mismatch).
- Measuring ruler, from photographs that include an object of known dimension (and orientation with respect to the artifact), like a measuring stick.

Metal detecting

- For detecting metals, an underwater detector, the Tesoro stingray II, was used. Discrimination of the detector was set on non-ferro metals, thus avoiding undesired signals of modern garbage, because ancient ferro-metals are not expected to be present in the upper sediment layer.
- The actual detecting was done swimming across the short side of the area 20 times, covering lanes of a meter in width each crossing. Strong signals were checked-out by inspecting the surface for the source.

Photographs, taking of

For taking photographs, a Sea & Sea digital underwater camera, equipped with external flash and wide angle lens of 20mm (surface) was used.
The photo mosaic was taken by hand, not using auxiliary tools like frames for controlling the object-distance (and thus field-angle) and verticality. Both object-distance and verticality were maintained during the session as good as possible. These deviations as well as that of exposure and contrast were corrected later by means of repair-options in PhotoShop™ (brightness, contrast, size and shape). The same software was used to stitch the photographs into a photo mosaic.
The Photographs were taken in the sequence shown in Figure b:

- All photographs were rotated to the same orientation (403 to 404).
- The visible tags on the photographs were highlighted by a black dot. This improved the ease of stitching dramatically.
- The photographs were stitched starting at pin 403 along gridline-01, gridline-A, gridline-03 and gridline-K, than along gridline-02 and finally filling the gaps between gridlines 01 - 02 and 02 - 03.
- The photo mosaic was saved as a jpg-file and enhanced with respect to brightness and contrast.
- The gridlines were highlighted by a red line.

It should be noted that due to parallax differences it is not possible to get a good overlap between photographs that cover a significant difference in height (like the gridline and the bottom. The large photo mosaic, which covers the entire gridline-area. Photo mosaic pictures of more confined areas can be produced with good overlap.

Appendix 3 The coordinates of all reference points, pins and artifacts.

Table a Coordinates of all objects with respect to the 405-406 references

Object	X	Y	Z (depth)	Location
	m	m	m	
401	28.79	23.13	-28.2	Top sediment
402	8.97	22.80	-24.1	Top sediment
403	8.84	13.02	-24.2	Top sediment
404	28.52	13.35	-28.8	Top sediment
405	9.52	0.00	-25.0	Bedrock
406	0.00	0.00	-23.0	Bedrock
A11	8.59	2.67	-24.5	Under sediment
A1	12.41	13.93	-24.8	Under sediment
A2	12.14	13.47	-24.8	Under sediment
A3	12.01	14.01	-24.8	Under sediment
A4	12.98	14.36	-24.8	Under sediment
A5	12.59	14.36	-24.8	Under sediment
A6	12.74	13.58	-24.8	Under sediment
A7	11.01	14.07	-24.8	Under sediment
A8	13.23	14.19	-24.8	Under sediment
A9	13.44	14.05	-24.8	Under sediment
A10	13.27	13.80	-24.8	Under sediment
A12	8.59	2.67	-24.6	Under sediment
M1	14.64	18.12	-26.0	Top sediment
M2	16.74	17.82	-26.4	Top sediment
M3	18.54	21.72	-26.8	Top sediment
BR1	27.97	32.30	-28.0	Top sediment
BR2	23.97	34.70	-26.0	Top sediment
BR3	19.97	34.40	-25.0	Top sediment
BR4	15.97	34.20	-25.3	Top sediment
BR5	12.97	34.50	-25.6	Top sediment
BR6	9.97	35.30	-26.0	Top sediment
BR7	27.84	2.22	-27.8	Top sediment
BR8	23.84	11.22	-27.0	Top sediment
BR9	19.84	3.32	-26.4	Top sediment
BR10	15.84	4.42	-26.0	Top sediment
BR11	12.84	4.32	-25.0	Top sediment
BR12	9.84	7.32	-24.6	Top sediment
BR13	-2.46	16.02	-21.3	Top sediment
BR14	0.94	20.02	-22.0	Top sediment
BR15	10.34	16.17	-24.8	Bedrock
BR15	10.64	16.47	-25.6	Top sediment

Appendix 4 Dive data of all project members.

Table a Full names of project members

Name	Full name
Besselaar	Joost van den Besselaar
Cornelissen	Noud Cornelissen
Derks-1	Brigitte Maassen-Derks
Derks-2	Diana Derks
Hoof	Eric van Hoof
Katunaric	Tea Katunaric
Lanen	Wilco van Lanen
Maassen	Rob Maassen
Mrcelic	Tino Mrcelic
Pennings	Marc Pennings
Seinen	Peter Seinen
Verrijt	Martien Verrijt

Table b Dive data of all project members.

Date 2010	Besselaar	Cornelissen	Derks-1	Derks-2	Hoof	Katunaric	Lanen	Maassen	Mrcelic	Pennings	Seinen	Verrijt	SUM
	min	min	min	min	min	min	min	min	min	min	min	min	min
September 16										35		35	
	41	41											
September 17		30								30			
	36												
	30									30			
September 18					30		30						
								40				40	
		34	34	34									
					37		37						
			38								38		
	32	32											
								36		36			
September 19								30		30			
					37		37						
	32			32									
						38					38		
	30											30	
							29	29					
			36		36								
						35					35		
												25	
September 20	35								35				
					34		34						
								38				38	
		37		37									
			37							37			
	31					31							
					33		33						
								39				39	
		36								36			
September 21	30					30			30				
					35		35						
			37									37	
		33		33									
								36		36			
	37					37	37		37				
			39		39							39	
								37		37			
September 22								29		29			
					37		37						
	41								41				
						48						48	
			36	36									
	37					37			37				
			30				30						
September 23	34												
									40				
All days	446	243	287	172	318	256	339	314	220	336	111	331	3373