Ancient Akrotiri Project

Dreamer's Bay Underwater Survey, 2018

Interim Report

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Introduction

From 10th to 25th September 2018 a team of archaeologists from the Centre for Maritime Archaeology, University of Southampton (UoS), UK, accompanied by a number of professional divers, a coastal geologist, and staff and students from the University of Cyprus, conducted an underwater survey of Dreamer's Bay, RAF Akrotiri, on the southern shores of the Akrotiri Penisnula (Figure 1). This work was conducted with the permission of the UK Sovereign Base Areas Administration, and of the Republic of Cyrus Department of Antiquities; with active support from the UK Ministry of Defence's Defence Infrastructure Organisation; and generous assistance from RAF Akrotiri, and the President of the Western Sovereign Base Areas Archaeological Society, Maj. Frank Garrod (ret.). The project hugely benefitted from the direct backing of RAF personnel who not only offered boats but also their time, expertise and support. A number of people helped in this manner but a particular thanks is extended to Sgt. Graham Moore as the official point of contact and Sgt. Sam Conway-Wallace for arranging all the boat support. Further support was provided by the Defence Infrastructure Organisation and the Western Sovereign Base Area Archaeological Society. Equipment and assistance was also offered from the University of Cyprus, MARELab, the Cyprus University of Technology kindly undertook the RTK survey, CP Marine Explorations, and Kembali Divers. The project was generously funded by the Honor Frost Foundation.

The research was conducted under the overall directorship of Prof. Simon James of the University of Leicester, the director and permit holder of the Ancient Akrotiri Project.

The primary target of the underwater survey work in Dreamer's Bay was the remains of an ancient breakwater submerged some 1- 5m below the water located in the eastern reaches of the bay. The underwater survey was designed to compliment and develop work undertaken over the previous three years (James & Score 2015, 2016, 2017), including an earlier season of survey and excavation in 2018 to investigate and record threatened archaeological remains along the shoreline at Dreamer's Bay (James & Score 2018), and to put these into the context of the Dreamer's Bay area and the settlement history and maritime cultural landscape of the Akrotiri Peninsula as a whole.

The Landscape context of Dreamer's Bay

Dreamer's Bay lies on the southern coast of the Akrotiri Peninsula (*akrotiri* meaning 'promontory': Figure 1). The peninsula is a unique and, by comparison with much of the rest of coastal Cyprus, exceptionally well-preserved block of coastal land, famed for its wildlife. It also contains extensive and important archaeological remains, most famously the

Aetokremnos site with pygmy hippo bones and the earliest evidence of human activity on Cyprus (c. 12,000 cal. BP; Simmons 2001, 2013).

Figure 1: The location of Dreamer's Bay on the Akrotiri Peninsula, Cyprus (Google Earth).

Since the Republic of Cyprus gained independence from British rule in 1960, under the Treaty of Guarantee Akrotiri has been part of the UK's Western Sovereign Base Area (SBA), one of two military base areas retained indefinitely (the other being the Eastern SBA of Dhekelia, east of Larnaca). The peninsula comprises a rocky former island, 9.6km long from Cape Zevgari in the west to Cape Gata in the east, and about 3.5km north-south. The land rises gently from north to south, reaching only a modest 50m above sea-level, and terminating on its southern edge in cliffs, except for c. 600m of low shoreline at Dreamer's Bay. Akrotiri is now connected to the mainland on the west side by a massive tombolo beach of large pebbles, and on the east side by a broad sand beach which runs into the outskirts of Limassol. The beaches frame a salt lake, famed for its flamingos, known as the Akrotiri Salt Lake.

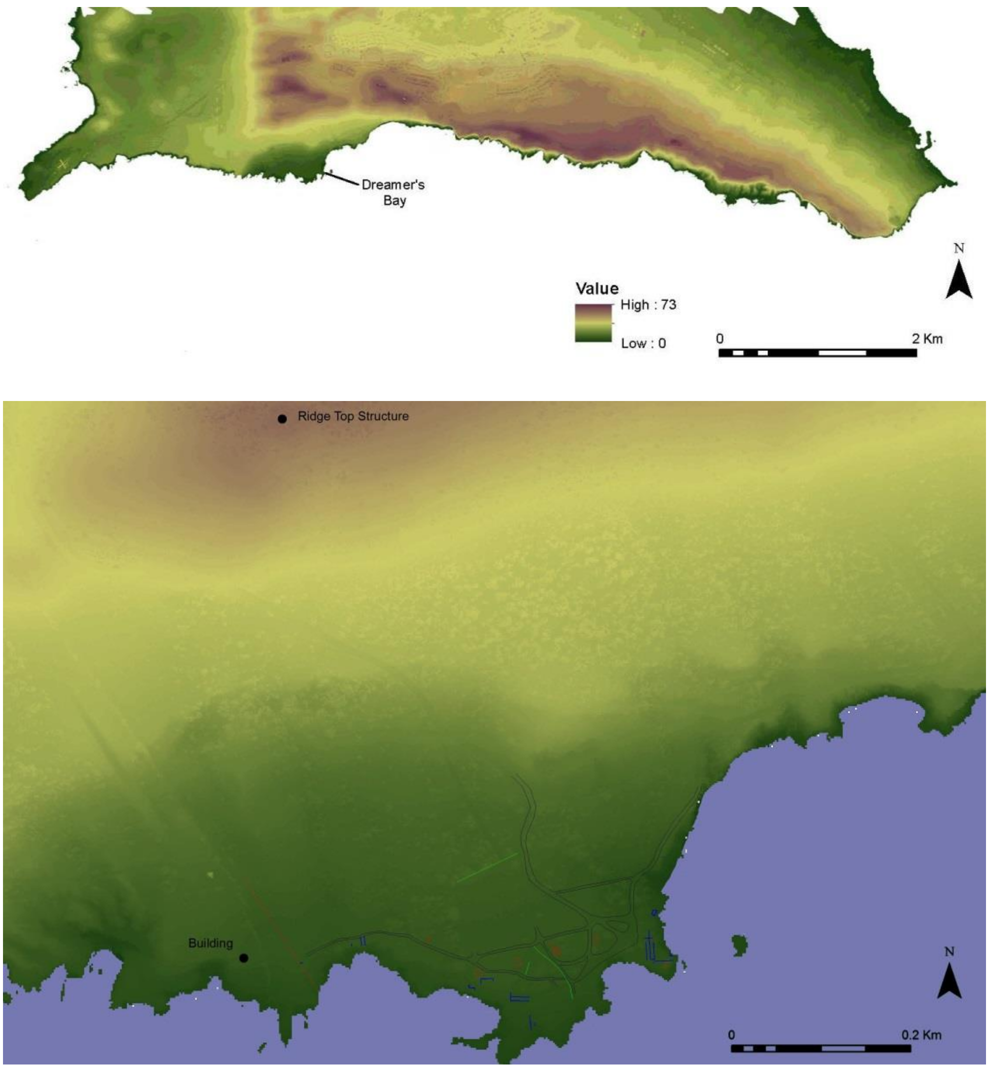

Figure 2: Digital terrain model of the southern part of the Akrotiri Peninsula showing the location of Dreamer's Bay.

The southern coast (Figure 2) of the Akrotiri Penisnula consists of high cliffs except for one area about 600m long in the west, where a broad area of lower-lying land projects into the sea. Here, around Dreamer's Bay, the shoreline stands nowhere more than about 5m above sea-level, with eroded rocky ledges and inlets, some of which have accumulated tiny sandy beaches. To the east forms a relatively deep natural anchorage, its use confirmed by the ancient artificial breakwater, anchors and other archaeology previously located on the sea floor in this region (see below).

This part of the southern coast has been protected by its location within the UK RAF base security perimeter. However, its location on the coast and the soft sandstone bedrock has resulted in coastal erosion.

Previous work at Dreamer's Bay

Remains of masonry buildings along the shoreline at Dreamer's bay were reportedly first exposed during heavy rains *c.* 1973-4 (Heywood 1982**:** 167). The remains visible on the surface at the start of the project in 2015, comprised masonry wall foundations and scatters of pottery and other material at various points along the east-west shoreline.

In the 1980's, in the cliff-lined bay east of the known shoreline buildings, a submerged artificial breakwater, built on an existing area of reef, was spotted from the air, and subsequently captured by aerial photography. It was subject to preliminary survey work by local avocational archaeologists including a comprehensive survey of the breakwater undertaken by Haggerty in the 1980's (1990). Subsequently further underwater survey was briefly conducted and in addition to the breakwater, ancient anchors and ceramic concentrations thought to attest wrecks, were also identified (Leonard and Demesticha 2004). The breakwater remains undated, but is thought likely to be Hellenistic (Leonard *et al.* 2007), and may have been initially built from the stone in the cliff-top quarries above. The breakwater may have provided an anchorage sheltered from westerly winds for centuries after construction.

Since 2000, survey work conducted by John Leonard and Stella Demesticha (Leonard and Demesticha 2004) led to a wider US/Canadian project at Dreamer's Bay. This was unfortunately cut short due to funding problems and the tragic early death of Danielle Parks, leaving it to Brad Ault of the University of Buffalo, to complete the survey (Leonard *et al.* 2006; Leonard *et al.* 2007; Ault 2010; Ault and Leonard forthcoming). Onshore work was largely confined to cleaning and recording of some of the remains, limited experimental geophysical survey work, and some initial survey of the submerged archaeology. Examination of the onshore evidence indicated that the buildings appeared to be associated with extensive quantities of overwhelmingly late Roman/early Byzantine ceramics, although some Hellenistic and earlier Roman material was also identified. The structures were identified as probably warehouses (*horrea*) rather than residential.

Underwater Survey of Dreamer's Bay 2018: Approach and Objectives

The 2018 underwater survey season was specifically designed to target the submerged breakwater that is located in the eastern reaches of Dreamer's Bay (Figure 3). The primary objective was to determine its precise function and date and specifically its relationship with the archaeological remains of Roman/early Byzantine date investigated in previous seasons along the western shores of the bay, as well as the ancient cliff-top quarries, which overlook the waters it protected. The overall aim was to build up a more complete picture of the port as part of the ancient settlement of the Akrotiri Peninsula, within the context of the southern coast of Cyprus and more widely within the eastern Mediterranean.

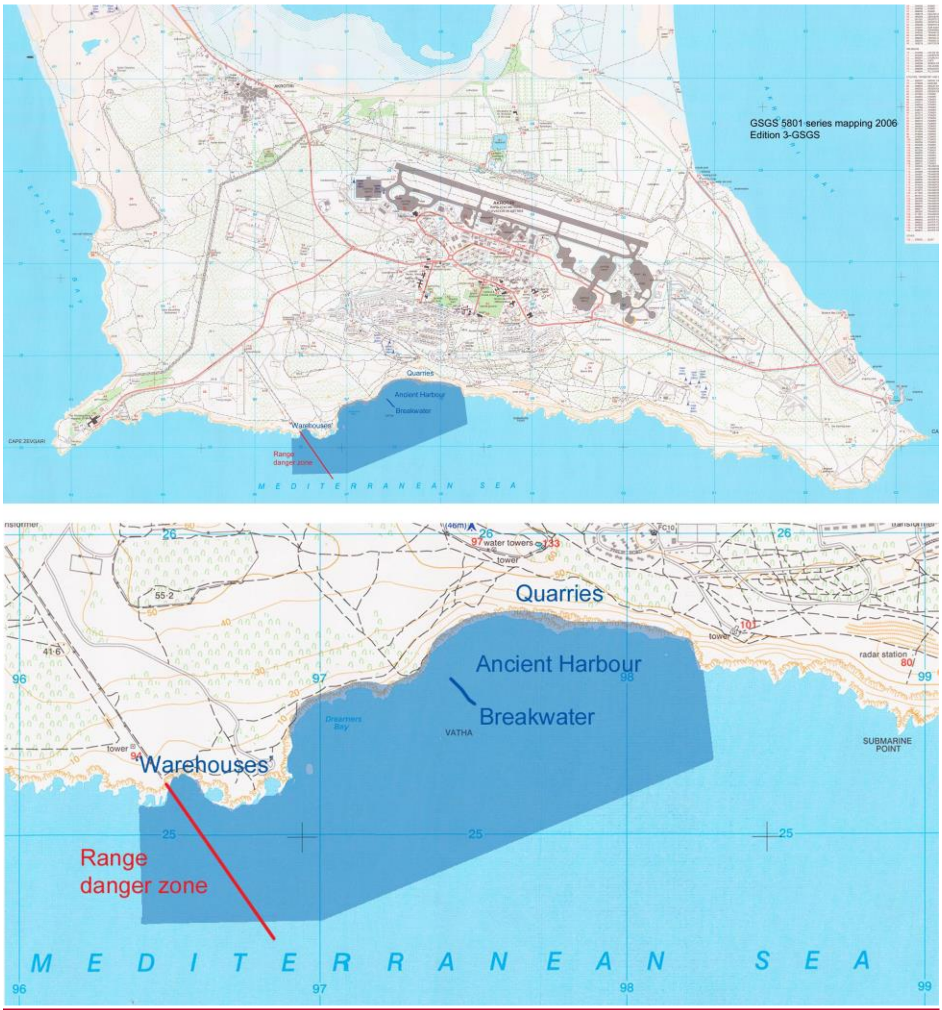

Figure 3: Underwtaer and shoreline survey work area conducted at Dreamer's Bay, September 2018. Large ruled squares are 1km on a side.

The submerged ancient breakwater is currently located some 90m offshore extending over a distance of 135m (Figure 3 and 4). The most substantial record of this submerged feature to date was documented by Haggerty (1990) in the 1980's. The intention of the 2018 survey, was thus to build on Haggerty's plan (Figure 4) and extend the record of the breakwater to include a third vertical dimension through the use of photogrammetry, so producing a 3D model of the feature (see **Photogrammetry Survey** results below). The breakwater was also located in space using a RTK DGPS and aspects of its construction were recorded in detail using photography and sketches. The objective of this more detailed survey was to further define the extent and nature of the ancient breakwater, and through more detailed examination, it was hoped to record its key features in order to clarify the method and date of its original construction, its specific function, and the reason for its eventual decline.

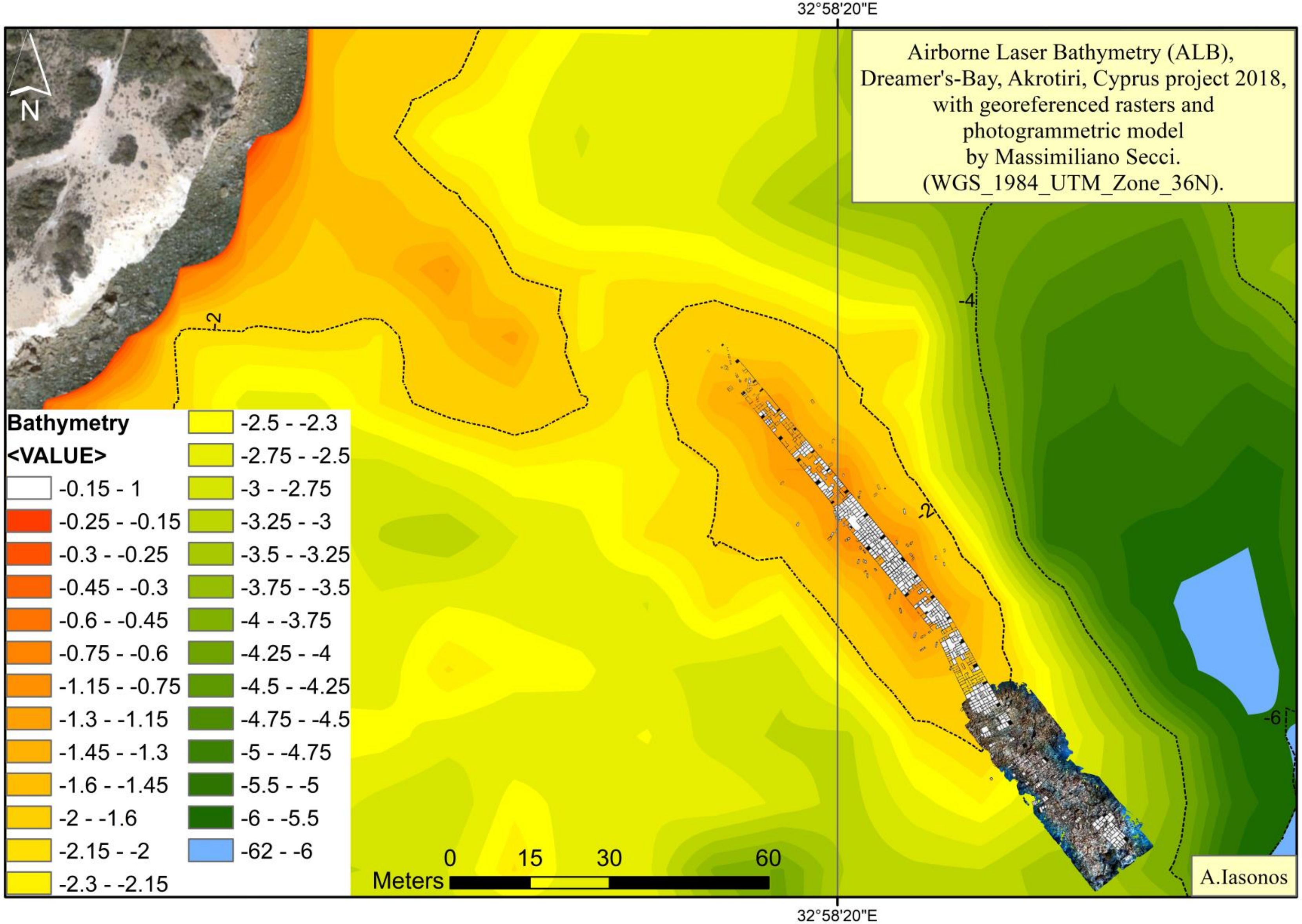

Figure 4: The breakwater as recorded during the 2018 season as compared with Haggerty 1990 (A. Iasonos and M. Secci)

The breakwater's northern end was examined, in order to determine if it was originally connected to the land. The coastline to the north of the breakwater has been subject to coastal erosion and the end of the breakwater is now dislocated by some 90m. The aim was to determine the original relationship between the structure and the cliff face. Towards the southern, seaward end of the breakwater, the water depth increases and the construction widens and extends to a greater depth underwater. This area was examined in detail to determine its specific function.

Originally it was the intention to also attempt to excavate a small section either side of the breakwater but this idea was quickly abandoned, as rubble packed up against the sides of the structure was too dense and the shallow water made excavation with a water pump almost impossible.

Sedimentology was also conducted underwater in the region of the breakwater. A number of sediment cores (four successful; see Figure 20 below) were also extracted in order to try and determine the nature of the environment either side of the breakwater over the course of its life – sediments deposited in calmer waters indicating that shelter was available, whereas those deposited in more tempestuous seas would indicate that the shelter previously provided by the breakwater was no longer afforded and the area had become exposed to the prevailing maritime conditions. The **Underwater and Coastal Geological Survey** describes the process in more detail. The cores are being further analysed to determine if any dating materials have been preserved that might help identify the date of its establishment and the transition phase of the breakwaters decline, and hence the date that the breakwater fell out of use.

Thus, the main aim of the survey was to establish the primary function, date and construction sequence of the breakwater feature and ultimately whether or not the feature was indeed a breakwater providing shelter along its length in its lee, or in fact a jetty that was primarily accessed via deeper waters to the south. A jetty would have facilitated the offloading of goods and people transported along its length assuming the jetty was originally connected to the base of the cliff face to the north, or via smaller craft to the shore and/or the structures on the shore to the west of Dreamer's Bay.

Besides the focused survey of the breakwater, further systematic underwater survey was conducted in the rest of the bay in the vicinity of the structure and the entire bay to the west and east of the breakwater, with the objective of locating new and/or relocate previously discovered archaeological finds on the seabed. Underwater survey was also conducted in front of the archaeological remains on shore to the west of Dreamer's Bay as far west as the Rifle Range (Figure 3). The primary objective of this extended survey was to determine if there are any archaeological remains underwater that may relate to the 'warehouses' and pottery scatters located on the shore.

All finds were noted, described and photographed underwater and a record of their location taken using GPS. Selected finds were lifted when archaeologists felt they were either in danger of further displacement and erosion on the seafloor, or that they were useful as chronological indicators. Distribution and quantities were noted to explore the nature of activities either side of the breakwater in order to help determine its function (for details of the survey methodology and results see **Extended Underwater Survey** below).

Overall the survey aimed to place the breakwater both functionally and chronologically within the broader maritime landscape of the Akrotiri Peninsula.

Photogrammetry Survey - Massimiliano Secci

Introduction

The objective of the survey was to record the submerged breakwater located in Dreamer's Bay through the implementation of underwater photogrammetry, in order to create a three-dimensional (3D) model of the breakwater and surrounding seafloor. Photogrammetry represents a technique that allows the recording of an object, a feature, or a landscape or scene, by using photographic images, in a way that enables further metric analysis and model building.

For photogrammetric recording to be useful for archaeological analysis, the recording process must abide by a series of parameters: 1) photographic images must be taken according to specific data capture geometries, in order to cover the whole area to be reconstructed; 2) the photographic images should maintain a specific overlap with neighboring images, in order to ensure the whole area is covered and the photogrammetric software has the ability to find common points in the images; 3) a set of metric reference should be placed in the scene to be recorded, in order to allow scaling of the scene in a metric system.

Methodology

In Dreamer's Bay, the large extent of the area to be recorded prevented the team from recording the feature all at once, therefore the overall area had to be subdivided in smaller sections (see Figure 5).

The first step of the procedure involved two members of the team placing scale bars in specific locations along and around the breakwater structure (Figure 5). The scale bars served two main purposes: i) work as scale bars for scaling and orienting the breakwater three-dimensional model that was to be generated after data processing; and ii) to serve as Ground Control Points (GCPs) enabling connection of the neighboring sections together.

The scale bars (containing two markers at a calibrated distance of one meter) were placed on the eastern and western side of the breakwater. They were spaced approximately 15m apart and oriented in a N-S direction. The calibrated 1m scale-bar allowed proper scaling for the photogrammetry model and its orientation (i.e. in a North-South direction).

Subsequently, two 30m measuring tapes were laid either side of the breakwater as close as possible to the structure and acted as parallel baselines from which the photogrammetry survey was conducted (Figure 6). The end (points 0) of the baselines, were placed towards the southerly, seaward end of the main bulk of the breakwater parallel to one another. Compass bearings were used to place the end of the baseline at the same position on each side (W and E) of the structure. Two pairs of divers were stationed on the seafloor at the end of the baselines (point 0) and held a line with a floating buoy. The buoy and the divers acted as a guide/ reference point, indicating the direction of the transect along which the photographer on the surface had to orientate. The photographer swam on the surface from one side to the other across the breadth of the breakwater. Divers incrementally moved along the baseline at a 1m intervals, this procedure enabled the photographer on the surface to shoot a video along transects running progressively in a northerly direction between the 0, 1, 2, n meter marks along the baselines towards the 30m point. This operation was repeated along the length of the breakwater until the entire breakwater had been recorded. Due to the extremely shallow depth, the surveyor decided to shoot some video instead of still photographs in particular sections. In the post-acquisition phase, a number of still frames were extracted from the video footage and used for the photogrammetric processing within the software Agisoft Photoscan (see Figure 7).

Challenges

A few issues were encountered during the survey, particularly of the shallowest portion of the breakwater at the inland, northern extremity (Figure 5, Sections 1, 2 and 3), which relate to the specific environmental characteristics of the site location. Issues included the fact that:

- The breakwater lies in very shallow waters parituclarly towards the northern end i.e. less than 1m;
- The breakwater and rubble areas are covered with dense seagrass which is constantly being moved by the swell, hindering the photogrammetry exercise;
- The photographer on the surface was also being constantly moved by the swell, making it difficult to sustain straight transects lines, to keep the camera still, and maintain focus of the camera;
- Caustics[1] created by the sunlight penetrating the sea surface and being projected with a bright shine onto the seafloor surface, are a major issue in such shallow waters, and created further problems in the photogrammetric processing phase.

[1] Caustics are the effect of light refraction through a changing medium (in our case from air to water, specifically due to the water surface refraction). The light rays are refracted by the water surface and projected with a high intensity over the shallow seafloor. In the context of photogrammetry this creates issues because caustics location and intensity changes with the swell, and also the areas where caustics are present in a photo and the software (Photoscan) does not recognize points. Similarly to the case of seagrass, if the areas affected by caustics are continuously changing, the ability of the software to identify common points among different photos and reconstruct the scene is highly jeopardized. (as a visual example of caustics see: https://en.wikipedia.org/wiki/Caustic_(optics)#/media/File:Great_Barracuda,_corals,_sea_urchin_and_Caustic_(optics)_in_Kona,_Hawaii_2009.jpg)

The combination of seagrass and rippling caustics, jeopardized the ability of the algorithms within the photogrammetric software to identify common points among the images (which represents the basics for photogrammetrically reconstructing a scene). Simply put, the movement of seagrass and caustics within the recorded area changes the appearance of the scene (i.e. the luminescence changes, the location of the seagrass changes), as a still scene where common points can be recognized could not be guaranteed. This problem was further elaborated by the algorithms within the software. The combination of all these factors made it difficult to reconstruct the shallower portion of the breakwater (Figure 5, Sections 1-3).

Thanks to few favorable aspects, including the breakwaters relatively increased depths between 1 and 3.5m at its seaward end, and considerably less seagrass growth in this region, a more effective survey of the seaward portion of the breakwater was feasible (Figure 5, Section 4). These factors allowed the acquisition of photographic still images instead of video, and enabled the photogrammetric software to successfully align the images and reconstruct the feature (see Figure 7).

Some portions of the rubble areas were also surveyed photogrammetrically with the view of reconstruction, but unfortunately they were not sufficiently extended to be able to use the scale bars for scaling and orientation, but will be analyzed subsequently to determine the volume of rubble and hence the amount of material that has fallen from the breakwater. Also, the landward end (northern end) of the breakwater was reconstructed, but unfortunately the same problem applied: the scale bars where not repositioned, therefore making it difficult to scale the model and orient it properly. A photogrammetric survey was also done in a small area where four vertical courses of blocks were clearly visible (see below Figures 18 and 19).

Considering the site conditions and the issues related to its environmental characteristics, perhaps the best solution for future documentation of the breakwater that would more likely facilitate good representation and a three-dimensional model of the breakwater, could be to produce a drone photogrammetry survey, or acquire photographic images out of the water (i.e. perhaps with a telescoping fiberglass camera pole and a good compact camera). This approach would help overcome the shallow depths and mitigate the seagrass movement and, partially, the caustics effects. In order to mitigate the caustics, the only available option is to proceed with the data acquisition when the sun is rising and the effects of the caustics are limited (i.e. very early in the morning). However, the effect of caustics can also be partially reduced in the pre-processing phase, through image enhancement procedures.

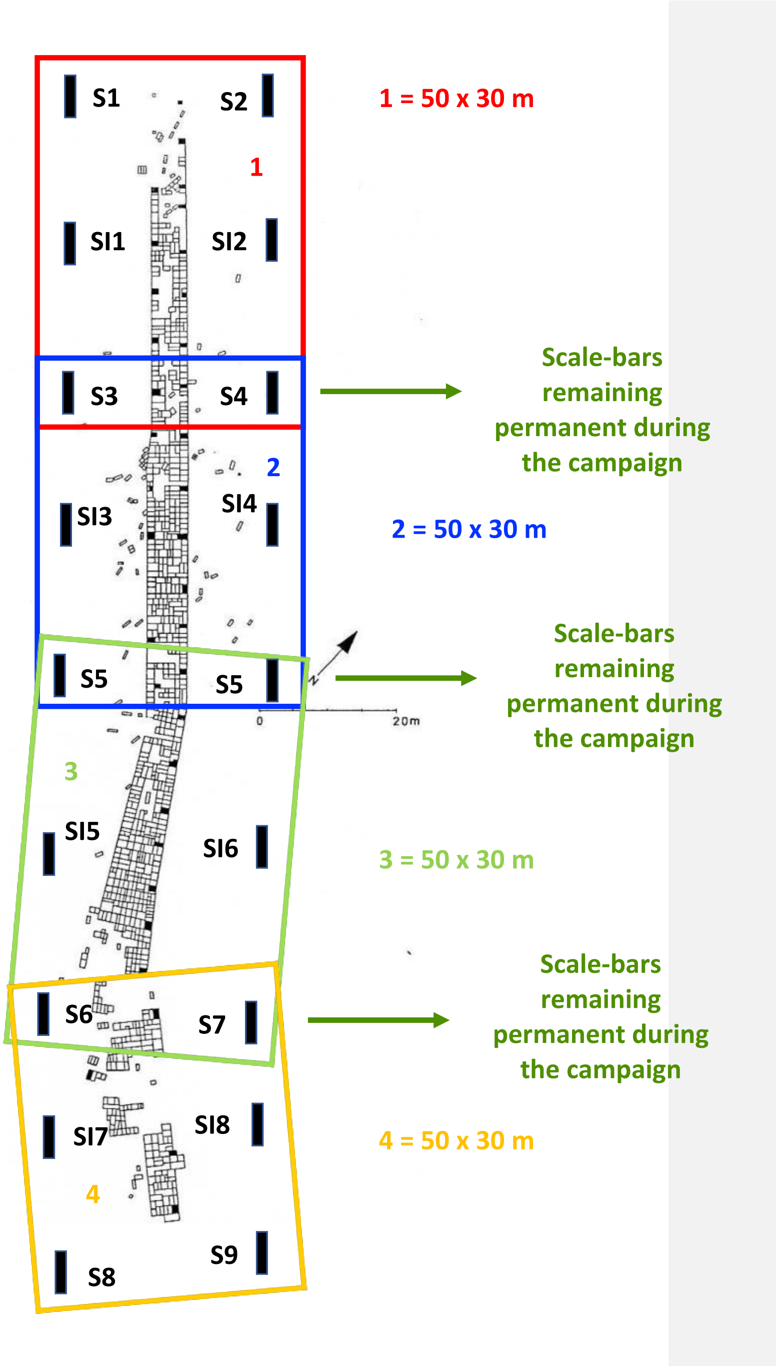

Figure 5: Plan of the photogrammetry survey, noting four survey sections and the location of the scale bars (S1 – S18) (developed by M. Secci; based on the breakwater site plan by Haggerty 1990).

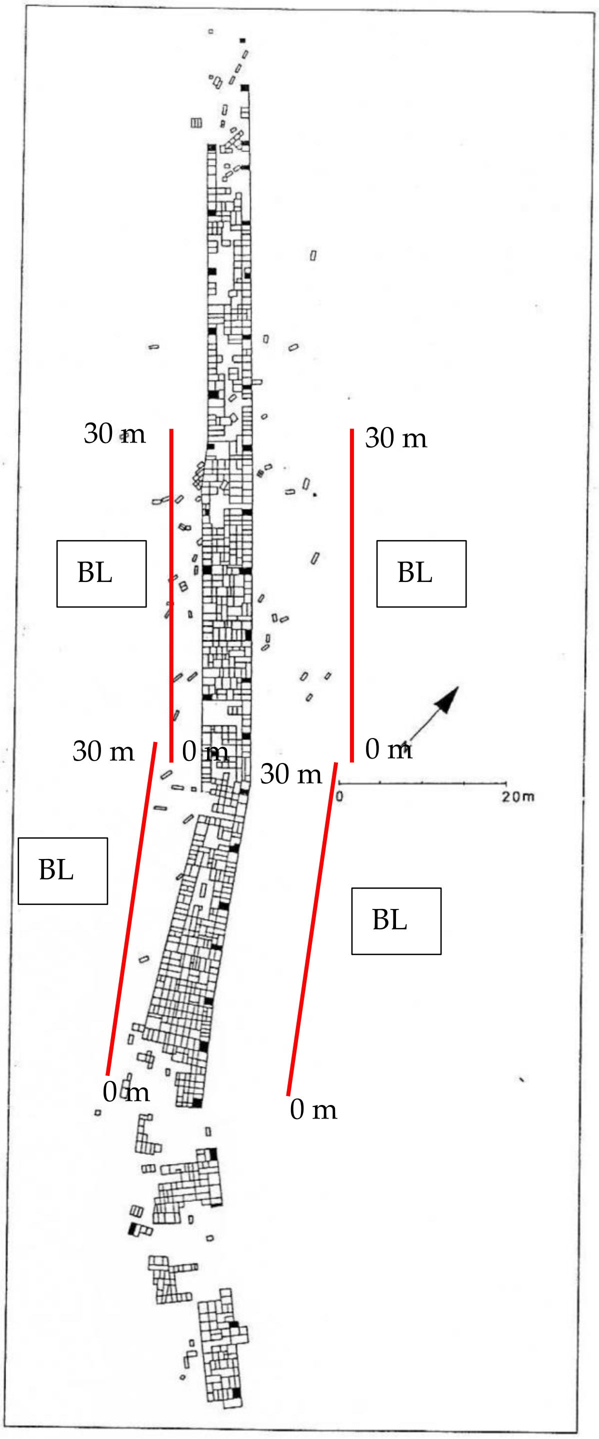

Figure 6: Plan of the BW, with the location of the baseline (BL) tapes (developed by M. Secci; based on the breakwater site plan by Haggerty 1990).

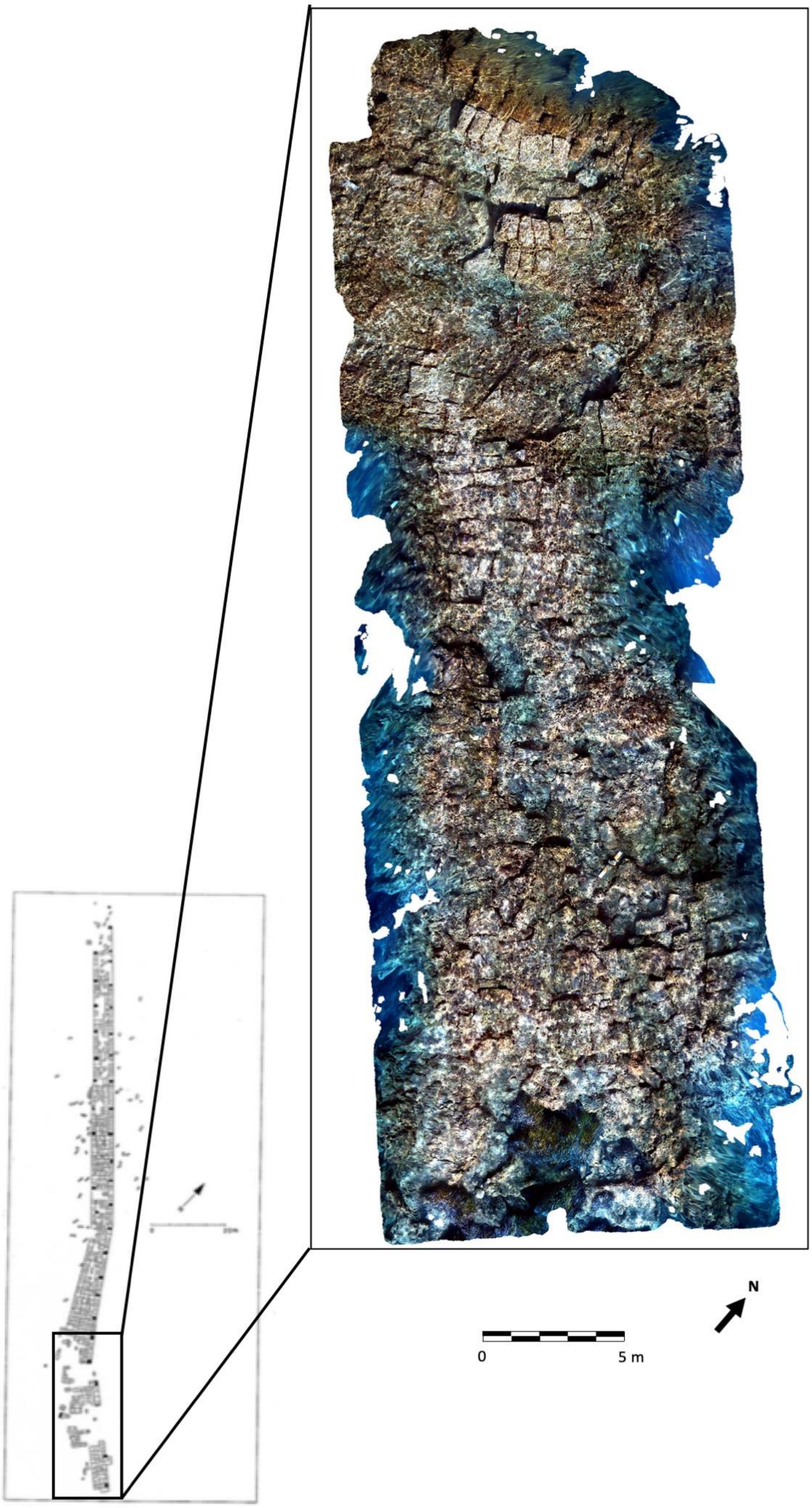

Figure 7: Orthophoto of the reconstructed portion of the southern end of the breakwater (Section 4, Figure 5) (Photogrammetry survey and processing: M. Secci).

Underwater and Coastal Geological Survey – Miltiadis Polidorou

Introduction

A coastal and underwater geological survey was conducted in September 2018 to the east of the archaeological site of Dreamer's Bay, Akrotiri Peninsula, Cyprus. The survey included geomorphological analysis of the coastline, identification of the geological formations, underwater core sampling, and seabed morphology analysis.

Methodology

Geomorphological analysis: Geomorphological mapping of both subaerial and subaqueous coastal sections of Dreamer's Bay area was carried out using topographic maps at a scale of 1:5000 and GIS. In order to reveal the palaeogeographical evolution of the area, sampling of the breakwater, seabed and coast, was undertaken.

Regional Settings and Geological analysis: Geological maps at a scale of 1:5000 were used for the identification of the geological formations and their relationship with the regional tectonic and stratigraphic settings.

Underwater core sampling: Five cores were retrieved from the seabed at various depths in the region of the breakwater. The cores were extracted using 2 inch diameter plastic pvc tubes into a metal tube housing with a drilling head. A hammer was used for the penetration of the tubes to the seabed. The core locations were strategically selected on the east and west side of the breakwater in order to identify the environment and the rate of sedimentation.

Seabed morphology analysis: Lidar data were used for the identification of the bathymetry and morphology of the seabed in order to locate possible geological/geomorphological features which will indicate former palaeo-sea levels.

Results and discussion

Geology: Akrotiri Peninsula is located at the west of Limassol town and covers an area of approximately 100 km^2. The bedrock of the area consists mainly of yellowish marls and chalks of the Pakhna Formation (Miocene Age), which are indicating a marine shallow depth deposition. The presence of calcarenitic layers and occasional development of conglomerates are characteristics of the shallow deposition (Figure 8). Overlaying the Pakhna Formation is the Nicosia Formation (Pliocene Age), which contains grey and yellow siltstones with layers of calcarenites, marls and calcarenites interlayered with sandy marls. Above the Nicosia Formation is located the Fanglomerate member (Pleistocene) which includes clastic deposits in the form of gravels, sand and silt. The same stratigraphy appears in the area where the coastal research was conducted in Dreamer's Bay (Figure 9).

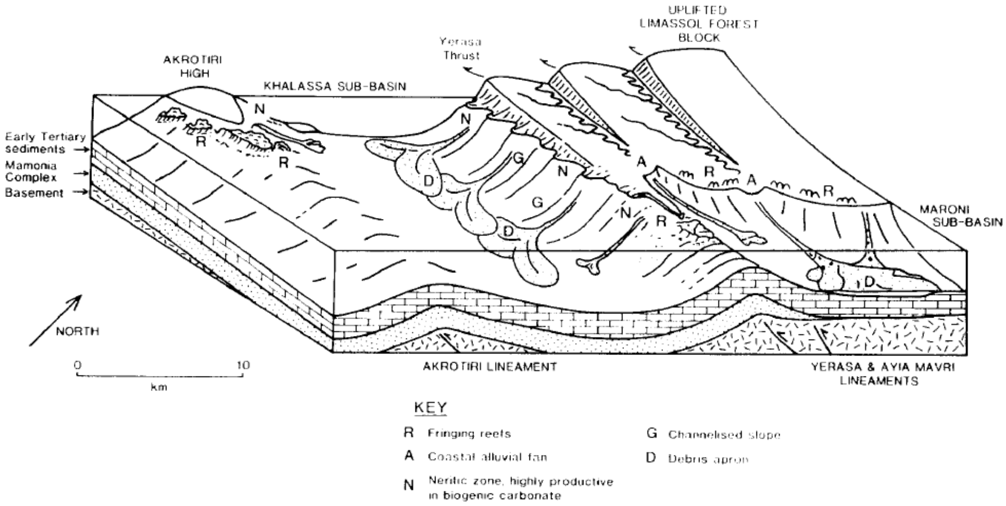

Figure 8: Schematic reconstruction of the local tectonic setting and depositional environments of the Pakhna Formation in southern Cyprus (Eaton and Robertson, 1993)

Figure 9: Coastal survey area. Yellow Marls of the Pakhna Formation on the base, gray and yellow siltstones with inlays of sandy marls of Nicosia Formation in the middle part of the section and Fanglomarate with gravels and sands on top, covered by Aeolian sediments (photo by Miltiadis Polidorou, 2018).

General Tectonic Settings: At Akrotiri Peninsula two main sets of Quaternary faults are identified (Figure 10). The first set of faults is orientated E to W, Left-lateral strike-slip faults with a vertical component are located towards the north of the peninsula (Fault A). The second set of faults have a NW to SE orientation, strike-slip faults with vertical component, and are located in the centre of the peninsula (Fault B). The impact of the faults is creating a horst- graben- horst type of geology to the topography in which the northern and the southern part of the peninsula is uplifting faster than the central part of the peninsula. This tectonic action is primarily responsible, along with Holocene rising sea-level, for the creation of the lagoon at the centre of the peninsula.

Figure 10: Active Quaternary Faults. A. Left-lateral strike-slip faults with vertical component orientated E-W, B. Strike- slip fault with vertical component orientated NW-SE (Geoter, 2003)

Coastal Geomorphology: The site of the survey is located at the south of the peninsula, east of Dreamer's Bay archaeological site. The main geomorphological features consist of steep cliffs with evidence of sub-aerial processes which includes mass movement and weathering of the cliffs. Also, there is strong evidence of high rates of coastal erosion in the form of Hydraulic action, Corrosion, Attrition and Abrasion (Figure 11). Not very well preserved notches are present indicating a gradual uplifting of the area (Figure 12). The notches were unable to be dated because of lack of biological or other indicators. At the seabed were identified stumps and evidence for previous landslides were noted, which are the result of the cliff undercutting by wave action.

Figure 11: High slope cliffs evidence of sub-aerial processes including mass movement & weathering

Figure 12: Uplifted notch

Underwater Geological Survey: Five cores were undertaken from the seabed on the east, west and south of the breakwater at depths from -1.70m to -4,82m (Figure 13). The locations of the cores were strategically selected in order to collect material from the protected side of the breakwater (East side, cores 2, 3 and 5) and the open side of the breakwater (West side, cores 4 and 6) (see Figure 13 for location of cores). Comparison of sediment from the cores (grain size, petrography, XRF and stratigraphy) will provide evidence of the time period that the breakwater was constructed. In more detail, grain size of the sediments that were deposited before the construction of the breakwater, will be identical for all the cores. After the construction of the breakwater the sediments deposited in the protected area will be finer in size as the sedimentation was deposited in a lower energy environment. Using Stratigraphic analysis, the transition layers (High energy to low energy environments), which reflect the time of the construction of the breakwater, will be identified. Petrography will be used as a proxy in addition to grain size and stratigraphic analysis, as the material and minerals deposited in the protected side are expected to have a different shape, morphology and type from the material deposited in the open area. Material for absolute dating (Radiocarbon) will be extracted from the transition layers and will be sent to a certified laboratory. The dates provided from the radiocarbon dating will reveal when the breakwater was constructed. The XRF analysis will provide information regarding the chemical components of the sediments and possibly the beginning of human activity at the site. The core samples have already been opened in laboratory facilities and detailed descriptions of the sediments are currently being documented (Table 1).

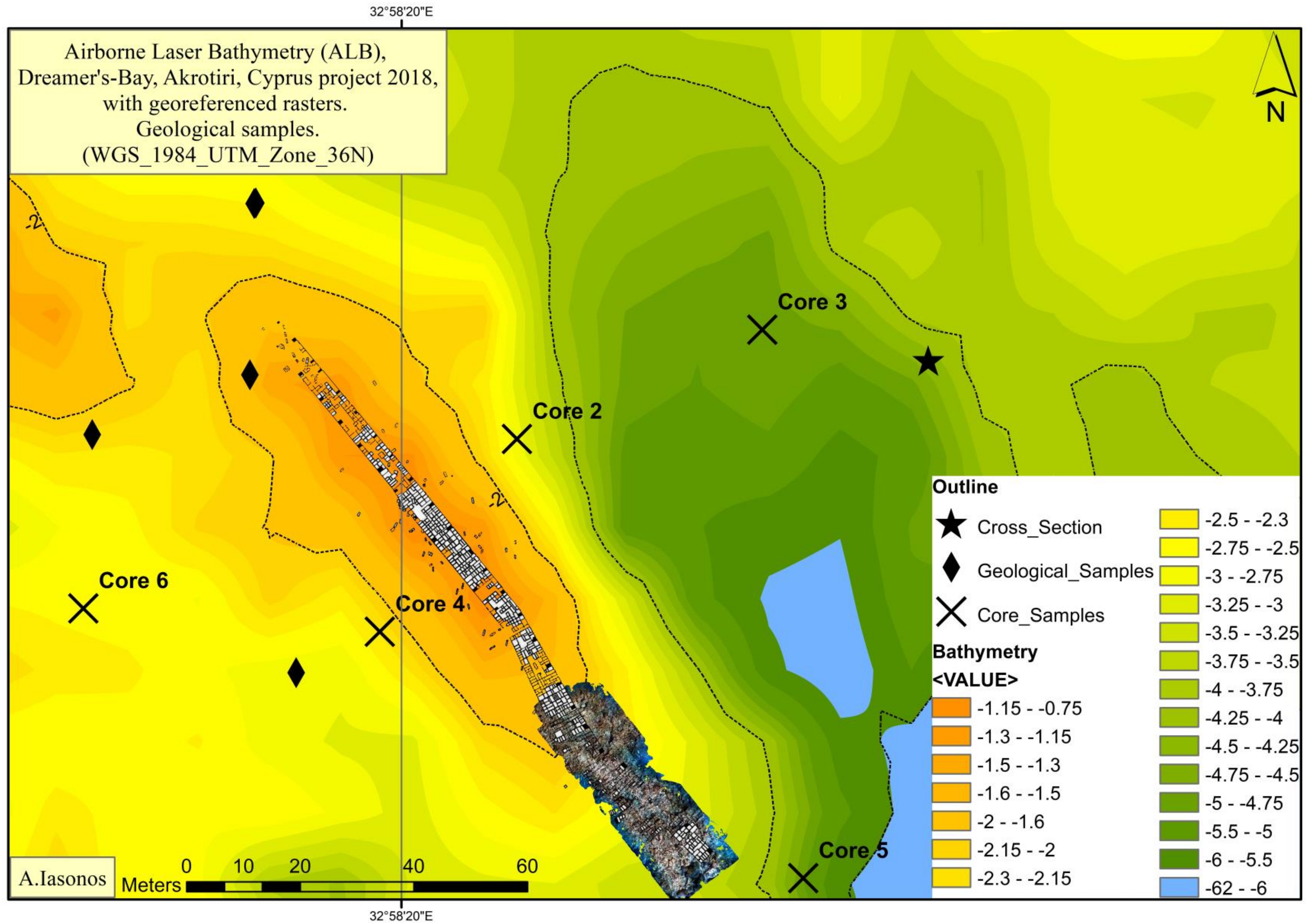

Figure 13: Location of geological cores extracted, together with the building stone and column samples (A. Iasonos)

In all sediment cores grain size analysis has been completed. Petrographic analysis will be done in all sieve fractions of each layer. After the identification of the petrographic properties, selected samples will be examined by an XRF analyser, and samples will be sent for radiocarbon analysis.

Core	Depth	Description	Color	Type of contact	Notes
Core 2	0-5cm	Coarse Sand	Brown -Yellow	Sharp	pebbles
	5-11cm	Silty Sand	Grey - Black	Sharp	Posidonia fibers
	11-15cm	Silty Sand	Grey - Black	Sharp	Angular Gravels, Posidonia Fibers and Fossils
	15-22cm	Silty Sand	Grey - Black	Sharp	Posidonia fibers
	22-23cm	Cley - Silty Sand	Grey	Sharp	Gravels
	23-26cm	Cley - Silty Sand	Grey	Sharp	Gravels
	26-27cm	Angular Gravels	Grey	Sharp	Angular Gravels
	27-30cm	Silty Sand	Grey		Posidonia fibers
Core 3	0-22cm	Coarse Sand	7,5YR 8/4	Sharp	Fossils
	22-31.5cm	Medium Sand	N6	Sharp	Fossils
	31.5-36.5	Cleyey Fine Sand	N8	Sharp	few fossils
	36.5-40cm	Medium-Fine Sand	N8	Sharp	Small fossils
	40-50cm	Cleyey Fine Sand	N8		
Core 4	0-14cm	Coarse - Very Coars Sand	Brown-Yellow	Sharp	
	14-24cm	Clay and Fine Sands	Grey -Black	medium	Fossils
	24-26cm	Clay with Lamination and Fine Sand	Grey -Black	Sharp	Purple lamination
	26-41cm	Clay with Fine Sands	Grey-Black		
Core 5	0-21cm	Coarse to very Coarse Sand	Brown-Yellow	Sharp	
	21-38cm	Coarse Sand	Brown	Sharp	
	38-46cm	Silty Cley	Yellow		
Core 6	0-6cm	Coarse Sand	Brown-Yellow	Sharp	Pebbles
	6-25cm	Silty Sand	Grey - Black		Posidonia fibers

Table 1. Core Sediment Description

Four samples from the building stones were also taken from the breakwater (see Figure 13). Under the stereoscopic microscope the material of the building stones seems to be consistent with calcareous marls and sandstone which can be located in the nearby surrounding cliffs and quarries. All the samples will be chemically analysed by an XRF analyser. This analysis will provide information which can be used to identify the quarries that provided the building stones. One rock sample was retrieved from a submerged column which was coarse to very coarse grained, uniformly red/black/orange with a felcic composition. The rock mainly consists of feldspar, quartz, mica and amphiboles and has a granular phaneritic texture which is typical of Aswan Granite (Figure 14)

Figure 14: Fragment of submerged column identified as Aswan Granite.

Conclusion

All the data retrieved from the coastal geomorphological/geological survey and the underwater survey will be used for the paleogeographic reconstruction of the area in terms of landscape evolution, sea-level change, coastal erosion rate and absolute dating of the site. The specifics of these results await the results of the underwater core analysis and subsequent radio carbon dating.

Landscape evolution: The coastal zone is a very active and dynamic system. From the geomorphological/geological survey several landforms were identified which are connected with subaerial processes and erosion. Additionally, the impact of human activity, which seems to be significant at the site, played an important role in the evolution of the topography both in the coastal zone and in the maritime space near the coast. With the analysis of the cores and the materials of the building blocks of the breakwater, it will ultimately be possible to quantify the interaction between the environment and the human activity and provide a map of the landscape at the time of the construction of the breakwater.

Coastal erosion: The rate of coastal erosion seems to be relatively high in the area of the archaeological site and the breakwater. With the analysis of the materials retained from the cores and the geomorphological features at the coastline and underwater, it will be possible to evaluate the rate of the erosion. The type of the sediments and the composition of the layers deposited near the shoreline are different to the layers deposited in open water. This distinction permits analysis to indicate the evolution of the coastline and the evaluation of the paleo-erosion in the area.

Absolute dating: With the radiocarbon dating of the cores, we hope to be able to place the breakwater in the correct time period, to calculate the rate of coastal erosion, and to record the sea level at the time the breakwater was functional. Also, with a detailed geochronological analysis of the retained sediments from the cores, it will be possible to identify the chronological evolution of the coastline and evaluate core layers (bimodal with broken shells) that on initial analysis, appear to relate to a catastrophic event.

Sea level: With the absolute dating of the breakwater and an estimation of its functional height at the time of its use (this will partly be achieved by comparing the structure with other identical structures in the region), and subsequently rebuilding the structure in its 3D environment with the use of the underwater photogrammetry, and the grain size, XRF and petrographic analysis of the core sediments, it maybe possible to record the sea level at the specific period of use. This will also allow useful comparisons of sea-level changes with other sites in Cyprus and the eastern Mediterranean in general.

Extended Underwater Survey

An extended underwater survey was conducted across the entire length and breadth of Dreamer's Bay, with a particular focus on the area immediately to the west and east of the breakwater, with the objective of locating new and/or relocate previously discovered (see above) archaeological finds on the seabed. This, combined with the momument condition survey, will determine if any further clues can be revealed in relation to the dating, function and ultimate decline of the breakwater. Greater proportions of finds and the location and/or clustering of particular types of finds, can give an indication of the nature and function of the material when deposited. Previous surveys (see above) had identified clusters of amphora sherds and anchors, and these were further explored as part of the 2018 survey.

The survey work was undertaken in teams of diver pairs. Starting at the northern end of the breakwater, and using it as a base, the teams of divers swam in parallel lines a fixed distance apart at ninety degrees to the breakwater along a fixed compass bearing (corridor swim line search method) to both the east and the west side of the breakwater. At a point when their air consumption reached a certain level, they turned round and swam parallel to and 180 degrees off, the first bearing, leap frogging to the south, back towards the breakwater. This system was repeated a number of times until the area both sides of the breakwater, into the bay to the east and the west, was systematically surveyed. Five survey lines were conducted to the west of the breakwater including a survey of the area around Vatha Island to the south west (West Line 4 & 5) (Figure 15), and nine to the east of the breakwater extending south and east into deeper water (Figure 16).

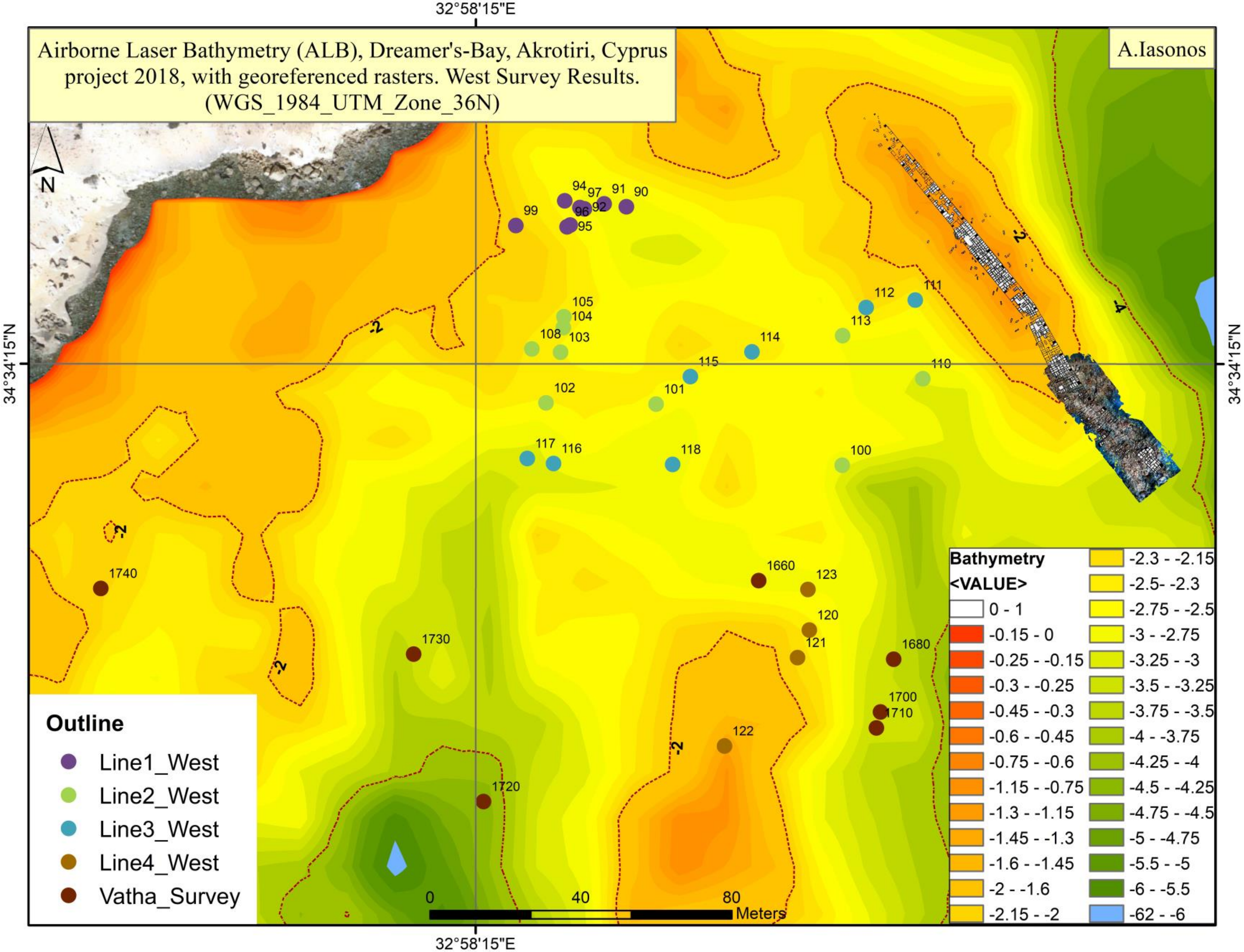

Figure 15: Survey lines to the west of the breakwater and in the region of Vatha Island (A. Iasonos)

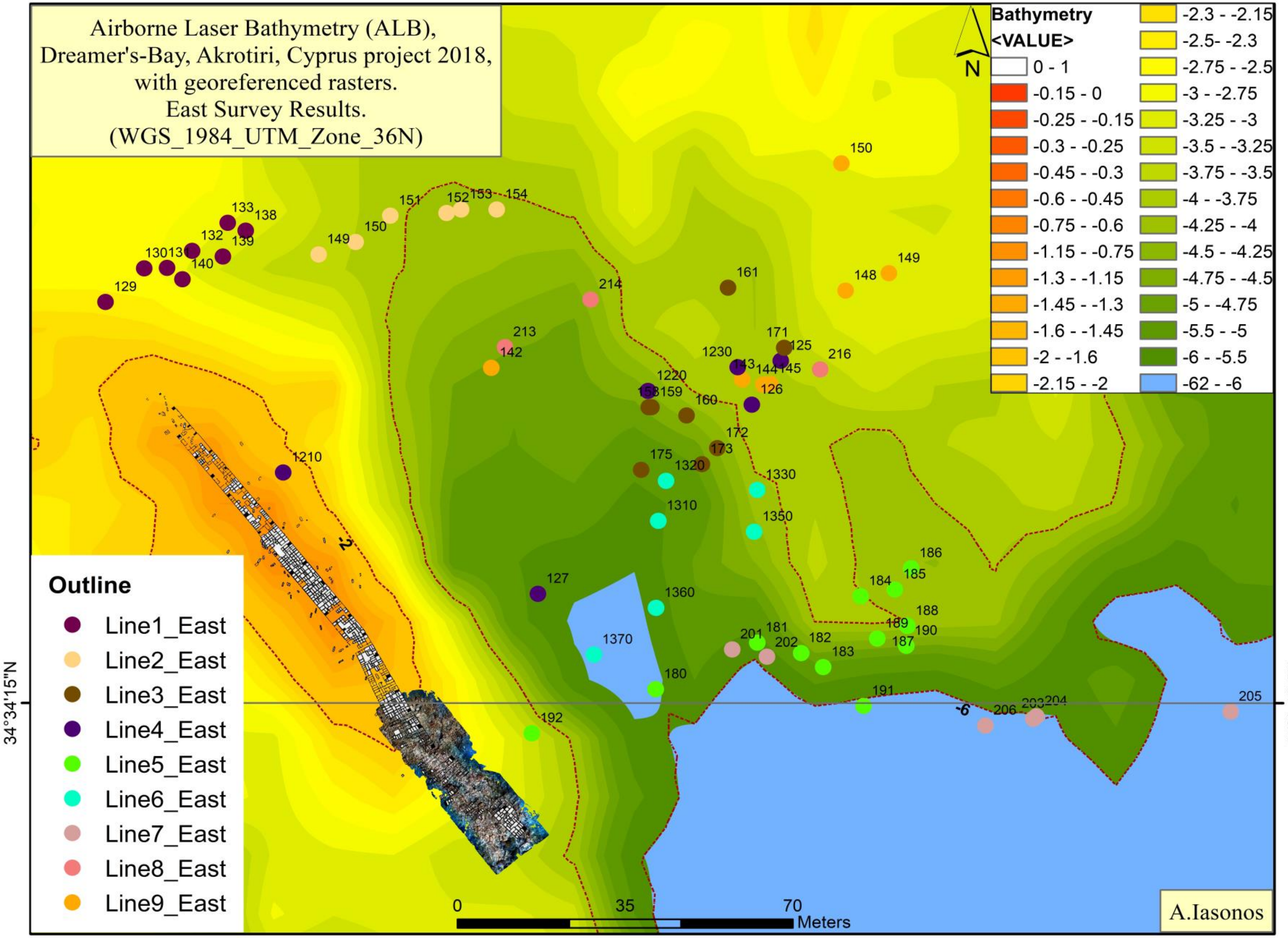

Figure 16: Survey lines to the east of the breakwater (A.Iasonos)

Underwater survey was also conducted in front of the archaeological remains on shore to the west of Dreamer's Bay as far west as the Rifle Range (Figure 3). The primary objective of this extended survey was to determine if there were archaeological remains underwater that may relate to the 'warehouses' and pottery scatters that have been located on the shore above (James and Score 2018). The methodology deployed in this region was simply a line of divers swimming parallel to the coast out to a maximum 200m offshore and to a maximum depth of 4.5m. A second team explored the coastal inlets and bays. The survey was conducted from west to east and extended into the main area of Dreamer's Bay to the east of the archaeological remains on land. Relatively little material was found to the south of the archaeological site which was surprising even when considering the fact that the coastline is quite exposed and had been subject to erosion at least in recent centuries (Andreou 2019; identified up to 14m of erosion in the last sixty years off the east coast of the archaeological site). However, much larger concentrations of artefacts were noted to the east of the site within the more sheltered westerly extent of Dreamer's Bay. This material has yet to be analysed, but it looks to have been associated with the site to the west. Higher concentrations of artefacts would be expected in this area, having been transported by longshore drift and coastal currents from the east, or alternatively, over time, eroded from the former coastline by waves and subaerial processes. It appears that prior to erosion the land may formerly have been joined to a small island to the southeast. In this area, large blocks of land-slide were observed underwater.

All finds were noted, described and photographed underwater and a record of their location taken using GPS. Selected finds were lifted when archaeologists felt they were either in danger of further displacement and erosion on the seafloor, or that they were useful as chronological indicators. Distribution and quantities were noted to explore the nature of activities either side of the breakwater in order to help determine its function. Besides amphorae, six stone anchors and three small columns were also noted underwater (see below). A note of their location was also taken and photographs taken of the objects in situ. A number of theses objects were also sampled to determine their geological make up and hopefully their origin. This material is still under analysis (see Underwater and Coastal Geological Survey above).

Results

The results of the survey are still under analysis. We are hopeful that the analysis of the cores will provide a more precise understanding of the date, function and reasons for decline of the breakwater. In the meantime, we are able to understand the breakwater in more detail and also comment on the nature of finds in the area of the breakwater.

The Breakwater

The photogrammetry survey

The photogrammetry survey was able to provide a more accurate plan of the breakwater (see Figures 4, 7 and 17). Once the plan of the breakwater had been geo-referenced as a result of the DRTK survey, it was then possible to accurately locate the breakwater in space and compare with Haggerty original plan (see Figure 4). Some difficulties were incurred in geo-referencing Haggerty's plan to the 3D image, as there were no visible certain or precise ground control points on the original plan. Moreover, when attempting to roughly geo-reference the plan with the RTK coordinates and orthophoto derived from the photogrammetry, we figured out that the scale and orientation of Haggerty's plan was not 100% accurate. This is obviously not a flaw of the surveyors who produced a remarkably accurate plan considering they were using available techniques and tools that were employed at the time (i.e. traditional tape measuring and compass bearings). Figure 4 illustrates the most accurate fit possible to compare Haggerty's plan with our orthophoto image.

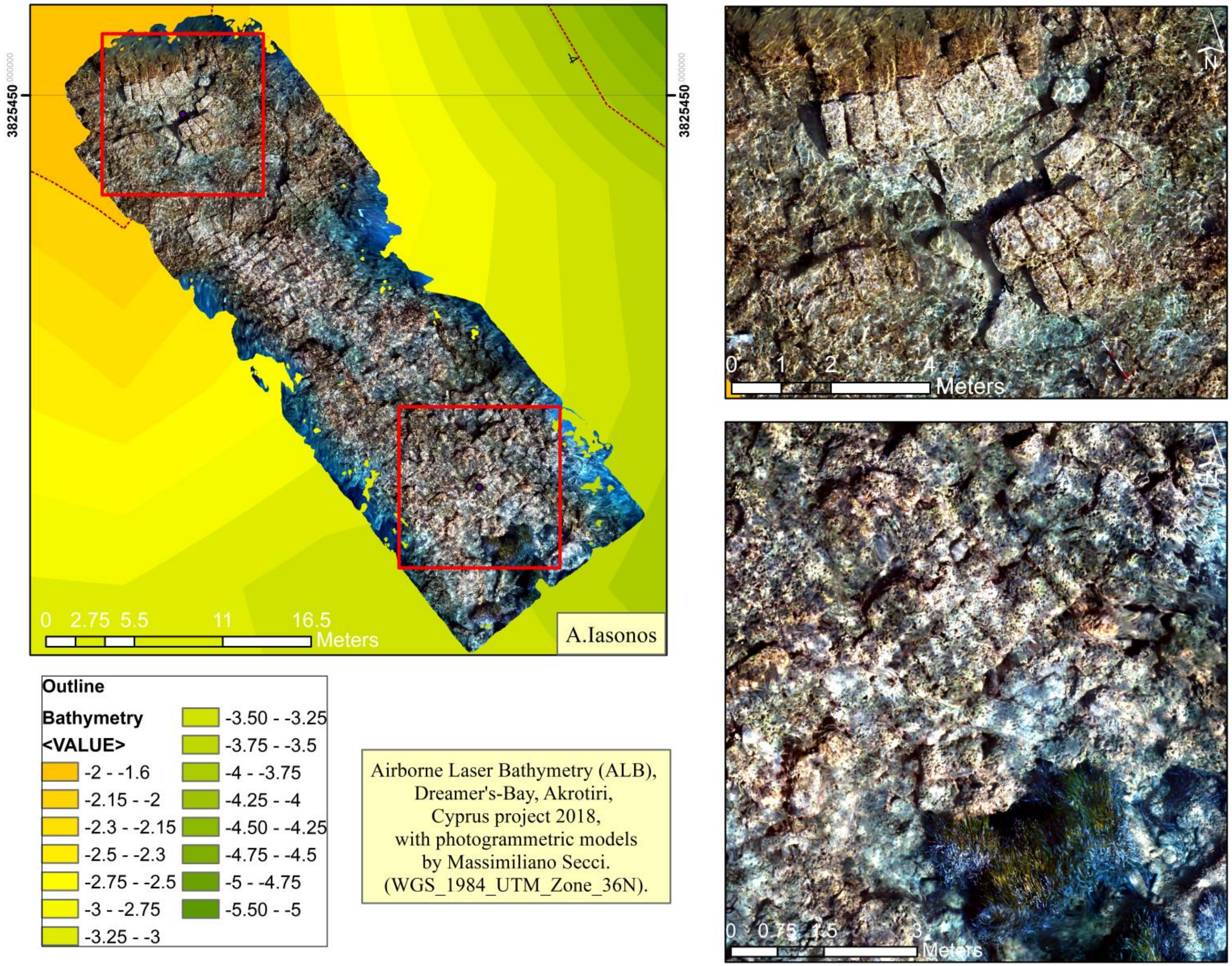

Figure 17A: Zoomed in sections of the southern part of the breakwater (M. Secci and A. Iasonos)

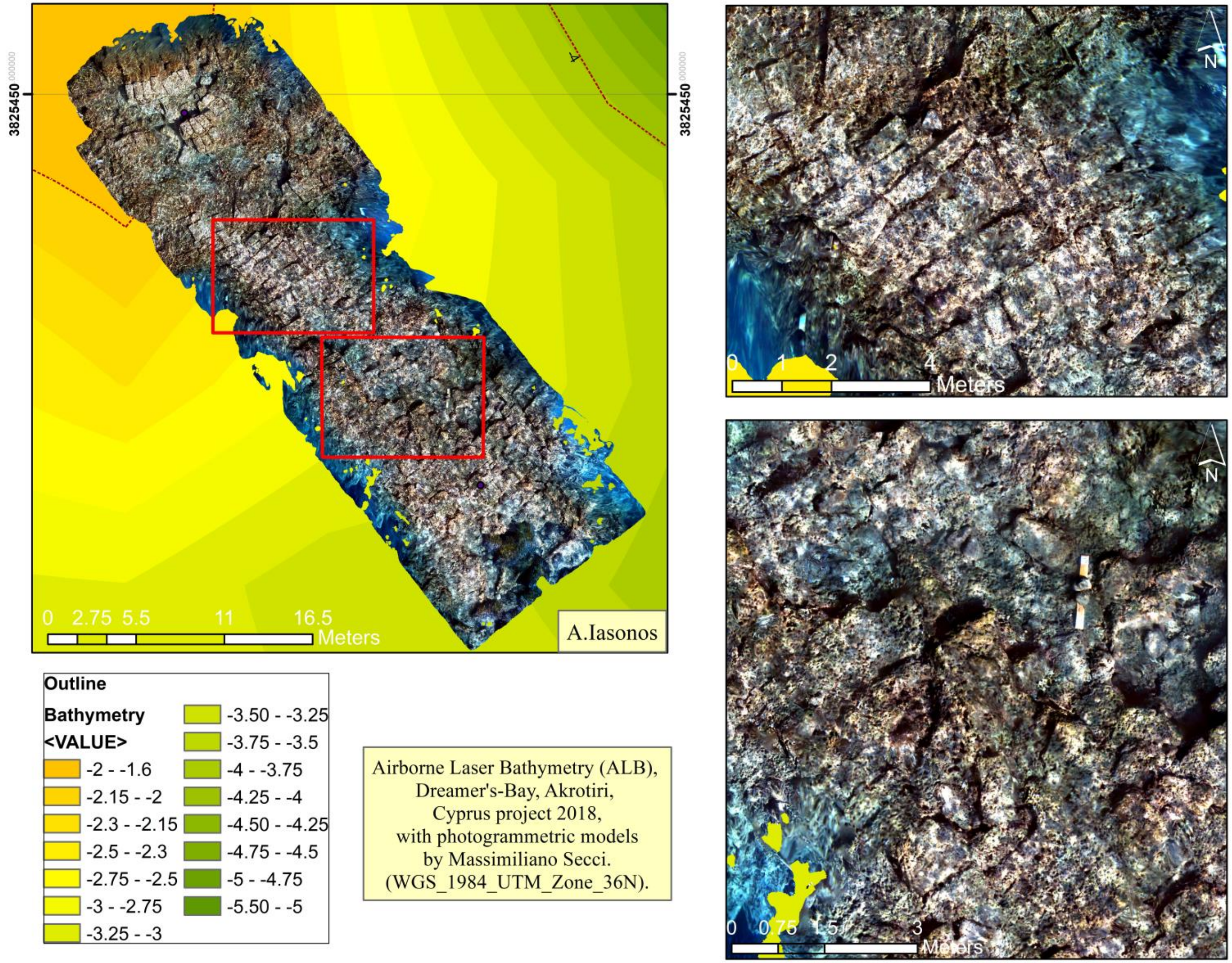

Figure 17B: Zoomed in sections of the southern part of the breakwater (M. Secci and A. Iasonos).

Construction and use of the breakwater

As noted previously, the breakwater extends offshore from the steep cliffs in a roughly south-south-easterly direction. It extends for an overall length of 135m and fluctuates between 4-7.5m wide along the different sections of the main body of the structure, widening out to 8.5-9m at the southern, seaward end. The maximum number of blocks observed *in situ* extended to four courses deep (Figure 18 and Figure 19) and the average size of the blocks was 0.9/1.1/1.3 x 0.4 x 0.3 (deep), thus suggesting an approximate maximum extant remaining depth of the breakwater at around 1.2m, although sections as deep as 1.55m were observed towards the very southern end of the structure, with a possible fifth course visible. It should be noted that not all blocks were of regular size, some were as much as 1.4m in length and others as shallow as 0.2m deep. Samples of the breakwater were taken along its length for analysis. The southern end of the structure, as noted above, extends out to sea and the water depth becomes deeper (maximum 3m on top of breakwater and some 4.7m at its base) and the breakwater according has a greater number of courses. The wider southern end is also more dislocated than the main body of the structure. At the very southern end, the ashlar blocks return to face the south along their length and finish off the breakwater. This would imply that the original end of the structure remains intact, although we cannot be sure if it is in the original location. The interpretation of the structure at its southerly base, is that the breakwater would have originally supported a much broader platform of operation accessible by vessels approaching from the deeper waters.

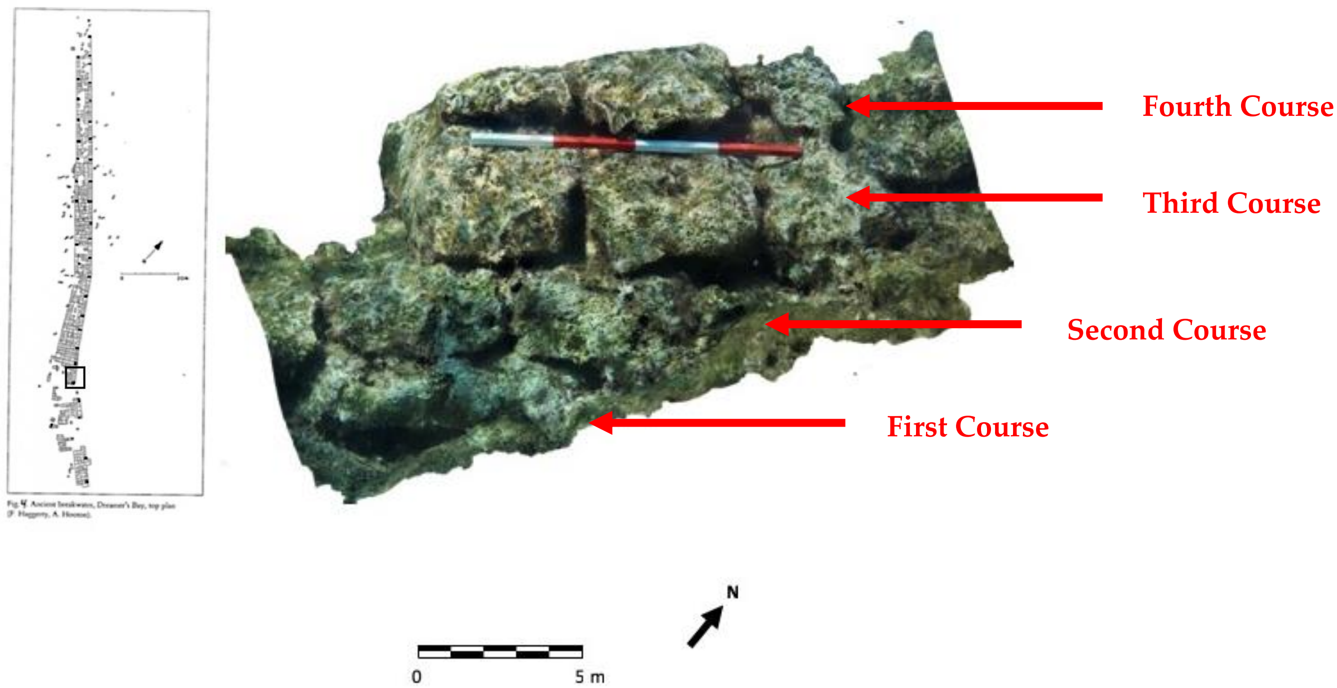

Figure 18: Orthophoto of the reconstructed portion of the eastern side of the breakwater (Section 3, Figure 4) (Photogrammetry survey and processing: M. Secci).

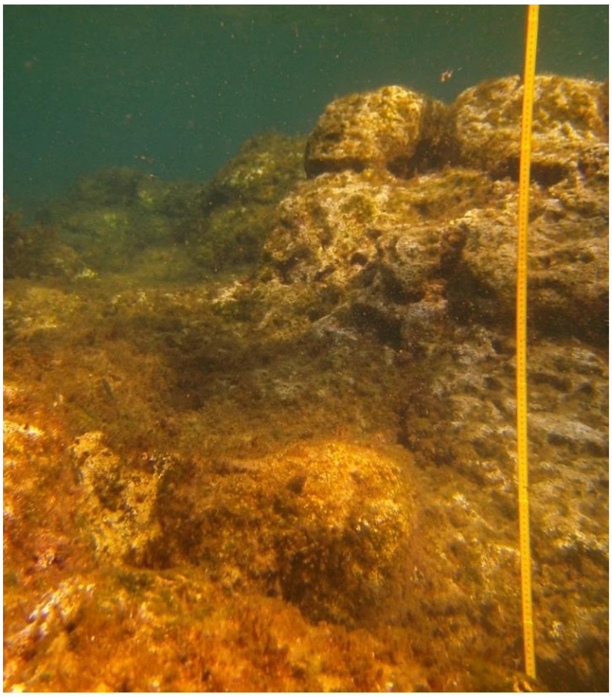

Figure 19: Photo of course of breakwater on south-western portion (L. Blue)

At the northern end of the breakwater the structure appears to end in a regular manner with ashlar blocks *in situ*, in effect closing off the north-north-western end of the feature. The depth of water in this region is approximately 1.1m depending on the state of the tide. To the north of the breakwater towards the base of the steep cliff, no noticeable features were apparent which indicates that the breakwater was either constructed deliberately not to reach the cliff base or that the coastline has eroded since the time of its construction and use. A survey conducted by Andreou (2019) to ascertain the degree of modern coastal erosion as deducted from aerial photographs, recorded coastal erosion rates of between 1.5-2m in the last sixty years in this region. Of course these reflect modern erosion rates and we are not able to extrapolate these rates back in time to when the breakwater was in use.

Survey Observations

Initial observations of the survey conducted either side of the breakwater reveal a significant distinction between the two areas. Whilst the nature of the ceramics on initial observation (ceramic analysis on-going) appear to be fairly homogenous, material to the west of the breakwater appears to be much more spread out and less densely concentrated than the distribution of material to the east of the breakwater. However, the archaeological material was not dissimilar both sides of the breakwater and included quantities of amphora sherds and some roof tiles. Less material was observed further offshore and towards Vatha Island to the southwest, although one of the six stone anchors was located here (Figure 20).

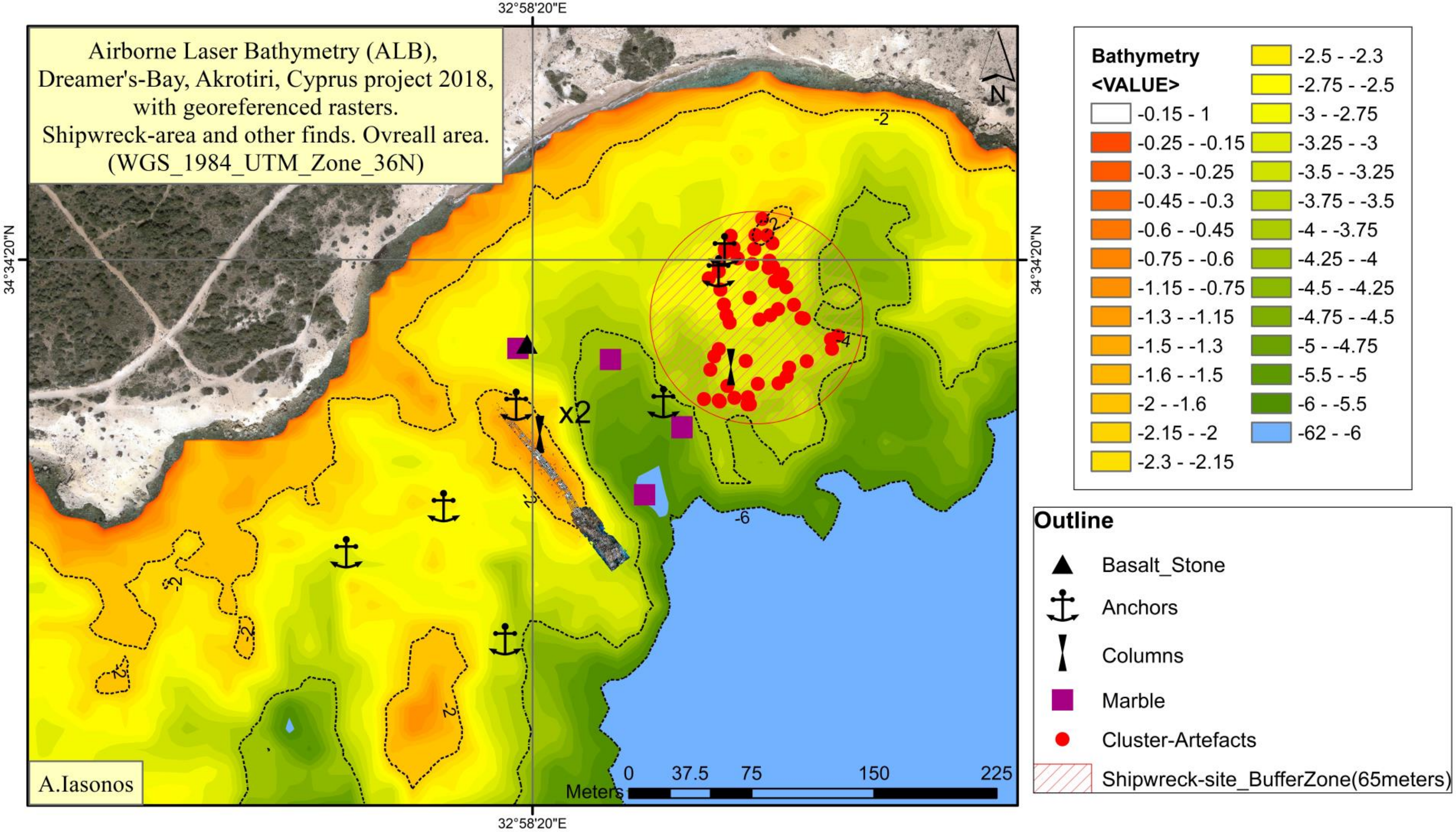

Figure 20: Distribution of objects on the seabed in the vicinity of the breakwater. Including stone anchors, columns, pottery clusters, marble fragments and ballast stone (A. Iasonos)

To the east of the breakwater however, the story was quite different, with much larger quantities of ceramics identified, some of which were lifted for dating purposes. Immediately to the east of the breakwater the concentration of rubble having fallen from the breakwater, is apparent (Figure 21).

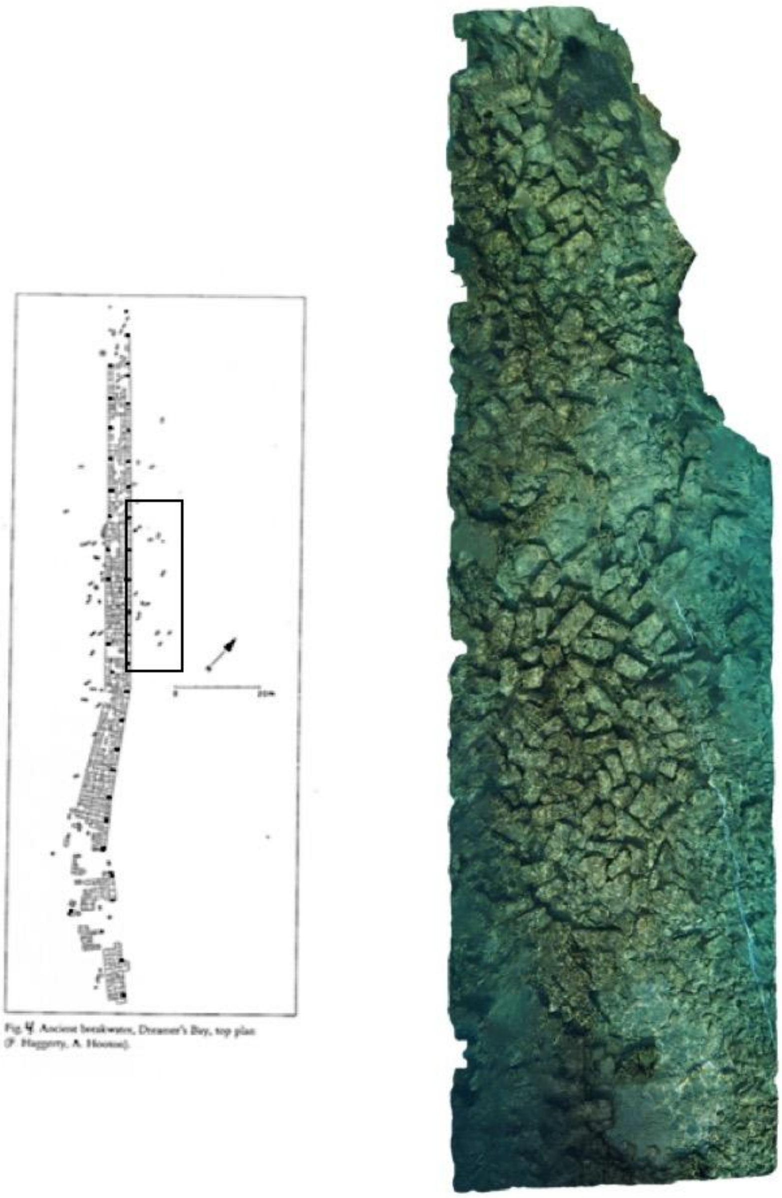

Figure 21: Orthophoto of the reconstructed portion of the Eastern side of the breakwater (section 2, Figure 4) (Photogrammetry survey and processing: M. Secci).

Beyond the rubble to the east and northeast, larger areas of open seabed were encountered with undulating mounds of sandy seagrass. These mounds were sectioned and it was revealed that quite large amounts of ceramics were trapped within their matrix of sand and decomposed seagrass, suggesting the ceramics had been trapped along with the sand *in situ* by the seagrass, which subsequently decomposed forming large, solid mounds.

Further to the east and northeast, the number and intensity of ceramics increased. The sherds were seemingly homogenous, believed to be Roman and late Roman in date (ceramic analysis on going) (Figure 22), many pieces being concreted into the rocky seabed or trapped in rocky crevasses (Figure 23). Pieces of marble, some worked, were identified in four of the nine transects, as well as a number of mounds of what appear to be ballast stones (Figure 20), concentrated towards the north-eastern end of the breakwater.

Figure 22: Pottery fragments recovered from the seafloor on eastern side of the breakwater

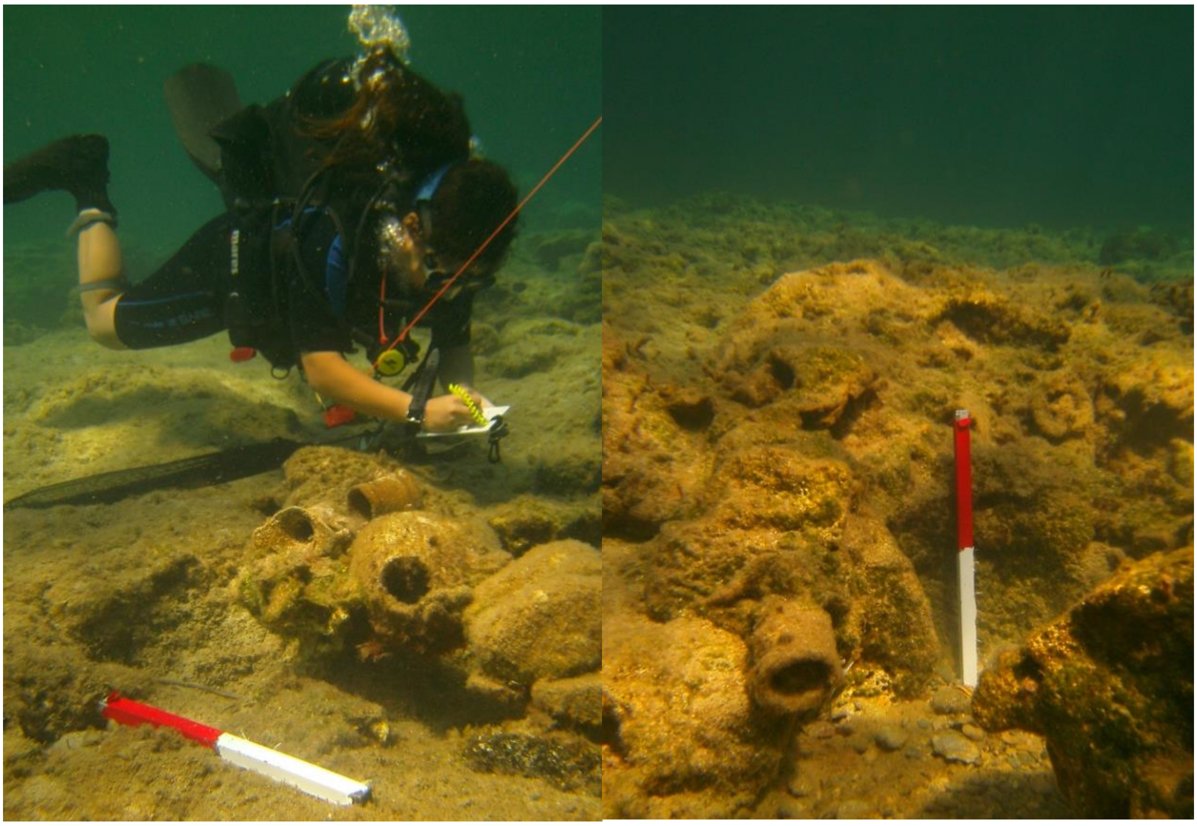

Figure 23: Pottery fragments concreted into the seabed on the eastern side of the breakwater (L. Blue)

Shipwreck

On first evaluation, the large concentration of relatively homogenous ceramics, located between 80-200m to the east and northeast of the breakwater, could well represent the very fragmentary remains of a shipwreck. The material is very broken up but the manner in which it is concreted in concentrated areas into the seabed, is telling (Figure 24). In addition, four of the six stone anchors were also identified to the east of the breakwater (Figure 24), as well as three short columns of what appears to be Aswan granite (see above) (Figures 24 and 25). Two of the columns were located on top of the rubble that fell to the east of the structure, and a third in the middle of the ceramic concentration currently thought to be a shipwreck. The initial interpretation is that the columns were also part of the cargo of the ship that wrecked against the breakwater after it fell into disuse, as it is difficult to conceive how such large pieces (which due to the fact they are all very similar, presumably came from the same source), could be distributed over such a large area. Further analysis of the ceramics is clearly essential, as is additional mapping of the so-called shipwreck site.

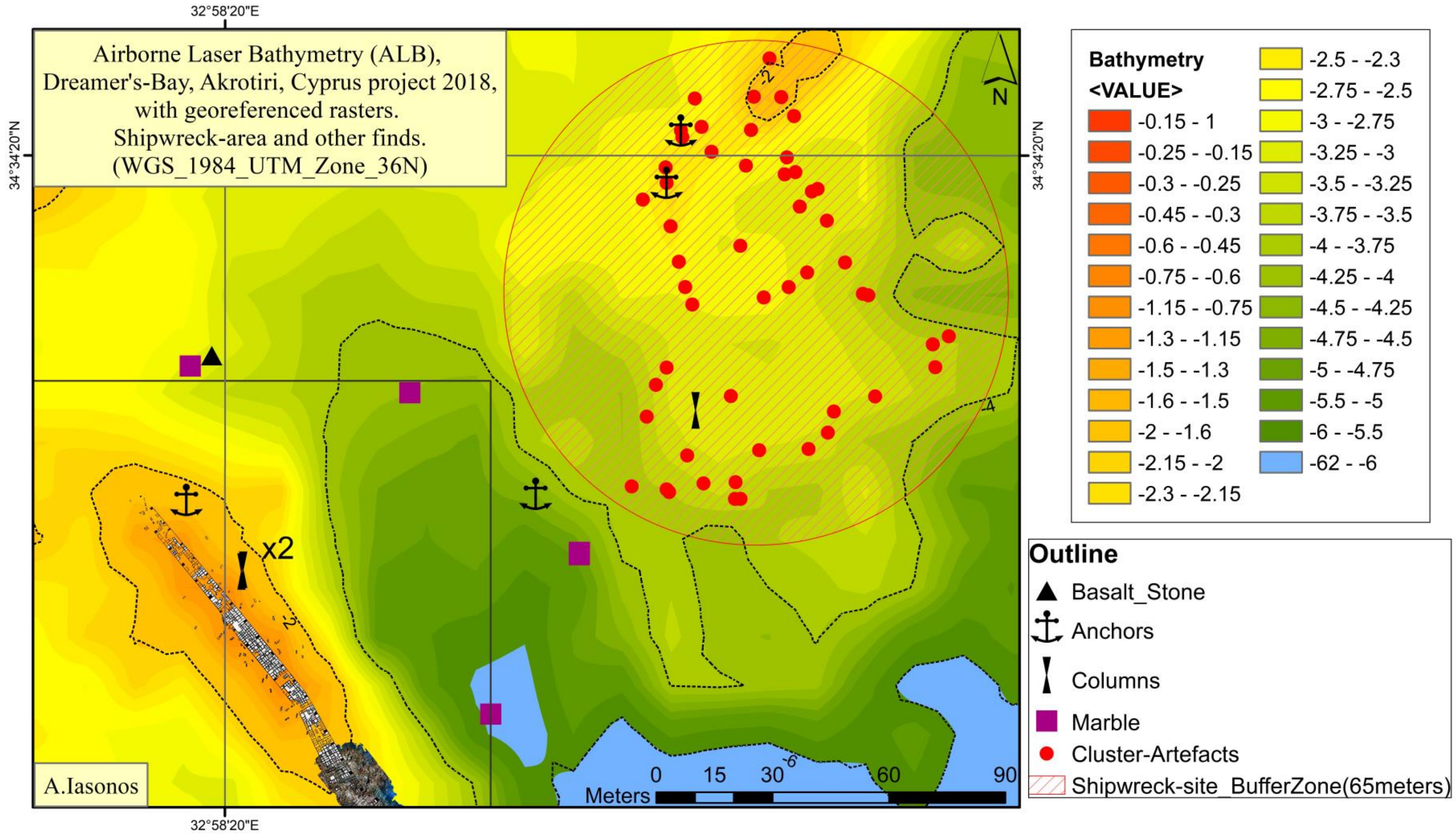

Figure 24: Concentration of finds to the east of the breakwater in the area believed to be the shipwreck (A. Iasonos)

Figure 25: Marble column on the seabed. (L. Blue)

As indicated, all objects located were photographed in situ and a small number were raised and documented and sent accompanied by an inventory to the Department of Antiquities.

Discussion and Conclusions

The results from the 2018 were able to more fully document the breakwater and identify what is believed to be a shipwreck. Analysis of the ceramics and the cores extracted underwater, will hopefully reveal a more detailed story in relation to the biography of the breakwater and with dateable samples, provide some indication of the date of its construction and decline. Future analysis of the so-called shipwreck is proposed to determine if this is indeed a homogenous cargo.

Acknowledgements

The project team would like to express its gratitude to the UK Sovereign Base Areas Administration and the Republic of Cyprus Department of Antiquities for enabling the fieldwork to take place. We would also like to thank the Republic of Cyprus Department of Antiquities for their support and advice, especially the Director Dr Marina Solomidou-Ieronymidou, Eleni Procopiou, Demetra Aristotelous and the staff of Kourion Museum.

SBAA officials, notably Antonis Antoniades, also provided indispensible assistance in preparing and running the expedition, an effort also relying on support from DI) Environmental staff, both in the UK with archaeologist Philip Abramson playing a key role, and in Cyprus, David Reynolds. RAF Akrotiri station commander Group Captain **Chris Smith** offered warm support, and Maj Steven 'Smudge' Smith provided vital practical help with security clearances, equipment, and valuable guidance.

The project hugely benefitted from the direct backing of RAF personnel who not only offered boats but also their time, expertise and support. A number of people helped in this manner but a particular thanks is extended to Sgt. Graham Moore as the official point of contact and Sgt. Sam Conway-Wallace for arranging all the boat support. Maj Frank Garrod (ret.), Chairman of the WSBA Archaeological Society, offered us generous hospitality, gave us the use of the Society's well-equipped club house, and provided key equipment, above all access to cheap vehicle hire. Dimitrios Skarlatos also kindly undertook DGPS survey work for the project.

Lastly, thanks goes to the entire team of the 2018 underwater survey for all their hard work and patience. Thank you specifically to Massi, Achilleas, Maria and Miltiadis for their help with preparation, logistics and data processing and report writing. And finally, thank you to our funders the Honor Frost Foundation for all their support.

Bibliography

Andreou, G. 2019. Digital shoreline analysis. Akrotiri Peninsula. Unpublished report commissioned by the Honor Frost Foundation.

Ault, B.A. 2010. *The Akrotiri-Dreamer's Bay Ancient Port Project (ADBAPP) Final Report*, *2010*, unpublished archive report.

Ault, B.A. and J.R. Leonard forthcoming. 'The Akrotiri-Dreamer's Bay Ancient Port Project: Ancient Kourias Found?' in E. Herscher, Ed., *The Ancient Kourion Area: Penn Museum's Legacy and Recent Research in Cyprus. Proceedings of a conference held at the University of Pennsylvania Museum of Archaeology and Anthropology, Philadelphia, Pennsylvania, March 27–29, 2009*, Philadelphia, University Museum Publications.

Haggerty, F. 1990. *The Akrotiri wall: an ancient underwater construction.* [unpublished typescript report.]

Heywood, H.C. 1982. 'The archaeological remains of the Akrotiri peninsula', in H.W. Swiny, Ed., *An Archaeological Guide to the Ancient Kourion Area and the Akrotiri Peninsula*, Nicosia, Department of Antiquities, Cyprus, 162-175.

James, S.T. and V. Score 2015. *Ancient Akrotiri Project: Dreamer's Bay excavation & survey, September 2015, Interim Report*.

James, S.T. and V. Score 2016. *Ancient Akrotiri Project: Dreamer's Bay excavation & survey, September 2016, Interim Report.*

James, S.T. and V. Score 2017. *Ancient Akrotiri Project: Dreamer's Bay excavation & survey, April 2017, Interim Report.*

Last, J.S. 1954. Preliminary Report on an Archaeological Surface Survey of Part of Akrotiri, 6th, 9th and 10th March 1954. [Manuscript]

Leidwanger, J. and D.S. Howitt-Marshall 2006. 'Episkopi Bay and beyond: recent collaborative fieldwork and new prospects on Cyprus,' *Institute of Nautical Archaeology Quarterly* 33: 13–22.

Leonard, J.R., B.A. Ault and S. Demesticha 2007. *Report 2007 Akrotiri-Dreamer's Bay Ancient Port Project*, Cyprus**:** 13pp.

Leonard, J.R. and S. Demesticha 2004. 'Fundamental Links in the Economic Chain: Local Ports and International Trade in Roman and Early Christian Cyprus', in J. Eiring and J. Lund, Eds, *Transport Amphorae and Trade in the Eastern Mediterranean. Acts of an International Colloquium at the Danish Institute of Athens, 26-29 September 2002 (= Monographs of the Danish Institute at Athens, Vol. 5)*, Aarhus, Aarhus University Press, 189-202.

Leonard, J.R., D.A. Parks and B.A. Ault 2006. *Report 2006 Akrotiri-Dreamer's Bay Ancient Port Project*, unpublished archive report 3pp. (unpag.).

Morhange, C., Marriner, N., 2015. Archeological and biological relative sea-level indicators, in: Handbook of Sea-Level Research. John Wiley & Sons, pp. 146–156.Procopiou, E. 2014. 'The Katalymata ton Plakoton: New Light from the Recent Archaeological Research in Byzantine Cyprus', in A.W. Carr, T.W. Davis and C.A. Stewart, Eds, *Cyprus and the Balance of Empires: Art and Archaeology from Justinian I to the Coeur de Lion*, Boston, American Schools of Oriental Research, 69-98.

Salomon, F., Blue, L., Farr, H., 2015. T*he tombolo of Akrotiri and the harbour of Dreamer's Bay: Geomorphological and underwater archaeology report.* University of Southampton, RoMP Project, Southampton.

Salomon, F., Keay, S., Carayon, N., Goiran, J.-P., 2016. 'The Development and Characteristics of Ancient Harbours—Applying the PADM Chart to the Case Studies of Ostia and Portus'. *PLOS ONE* 11, e0162587. doi:10.1371/journal.pone.0162587

Simmons, A.H. 2001 'The First Humans and Last Pygmy Hippopotami of Cyprus', in S. Swiny, Ed., *The Earliest Prehistory of Cyprus. From Colonization to Exploitation*, Boston, Cyprus American Archaeological Research Institute Monograph Series, Vol. 12. American Schools of Oriental Research Reports, No. 5, 1-18.

Simmons, A.H. 2013 'Akrotiri-Aetokremnos (Cyprus) 20 Years Later: An Assessment of its Significance,' *Eurasian Prehistory* 10: 139-155.