Ancient Akrotiri Project

Dreamer's Bay Underwater Survey, 2019

Interim Report

Lucy Blue

Contents

Introduction

Between September 8th and 19th 2019, a second season of underwater investigation was conducted at Dreamer’s Bay RAF Akrotiri, on the southern shores of the Akrotiri Peninsula, Cyprus. The team consisted of professional diving maritime archaeologists, students of maritime archaeology, divers, surveyors, photographers, and terrestrial archaeologists, including archaeologists from the Centre for Maritime Archaeology, University of Southampton, UK, and students and staff from the University of Cyprus (Figure 1). Unlike the previous year that documented the remains of the ancient breakwater submerged some 1-5m beneath the water, the primary focus of the 2019 season was to complete a broader survey of the entire bay and the offshore approaches, and in particular to investigate an area to the east of the breakwater where a large amount of pottery was located in the 2018 season. The team suspected that this dispersed and concreted concentration of largely homogenous amphorae, was the remains of a shipwreck.

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

This work was conducted with the permission of the Republic of Cyrus Department of Antiquities and the UK Sovereign Base Areas Administration, 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 Flying Officer Olivia Henderson, WO Gaz Hathaway, SAC Graham Dean, Sgt. Sam Conway-Wallace for all there help with boat support, driving and diving, most especially to Sgt. Graham Moore as the official point of contact and for helping with all the logistical arrangements. Further support was provided by the Defence Infrastructure Organisation and the Western Sovereign Base Area Archaeological Society. This season we were honoured to welcome for a day the Station Commander Group Captain Chris Snaith as a visiting diver. Equipment and assistance was also offered from the University of Cyprus, MARELab, in the form of an excellent dive boat. The University of Cyprus also provided expertise, particularly with respect to ceramic identification offered by Dr. Stella Demesticha. Nicosia based CP Marine Explorations provided the dive logistics, safety and underwater survey scooters, and Kembali Divers the tanks and air. The project was generously funded by the Honor Frost Foundation, UK, and sustained by a hard working team of young maritime archaeologists. We were also very honoured to have the support both financial and physical, of Brian Richards, one of the pioneer divers at Dreamer's Bay who helped relocate finds from previous decades and was an excellent team member.

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 2019 season focused on three main tasks: further investigation of the ancient breakwater submerged some 1- 5m below the water located in the eastern reaches of the bay; completion of the survey of Dreamer's Bay, its approaches, and the area offshore of the buildings excavated by the University of Leicester's team on the coast to the west of the bay (Figure 2); and further analysis of the ceramic concentration to the east of the breakwater in order to determine its nature. The underwater survey was designed to compliment and develop work undertaken over recent years to investigate and record threatened archaeological remains around Dreamer's Bay (James & Score 2015, 2016, 2017, 2018, 2019), 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.

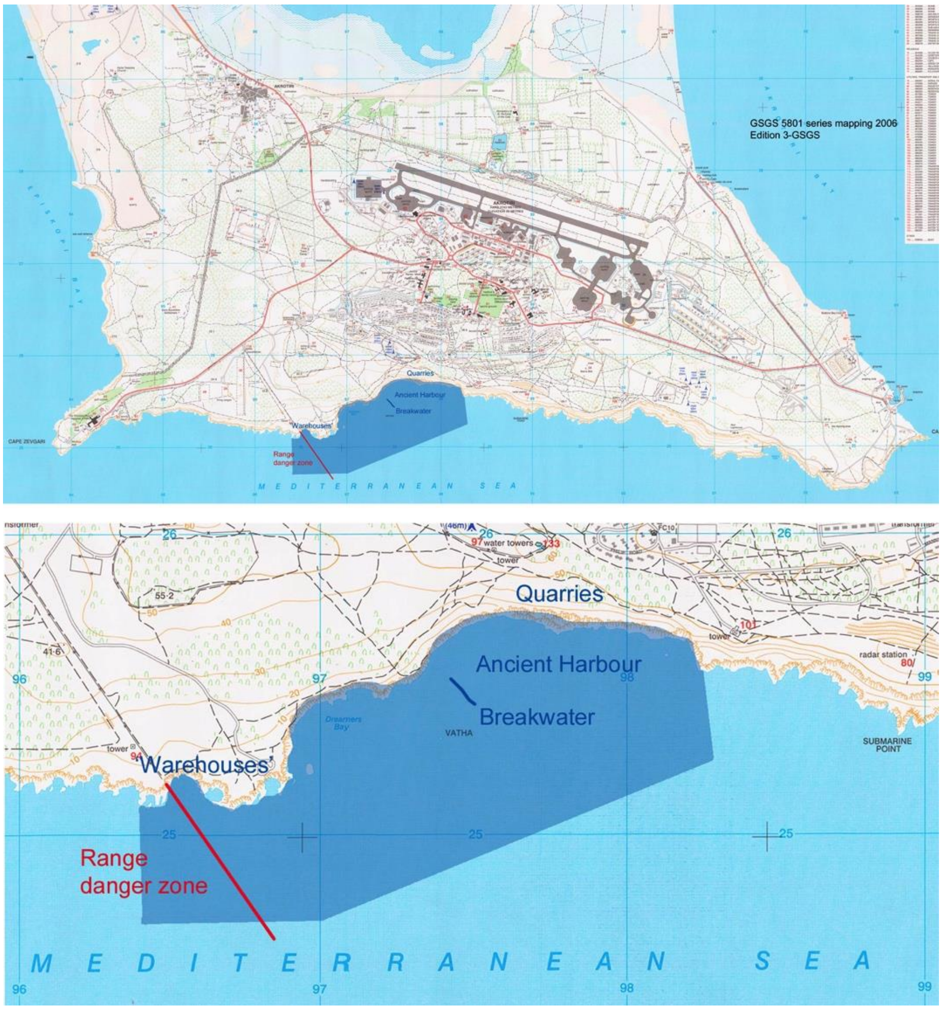

Figure 2: Underwtaer and shoreline survey work area conducted at Dreamer's Bay, September 2019. Large ruled squares are 1km on a side.

The Landscape and Geological Context of Dreamer's Bay – Miltiadis Polidorou

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).

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). Akrotiri Promontory is located west of Limassol at the southern end of the Island of Cyprus and covers an area of approximately 60 km^2 (Figure 1). 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 to south.

Geologically, the Limassol-Akrotiri region is broadly defined as a shallow syncline of Miocene, Pliocene, and Quaternary sediments with an east–west axis (Eaton and Robertson 1993). The Quaternary tectonic setting of the area (Soulas 1999) suggests a gradual uplift of the south-western extension of the Akrotiri Peninsula, which is driven by a left lateral strike slip fault with vertical components (Figure 3).

The peninsula represents a former island now joined to the mainland on the western side by a massive tombolo beach of large pebbles, and on the east side by a broad sand beach which extend into the outskirts of Limassol (Bear and Morel 1960; Polidorou et al. 2020). The maritime space between Akrotiri Island and the mainland eventually closed during the Quaternary and several geomorphic features developed (Figure 3). At the centre of the peninsula lies the Limassol or Akrotiri Salt Lake, which was formed in the middle Holocene and is surrounded by extensive dune fields (Polidorou et al. 2020). The land rises gently from north to south, reaching only a modest 50m above sea-level, and terminating on its southern edge in step cliffs, except for c. 600m of low shoreline at Dreamer's Bay (Figure 4). The cliffs are subject to sub-aerial processes that include mass movement and weathering. Also, there are geological indicators of high rates of coastal erosion in the form of hydraulic action, corrosion, attrition and abrasion (Figure 5). A number of badly preserved notches are present indicating a gradual uplifting of the area which is consistent with the tectonic action of the left lateral strike slip fault during the Quaternary period (2.588 ma – today). On the seabed stumps and evidence for previous landslides were noted.

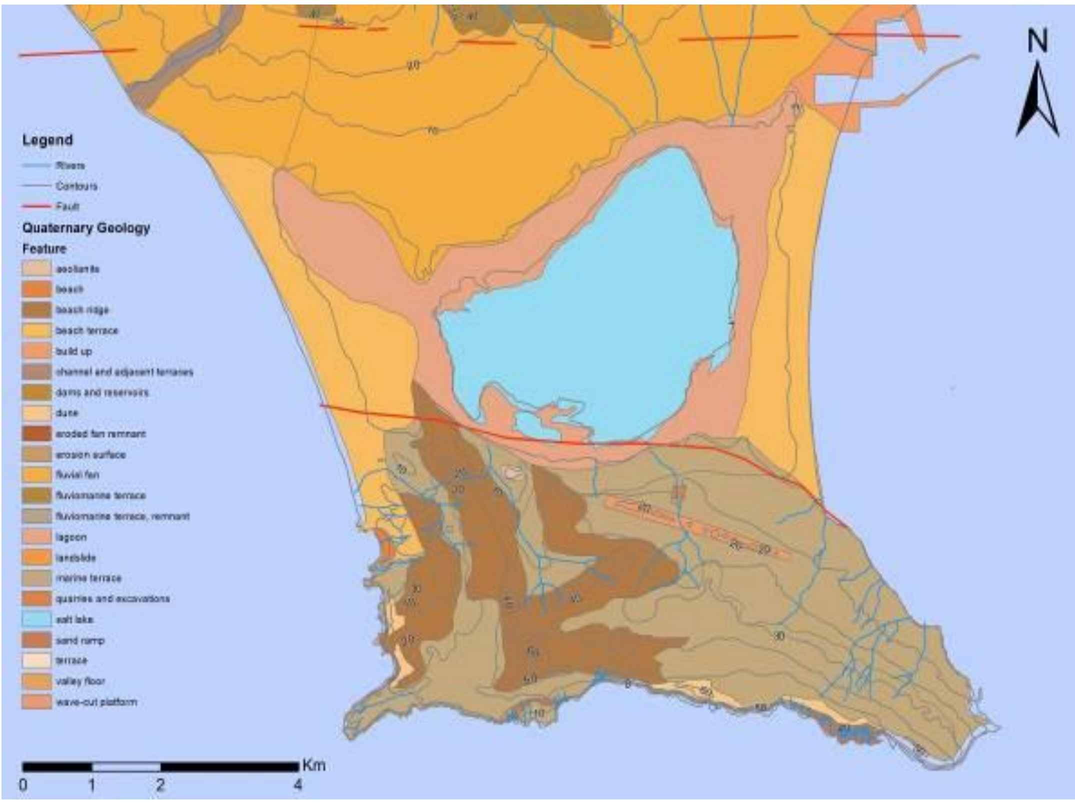

Figure 3: Simplified Quaternary Geology Map (GSD modified by M. Polidorou).

Dreamer's Bay, unlike the rest of the southern coast (Figure 4 and Figure 5) of the Akrotiri Peninsula, extends as a broad area of lower-lying land that projects into the sea. At the western extent of 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).

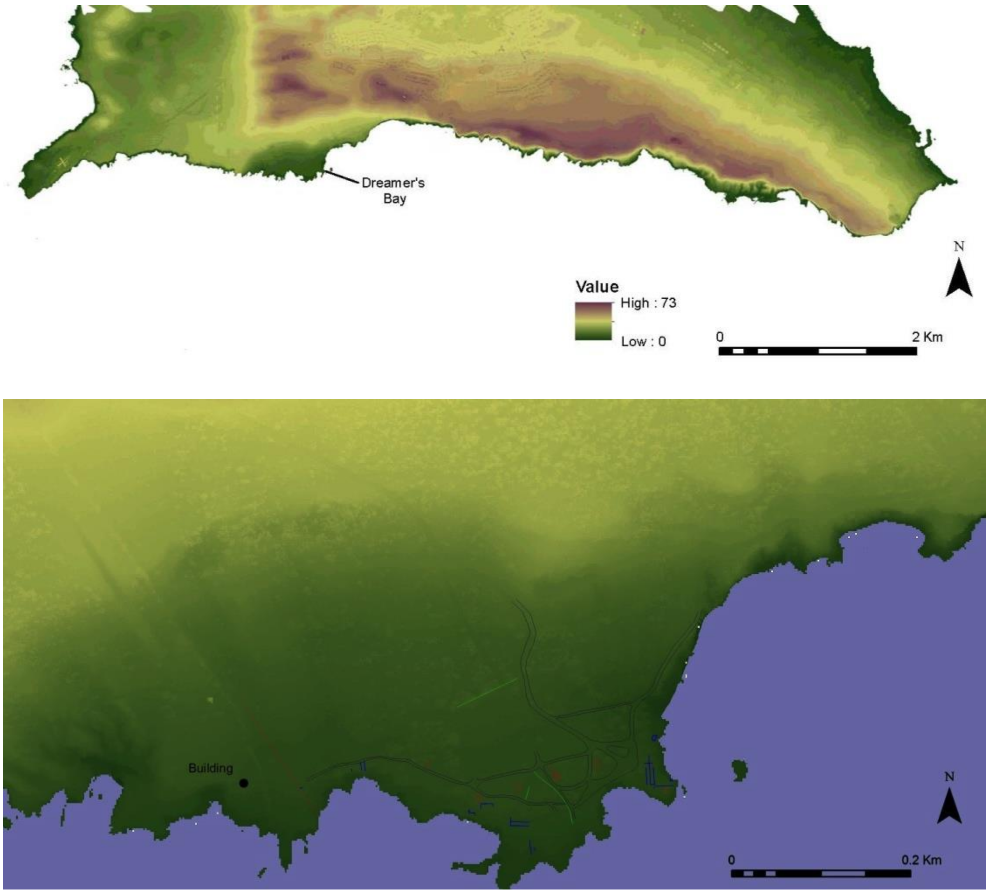

Figure 4: Digital terrain model of the southern part of the Akrotiri Peninsula showing the location of Dreamer's Bay.

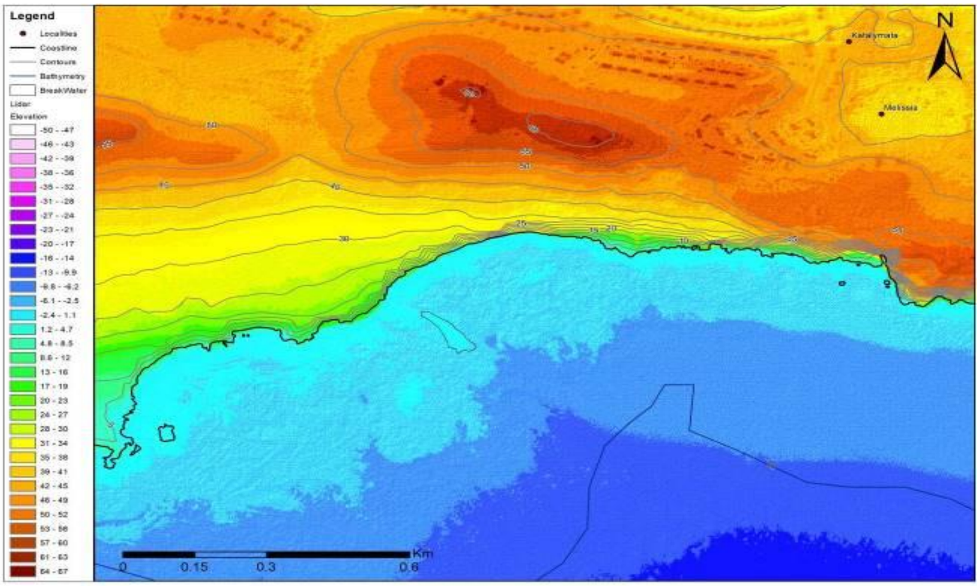

Figure 5: Dreamers Bay study area. DEM model and bathymetry constructed by Lidar data (M. Polidorou 2019)

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 an extremely 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 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. More recently of course, the University of Leicester has been conducting survey and excavation around the shores of Dreamer's Bay adding further to our knowledge of the archaeology of the region (see James and Score 2015, 2016, 2017, 2018, 2019).

Underwater Survey of Dreamer's Bay 2019: Approach and Objectives

The 2019 underwater survey season was specifically designed to complete a broader survey of the entirety of Dreamer's Bay from the west, southeast of the Firing Range, to the eastern limits of the bay, including the offshore approaches. Besides checking specific attributes of the breakwater and in particular the extent of the associated rubble, an area to the east of the breakwater where a large amount of pottery was located in the previous season, was also targeted. The team suspected that this dispersed and concreted concentration of largely homogenous amphorae, was the remains of a shipwreck (Blue *et al.* 2018). The overall objective therefore was to finally provide context to the breakwater, determine its precise function and date, and specifically its relationship with the archaeological remains of Roman/early Byzantine buildings investigated in previous seasons along the western shores of the bay. 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.

Methodology

The majority of the survey particularly in the shallower waters of Dreamer's Bay, was conducted by divers on SCUBA, and occasionally snorkels. Underwater scooters aided the survey of areas further offshore to the west, east and southeast of the breakwater. Scooters enabled a more extensive area of seabed to be covered in as short a time period as possible, thus, hopefully locating archaeological finds more efficiently. One person would drive the scooter and a second would hold on to the scooter and check the area for archaeological finds. Compass bearings, grids and area of coverage were pre-determined prior to each scooter survey to insure sufficient coverage. When an isolated archaeological find or a concentration of finds, were found, the divers would pull the surface marker buoy (SMB) they were carrying up and down in the water column to indicate their position and thus that of the underwater find. Subsequently, a waiting team member in the boat that was following the scooter on the surface above, would note the location of the SMB. The location of finds were recorded using a handheld GPS. Scooter surveys were conducted between the 10th to 14th September 2019.

In shallower waters diver surveys with no scooters were conducted. On the discovery of a find or concentration of finds, numbered markers buoys were deployed by divers to the surface to identify the specific location on the seabed. The co-ordinates and the number of the marker buoy were subsequently noted on the surface by a snorkeler with slate and a handheld GPS. This was a continuity of the methodology utilised in the 2018.

The Breakwater survey - Lucy Blue and Miltiadis Polidorou

As noted, the submerged ancient breakwater currently extends over a distance of 135m roughly in a north-south alignment[1] perpendicular to the coastal cliff (Figures 2 and 6). The coastline to the north of the breakwater has been subject to coastal erosion and the end of the breakwater is now dislocated some 90m from the base of the cliff. Towards the southern, seaward end of the breakwater, the water depth increases and the feature widens out to 8.5-9m and extends to a greater depth underwater.

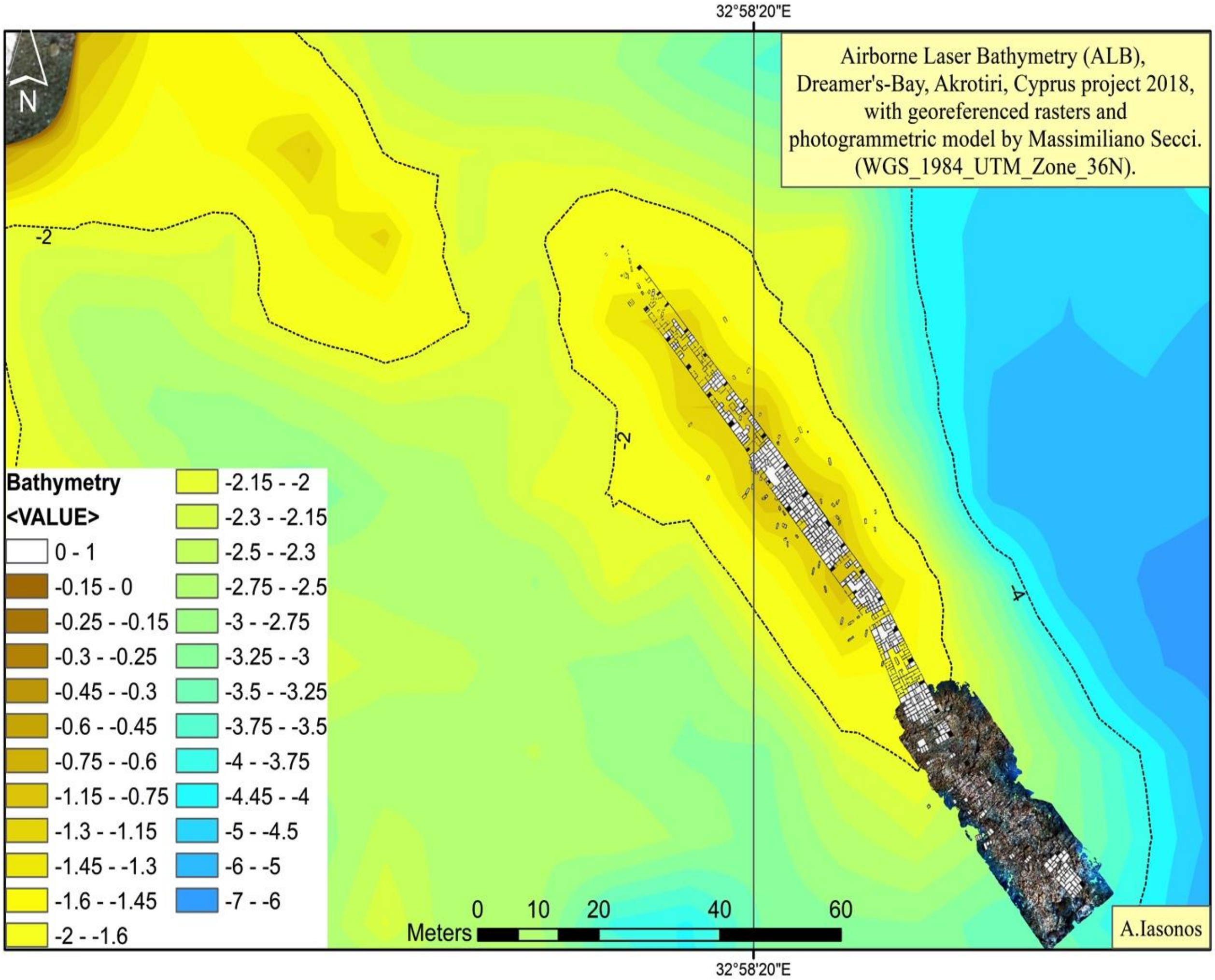

Figure 6: The breakwater as recorded during the 2018 season as compared with Haggerty 1990 (A. Iasonos and M. Secci)

[1] The breakwater is more accurately described as being aligned NNW-SSE but for the sake of ease north-south is generally referred to as its orientation in the text

The breakwater is made up of layers of blocks. The maximum number of blocks observed *in situ* extended to four courses deep (Figure 7) and the average size of the blocks was 0.9/1.1/1.3 (length) x 0.4 (breadth) x 0.3 (depth). The average depth of the surface of the breakwater beneath the water was around 1.2m, although sections as deep as 1.55m were observed towards the 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 up to 1.4m long and others as shallow as 0.2m deep. Others were very fragmented particularly towards the southern end of the breakwater, where the structure is also more dislocated than the main body of the breakwater. At the very southern end, the ashlar blocks return to face the south along their length, finishing off the breakwater. This would imply that the original end of the structure remains intact.

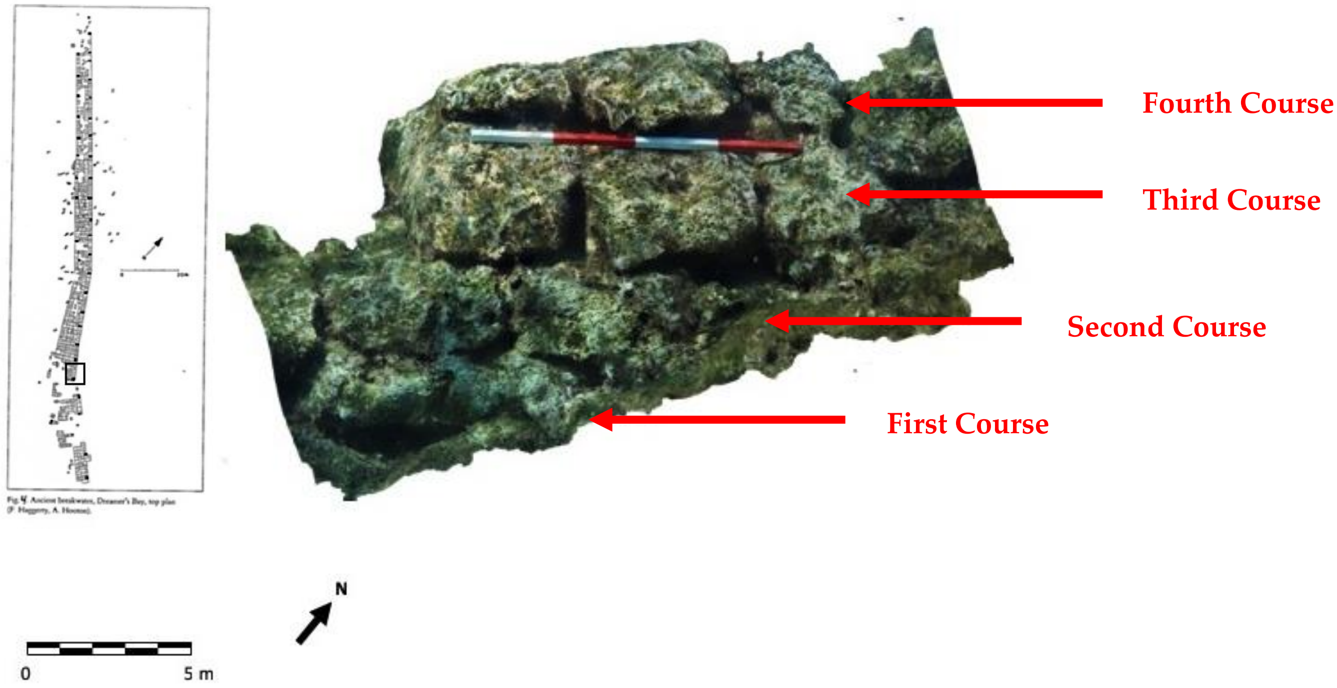

Figure 7: Orthophoto of the reconstructed portion of the eastern side of the breakwater (Photogrammetry survey and processing: M. Secci).

The breakwater was extensively surveyed in 2018, both visually and photogrammetrically (Blue *et al.* 2018), producing a geo-rectified image of the plan view of the breakwater, along with an orthophoto of the reconstructed portion of its southern end of the breakwater (Blue *et al.* 2018). Further analysis of the breakwater in the 2019 season commenced on the 10th of September, and included a more detailed analysis of the extent and nature of the associated rubble that had fallen from the breakwater. The specific aspects of the survey included the following:

- Investigation of the rubble east and west of the breakwater
- Analysis of the different construction techniques deployed in different parts of the breakwater, to inform the geotechnical construction and, ultimately, the destruction of the breakwater
- Estimation of wave height and energy that caused the destruction of the breakwater
- Analysis of biological development and relative erosion of the breakwater blocks
- Further analysis of the breakwater

Investigation of the rubble along the western and eastern sides of the breakwater

During the collapse of the breakwater, portions of the structure had fallen as rubble on both sides of the breakwater, with a larger concentration on the eastern side, as depicted in the results of the 2018 photogrammetrical survey (Figure 8). However, the photogrammetrical data alone was not adequate to calculate the extent and nature of the rubble that had fallen and thus, a primary aim of the 2019 season was a re-examination of the breakwater rubble in order to try and ascertain its original height, scale and possibly volume.

The conclusion presented as a result of the 2018 investigation (Blue *et al.* 2018), was that the breakwater was subject to the impact of a large storm/ high-energy wave event or tsunami (or series of waves) in antiquity, predominantly moving from west to east. This event(s) caused substantial damage to the breakwater, moving large sections of the upper courses of the feature (blocks and fragments), and re-depositing them on the seabed. The exact date of this event(s) has yet to be determined as we are still awaiting radio-carbon analysis delayed due to COVID-19. In order for a wave to cause this type of damage, it indicates that structurally the breakwater was vulnerable prior to the ultimate destruction event. This weakness can be due to two reasons 1) poor design and construction, although extensive visual inspection of the breakwater indicates that was it well built, or 2) previous events that caused structural damage to the breakwater. According to the geological history of the area (Polidorou *et al.* 2020), it is most likely that previous structural damage is linked to tectonic movements in the area (Soulas 1999). However, this section seeks to explore in more detail the specific events that resulted in such large-scale damage to the breakwater.

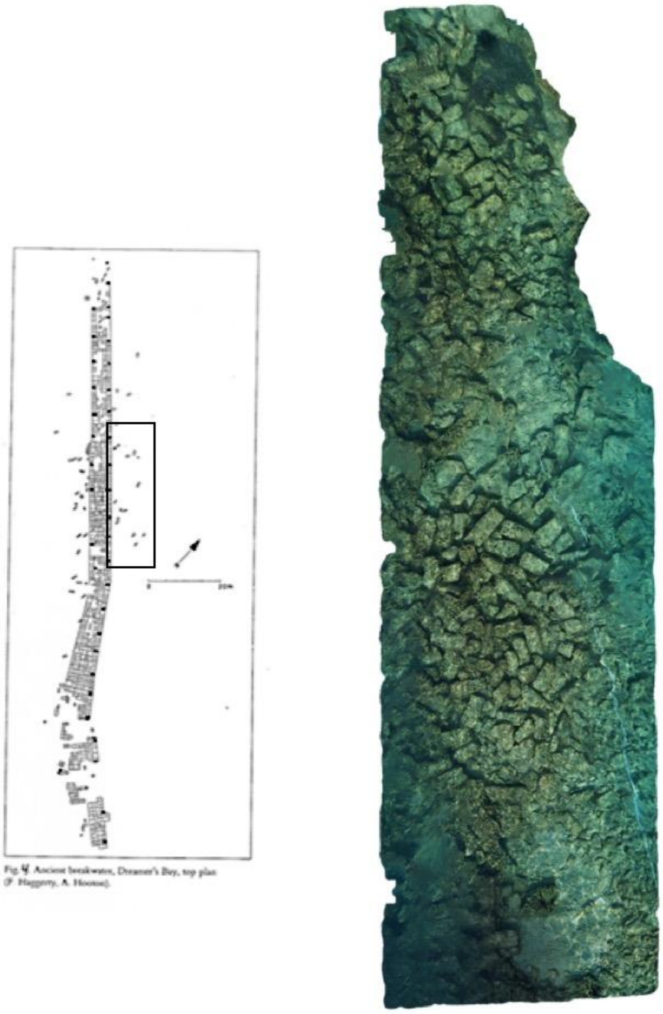

Figure 8: Orthophoto of the reconstructed portion of the rubble along the Eastern side of the breakwater as documented in 2018 (Photogrammetry survey and processing: M. Secci 2018).

Rubble on the western side of the breakwater

Due to the prevailing direction of the storm event (see above), rubble on the western side of the breakwater was pushed up against the edge of the breakwater. In the process of the destruction, the breakwater created an obstacle to the movement of material, which caused the anomalous deposition of blocks and block fragments against its western edge. The rubble extended approximately 7m to the west. There was no evidence for zonation with respect to the size and volume of the rubble in this area. Thus, rubble on the western side of the breakwater is made up of a mixture of different size blocks and fragments of stone, which are lying on the seabed in a roughly east-west orientation (Figure 9).

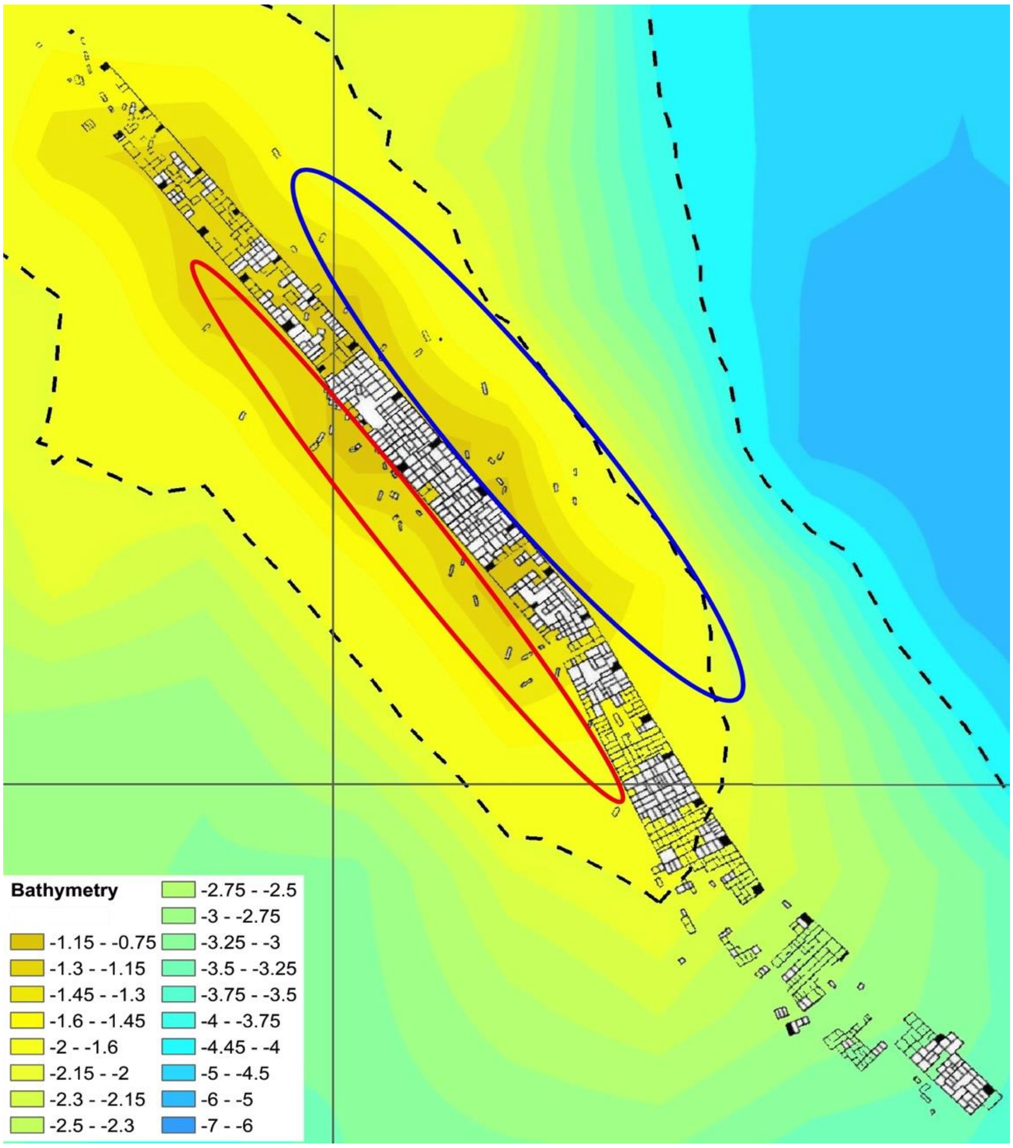

Figure 9: Schematic representation of the rubble orientation either side of the breakwater (M. Polidorou).

Rubble on the eastern side of the breakwater

On the eastern side of the breakwater, the rubble morphology is different when compared to the west. Zonation regarding size and volume is observed. Bigger blocks are observed in close proximity to the edge of the breakwater and smaller fragments are deposited at greater distances from the eastern edge of the breakwater. Some of the building blocks are overhanging the top of the breakwater.

In order to try and determine the extent and volume of the rubble along the eastern side of the breakwater, a base-line tape was extended from the south along the eastern, top edge of the breakwater, towards the northern extent of the rubble. Offsets were measured every 5m from the breakwater edge perpendicularly out to the farthest north-eastern extent of the rubble (Figure 10). The depth of the top of the rubble on the seabed was also noted along the extent of the perpendicular offset, thus mapping the rubble extension and depth below the surface of the water (see Figure 10 and Table 1 below).

The maximum extent of the rubble towards the northeast from the eastern breakwater edge was approximately 20-25m. The rubble appears to have greater reach in the southern, deeper extent of the breakwater (Figure 10). Unsurprisingly, the maximum depth of rubble deposition was also noted in the southerly area, at almost 5m in depth. The rubble appears to have been prevented from extending any further by a natural topographical high along its eastern edge, which appears to act as a natural barrier. Archaeological finds lie within the rubble concentration including an anchor (Figure 15). All the gathered data suggest an event (or several events) of movement of material from the top of the breakwater to the northeast, as described above.

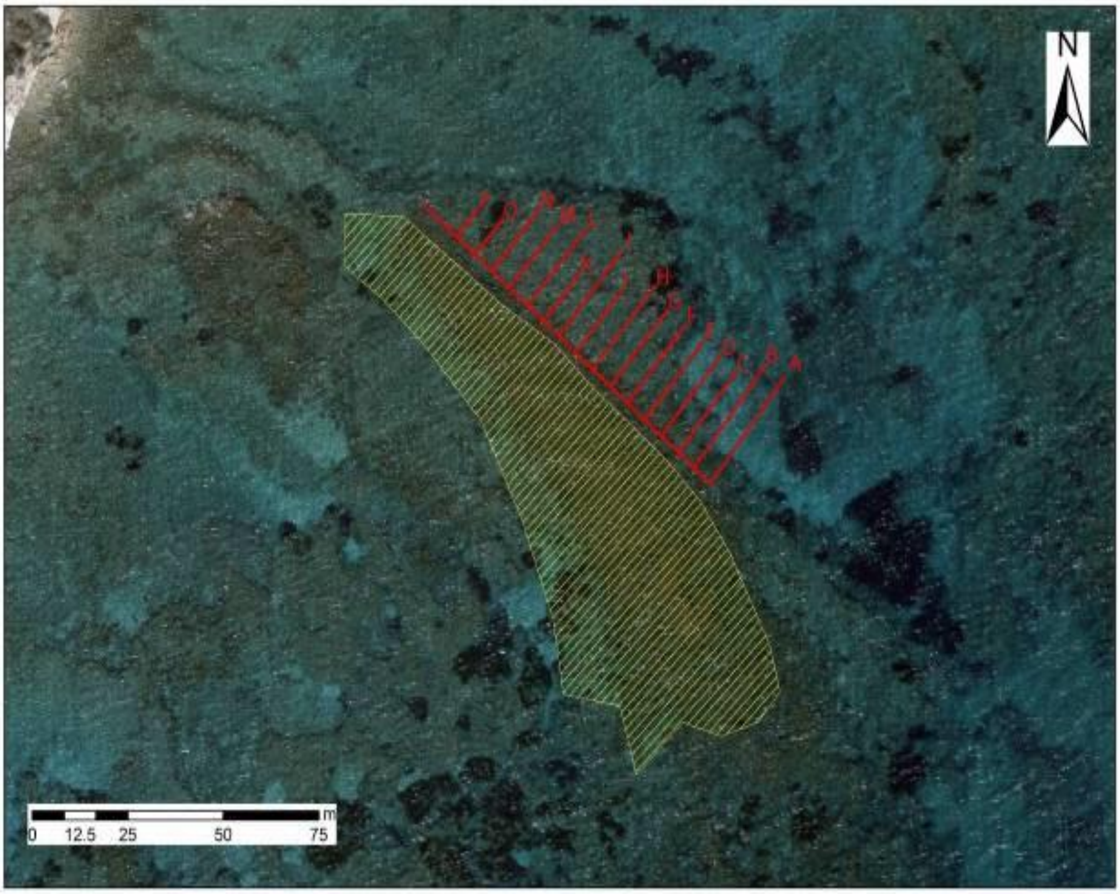

Figure 10: Maximum distances (ref to Table 1) of rubble east of the breakwater. NB. The yellow lines identify the area of the breakwater. The red line that runs along the eastern edge of the breakwater indicates the position of the baseline tape and the survey lines that extend perpendicular out from this towards the northeast, to the maximum extent of the rubble (M. Polidorou).

ID	Distance along baseline from south to north (m)	Maximum distance from baseline (m)	Maximum depth (m)
A	0	25.1	4
B	5	25	4.8
C	10	19.6	3.8
D	15	19.9	3.4
E	20	19.7	4.1
F	25	19.1	3.2
G	30	19.3	2.8
H	35	20.9	2.8
I	40	14.8	2.3
J	45	20.8	2.7
K	50	20	2.8
L	55	19.7	2.5
M	60	16	2.1
N	65	16	2.1
O	70	9	2.3
P	75	6.9	2.5

Table 1: Distance that the rubble on the north-eastern side of the breakwater had been moved relative to the breakwaters edge, and the associated depths (from roughly south to north). Each letter (A-P) represents a point 5 metres to the north of the previous letter/ point (L. Blue & M. Polidorou).

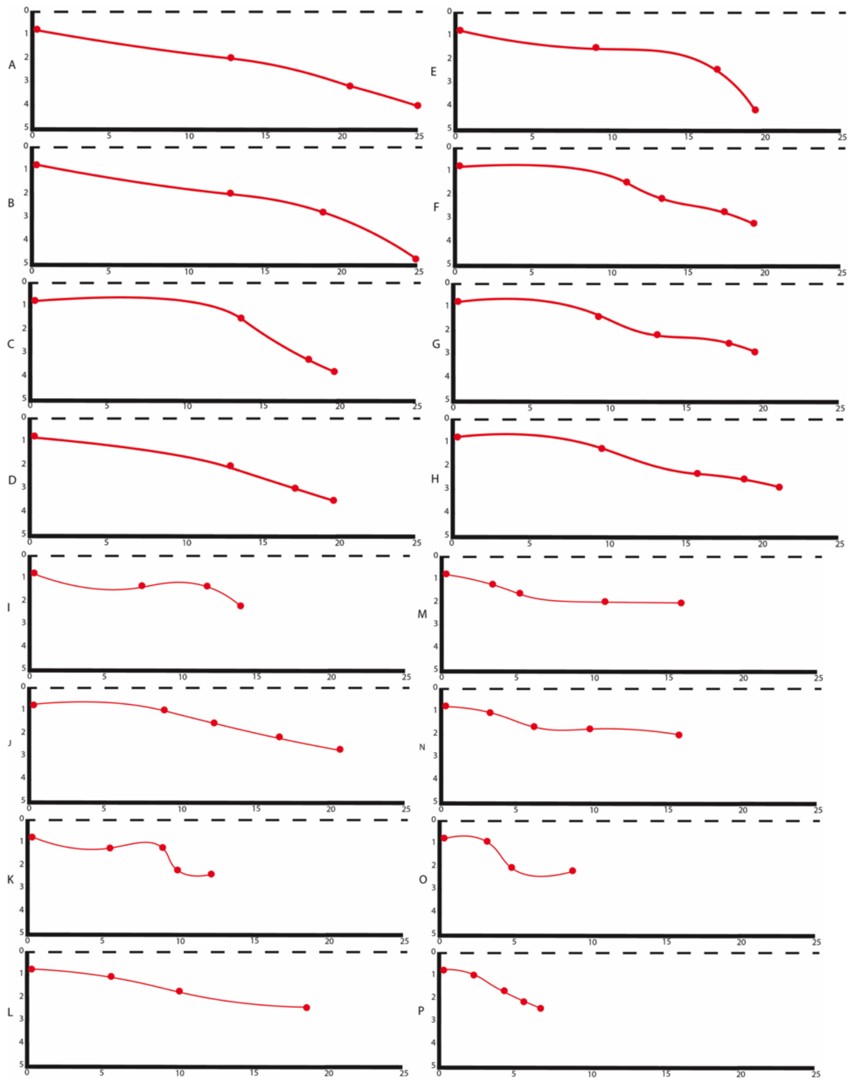

Figure 11. Profiles from south to north (A-P) along the eastern edge of the breakwater to the north-eastern extent of the rubble (M. Polidorou)

Estimation of the energy and height of the wave that caused the destruction of the breakwater

The field observations and measurements of the rubble (see above), lead to the hypothesis that a wave event (or several events) occurred, that caused the movement of material from the top of the breakwater largely towards the east. Information derived from the location and orientation of the breakwater blocks on the seabed, can inform on the trajectory and force, and therefore the destructive power of the wave(s).

The impact of forces generated by tsunami or storm waves that attack a single block can only be calculated to any degree of accuracy using Computational Fluid Dynamics programs (Pignatelli *et al.* 2009) that are used to calculate transient flow phenomena. For blocks that are situated in shallow water, water flow is not continuous during wave impact. The waves hit the blocks repeatedly in short bursts. Between these strikes, during the phases of the wave troughs, the water withdraws so that the blocks are partially exposed above the sea level. This means that the velocity of the impact is not constant and thus, the impact on the blocks is also not continuous. As wave height and energy are connected, estimations can therefore be made of the wave height by taking into account the maximum momentum force as the wave strikes the boulder. In order to make this calculation, some simplified assumptions need to be made: (i) the block is loosely positioned on a horizontal substratum; (ii) the block is being attacked by water with uniform velocity on its front face, and thus, the water mass (mw) is deviated by the block perpendicularly. Thus, we are then able to calculate wave height based upon the position and orientation of the blocks that have been removed from the breakwater and re-deposited on the seabed.

Once the volume (and therefore the mass) of the breakwater blocks, and the reorientation and distance that the blocks were carried from the breakwater, is determined, it is then possible to calculate the height of the wave, and thus determine if it was caused by a tsunami or storm event. For the purposes of this case study, and based upon available evidence, the hydrodynamic approaches adopted by Pignatelli *et al.* (2009) will be applied (Table 2) to make the calculation and the hence the interpretation, of the breakwater's demise.

a-axis	b-axis	c-axis	c-axis	Volume	Mass	Density	Approx	Elevation	(ps-pw)/pw	Tsunami wave Height Pignatelli	Storm wave Height Pignatelli	Mean Beach
Length	Width	Height	Height	(m^3)	(Mg)	g/cm3	Distance	(m)				Angle
(cm)	(cm)	(cm)	(m)				(m)					θ
110	45	30	0.3	0.1485	0.29106	1.96	18		0.83	0.70	2.80	0

Table 2: Mean measurements of block and calculations for wave height (Pignatelli et al. 2009)

According to the above hydrodynamic equation, in order to estimate the wave height, measurements of block dimensions were taken and the volume of the blocks calculated. Based upon the known density of the water, it is possible to calculate the mass of the block. Combining the distance that the block moved from its original position, and the mass of the block, the Pigniatelli *et al.* (2009) equation gave two results. The first one is the estimation of a tsunami wave height and the second the estimation of a storm wave height, that would have been required to destroy the breakwater. The results accord much more closely with a tsunami event (0.83m), which more mirror more recent climatic data collected for the period 1961-1990 (Figure 12) from the area. Thus, the possibility that a tsunami wave hit the breakwater is much higher than a storm wave having destroyed the breakwater.

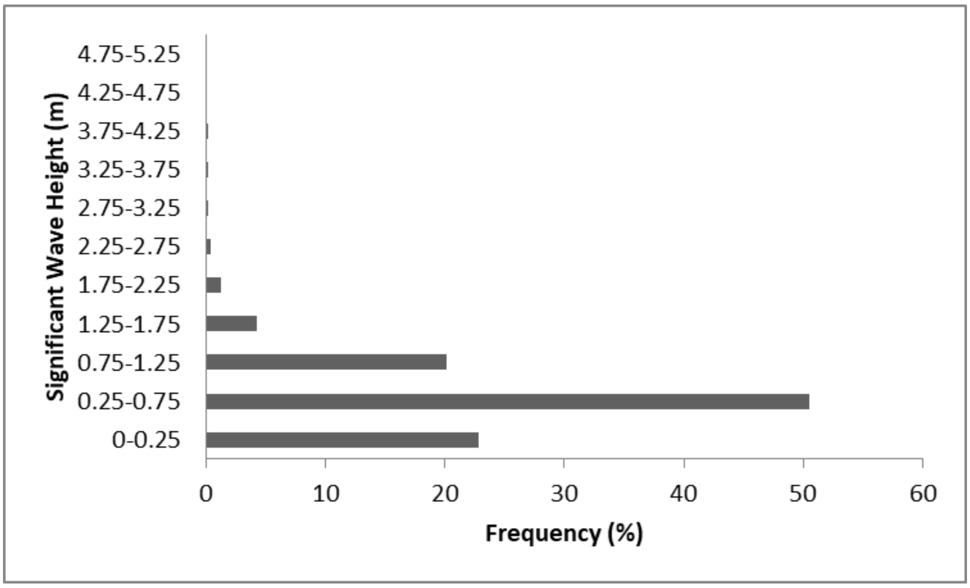

Figure 12: Frequency of Significant wave Height (m) measured at the study area between 1961-1990 (Loizidou and Dekker 1994)

Investigation of the different types of breakwater construction (north to south)

From north to south, two different types of constructions can be identified along the length of the breakwater. From the northern end of the breakwater and approximately 80m to the south, the building blocks have a specific size and are placed in a specific order with attention to alignment. The blocks along both edges of the breakwater are positioned with an east-west orientation, whereas blocks in the central section of the breakwater are orientated north-south. This type of robust construction adds strength to the edges of the construction against the energy of the waves and the currents. However, this construction arrangement, noted by Haggerty (1990) and mapped in the 2018 field season (Blue *et al.*, 2018), only describes the first 80m of the breakwater which appears to have been constructed to a high building standard. After 80m and towards the southern tip of the breakwater, the type of construction appears to be considerably different. Along the breakwater edges the blocks are placed with an east-west orientation but unlike in the northern section of the breakwater, towards the south the central section is made up of irregular blocks and fragments of blocks. Also, from underwater investigation, in contrast to the northern section of the breakwater that sits directly on marl bedrock, it appears that there is no solid foundation underpinning this part of the breakwater. This probably indicates that the southern extent of the breakwater was constructed in a hurry, recognizing a need to extend the breakwater after the initial phase of construction, in order to make it more functional. From Figure 5, it is obvious that the rubble relating to the northern part of the structure (Table 1 - Rubble with ID - I,J,K,L,M,N,O,P) was moved a much shorter distance than the rubble associated with the southern part of the breakwater. This is an indication of the different types and different strength of construction of two different phases of the breakwater (as described above; Figure 9).

Erosion and biological development of the breakwater

Biological growth (or bio-construction) is evident around sections of the breakwater blocks. This occurs only in the shallower water where a crust of calcareous algae or coral growth, forms around the edges of the blocks. This algal crust acts as a protective layer against chemical erosion and dissolution of the rock in salt water, and helps cement the blocks together. Towards the southern end of the breakwater there is evidence of high rates of erosion, as bio-construction is less inclined to occur in deeper water. Thus, where present, the bio-construction provides yet further rigidity to the construction particularly at the northern, shallower end of the breakwater. The algal crust is also evident on the rubble blocks but again in deeper water there is no biological growth, making it more susceptible to undermining.

Further detail of the breakwater

In order to determine in more detail specific attributes of the breakwater, two further analytical investigations were undertaken. Four stone samples were taken from all four corners of the breakwater in order to determine the nature of the stone and specifically if it was made of local stone from the ancient cliff-top quarries above the site. Analysis of the building stones indicated that it consists of cemented calcareous marls and calcarenitic sandstone, not the stone that was extracted from the quarries above the bay that consists of fine grain conglomerates (Figure 13).

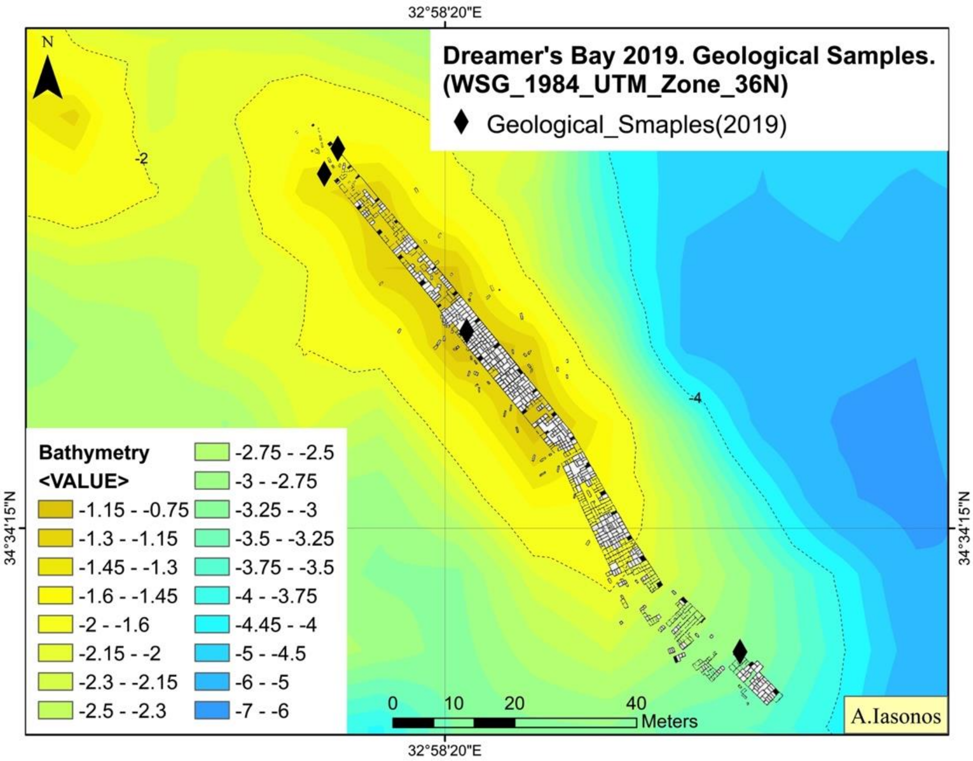

Figure 13: Map to identify the locations of the geological samples (A. Iasonos)

Secondly, elevation photos of the western face of the breakwater were taken in order to create a more accurate elevation photomosaic. The survey work was undertaken by two dive pairs, each with a scale and camera, each pair of divers having to insure a stable position, keeping scales and the cameras still in a strong swell, in order to secure an accurate record. The first pair was responsible for taking photographs of the western face, from the southwest corner towards the north, while the second pair started at the northwest corner and advanced in a southerly direction. When the two pairs met, the photogrammetric recording of the western face of the breakwater was complete.

Conclusions

From the gathered data and measurements taken during the underwater survey, we suggest that a physical event or several events (earthquake, seismic waves, and storm waves), were responsible for the breakwater's destruction. Most probably, one seismic event was responsible for weakening the structure and a second later event, caused the ultimate destruction. The location of the rubble suggests that a wave (storm wave or seismic wave) with direction from west to east, hit the breakwater, and spread the rubble a significant distance to the east. The low energy backwash of the wave (east to west), moved the rest of the loosen rubble a very short distance from the western edge of the structure where they were originally positioned, re-depositing them on the seafloor. Based on the hydrodynamic equations of Pignatelli *et al.* (2009), and according to the calculated wave height i.e. 0.83m (Table 2), it is most likely a tsunami wave that caused the deconstruction of the breakwater. Recent evaluation of significant storm events in the area, support this analysis, as wave regimes do not alter dramatically over time (Figure 12).

Regrettably we still await the date of this event as radio-carbon dating is outstanding. We were unable to determine the depth of the rubble as it was not possible to locate the base of the rubble, only its depth below the water, and thus, we could not determine the volume of the rubble and hence do not know the height of the breakwater prior to its destruction.

The construction of the breakwater, with blocks placed along both edges in an east to west orientation, suggests a well thought through design, not a rough construction. This type of construction consolidates the strength of the breakwater edges, combating the destructive power of the waves and currents. At the northern end of the breakwater and approximately up to 80m to the south, the inner building blocks have a specific size and they are placed in a specific order with attention to alignment. Further south the blocks are more irregular and fragmented, particularly in the central section. It also appears that there is no solid foundation upon which the southern part of the breakwater is constructed. This contrasts with the north that is built directly upon marl bedrock. Most probably, this difference of the inner filling material of the breakwater indicates a second phase of construction (not necessarily built during a separate phase of construction), which was not as detailed in design as the initial northern phase.

Extended area and offshore approaches surveys - L. Blue and M. Michael

Survey to the immediate east of the breakwater

Beyond the rubble to the east and northeast of the breakwater, further survey was conducted in order to more thoroughly investigate a channel some 5-6m deep. This area of open seabed was clearly mapped, and an entrance offshore leading to this more sheltered body of water in the lee of the structure, was noted. Also observed in this so-called anchorage area, were a series of 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 that the ceramics had been trapped along with the sand *in situ* by the growing seagrass, which subsequently died and decomposed forming large, solid mounds.

Offshore survey to the south of the breakwater

Survey conducted by divers using underwater scooters, enabled wider coverage of the offshore approaches to the south and southeast of the breakwater, in the area leading to the channel entrance. From a position 20m east off the south-eastern point of the breakwater, and following a fixed compass bearing of 70 degrees, divers surveyed offshore and then they turned around and returned on a 250 degrees bearing parallel to the first bearing (essentially conducting a corridor search). This system was repeated a number of times to cover a comprehensive area offshore the approaches of the breakwater up to 10m deep. A concentration of concreted roof tiles on a rocky seabed was located and a record of their location taken using GPS. The tiles were also photographed in order to create a three-dimensional (3D) model. Two roof tiles were lifted as chronological and typological indicators (Figure 14). Highly corroded metal iron was located within the concentration of the roof tiles, and amphora sherds and concentrations of small pieces of pottery were also located in the same area. A stone anchor was also identified. Subsequent scooter surveys in the area more precisely located the anchor and pottery, and further to the northeast six more anchors were identified, as well as an additional smaller concentration some 50m from the original find site. All the anchors were recorded and mapped *in situ* and were also individually photographed, as well as subject to photogrammetry so that 3D models could be constructed. In total ten stone anchors were located in the offshore approaches to the anchorage (Figure 15).

Figure 14: Roof tile DBT-2

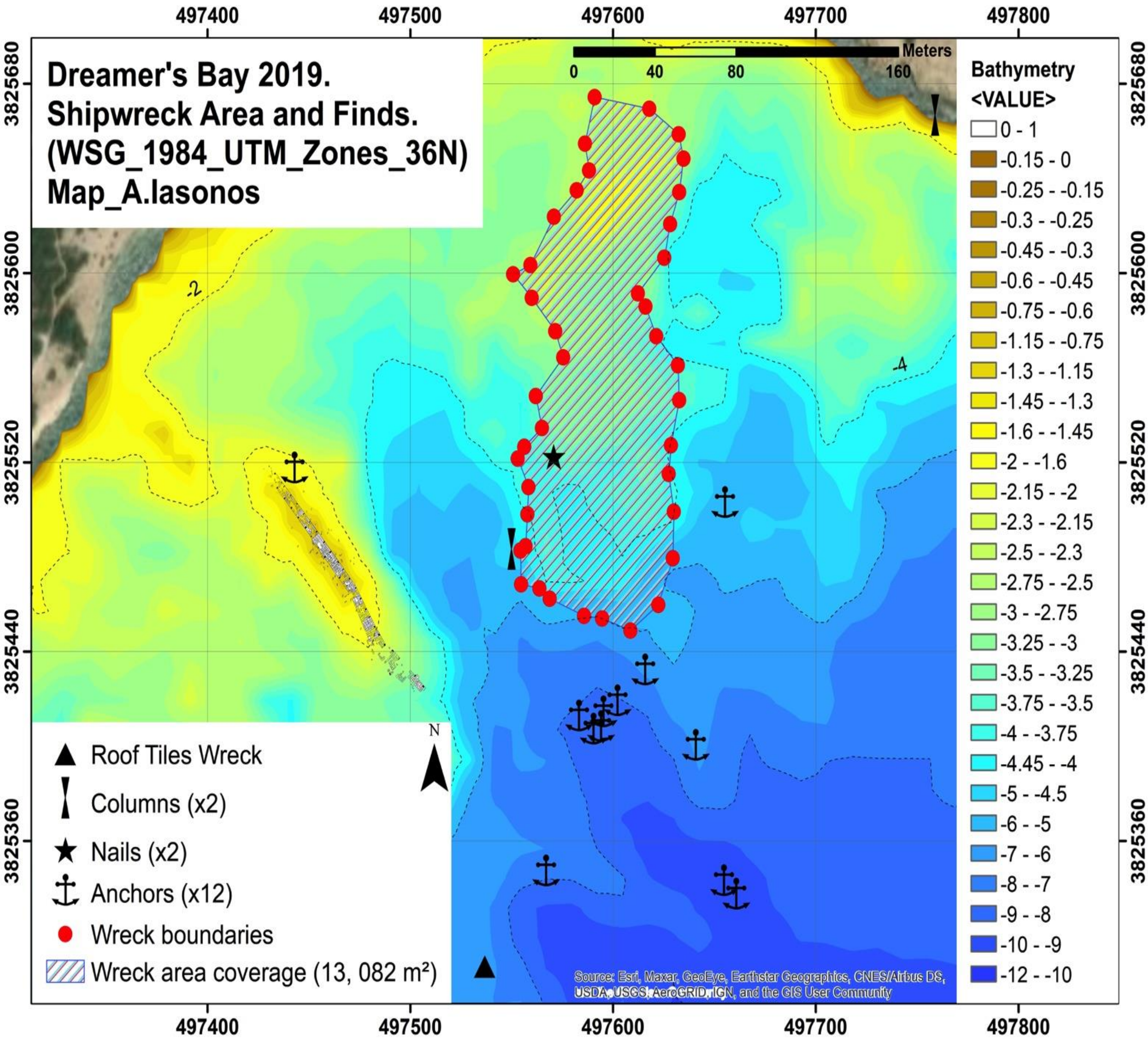

Figure 15: Distribution of finds as observed during the offshore anchorage and shipwreck surveys (A. Iasonos)

Survey west of the breakwater

Complementing the survey conducted to the west of the breakwater in 2018 when 14 survey lines and numerous finds concentrations were noted, further survey to the west of the breakwater was conducted in 2019 by both divers and in deeper waters, with the use of scooters. The objective was to locate both new and/or relocate previously discovered archaeological finds on the seabed. Initially, divers swam at a distance of 5m apart (swim line survey) on a fixed compass bearing of 160 degrees, from the western edge of the breakwater. After a fixed period of time, they turned round and swam 340 degrees parallel to the first bearing, back towards the breakwater. This system known as a corridor survey, was repeated a number of times to insure comprehensive coverage of the area to the west of the breakwater.

Small concentrations of diagnostic amphora sherds and two, two-holed, stone anchors were found in depths of 7m and 8.9m respectively. They were described and photographed underwater, and a buoy was deployed to mark their location. A surface diver noted the number of each buoy and recorded its location using a hand held GPS. During the continuation of this survey, several concentrations of concreted handles, rims and necks of amphorae and other ceramics, including an open vessel, two almost complete Gaza amphora and three anchors, were found (Figure 16).

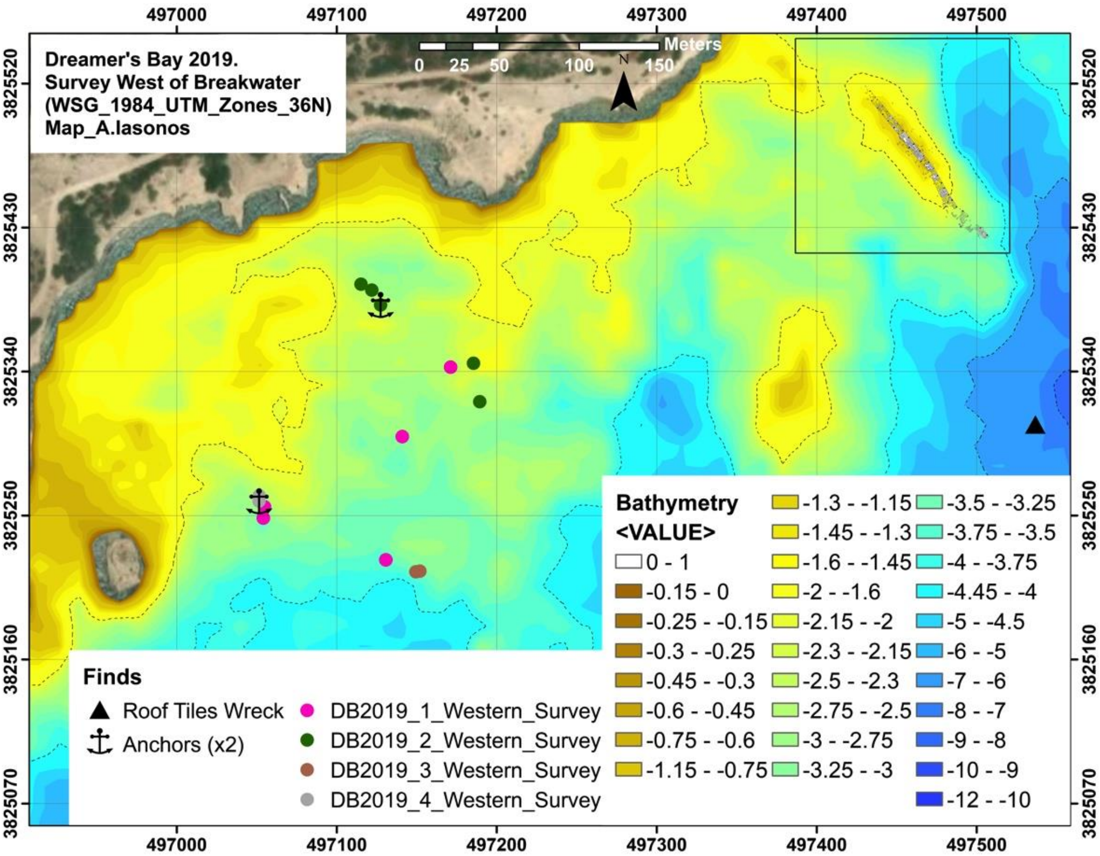

Figure 16: Finds located as part of the survey to the west of the breakwater (A. Iasonos)

Survey offshore the western shoreline buildings

Further west, a scooter survey was also conducted offshore in front of the shoreline buildings excavated by the Leicester University team (James and Score 2015, 2016, 2017, 2018, 2019). The objective of this survey was to determine if there were archaeological remains underwater that may relate to the terrestrial features on the shore above, and/or if an ancient roadstead could be identified offshore of these buildings where vessels would have moored at anchor (James and Score 2018). The survey extended as far west as the Rifle Range boundary and offshore to between 7m and 10.7m deep, and east as far as the island of Nissarouin at the eastern extend of the shoreline features. The seabed was rocky with some sandy patches. Regrettably no archaeological remains were identified thus making the theory that this was an area used as a roadstead, less feasible.

Snorkel Surveys

Snorkel surveys were conducted intermittently across the duration of the season focused largely in areas of shallower water and/or close to the cliff base. Brian Richards conducted most of these snorkel surveys in an effort to relocate finds he had discovered when he first swam in Dreamer's Bay in the 1960's. Besides various pottery sherds, a snorkel survey in the area of the shipwreck (see below), located a lead ingot (DBS-11) at a depth of 3.6m. Further survey relocated a column at the base of the cliff in 0.15m of water to the east of the northern point of the shipwreck, and a stone anchor at a depth of 5.2m east of the southern point of the shipwreck (Figure 15). Both finds were photographed and located using a handheld GPS.

The Wreck Site Survey

A further systematic underwater survey was also conducted to the east and northeast of the breakwater and the channel, in order to verify the nature of the much larger quantities of ceramics, pieces of marble, the Aswan granite column, two stone anchors and a number of mounds of what appear to be ballast stones, that had been identified during the 2018 survey season. This large concentration of concreted ceramics and other artefacts, located between 80-200m to the east and northeast of the breakwater, was initially interpreted as the very fragmentary remains of a shipwreck (Blue *et al.* 2018). Consequently, a more detailed examination had to be conducted to define its nature, extent and date.

On the 11th of September, a preliminary dive was conducted in order to determine the methodological approach, which could lead to a more detailed survey of this area. It was decided that the most effective way to understand the extent, nature and significance of this area was to determine the number of diagnostic pottery pieces (necks, handles or rims) in this underwater archaeological assemblage. In other words, it was necessary to determine the MNI (Minimum Number of Individuals) of the potential wreck site by counting the diagnostic pottery. The count was conducted in a series of blocks. Firstly, a perimeter was set up by deploying buoys to demarcate the limits of the site. Then a transect rope was laid that divided the site in half north to south (100m rope) and a second rope defined the northern extent of the first rope east to west (32m rope). The starting point of the survey was the apex of the gridded area at the intersection of the ropes. Three or four divers swam in parallel lines both west or east of the north-south rope, with 3m fixed distance between them until they reached the boundary of the wreck marked by the buoys, when they retuned parallel to and some 3m distant from, the first transect back towards the rope. The divers counted diagnostic pottery based only on necks with or without handles, and rims with or without necks. Firstly, the area on the south-western side of the 100m rope was surveyed, and then the area to the south-eastern side. At the end of each survey, a knot was made on the transect rope signalling the point that the team finished its survey. This served as an indicator to the next survey team where to commence the next survey. This system was repeated a number of times until the whole area both sides of the rope was systematically surveyed. When the survey was completed, the same system was repeated, extending the survey to the north, in order to survey a wider area and fully cover the entire area of the pottery concentration. Ultimately the survey extended much further north and south than had originally been envisaged (Figure 15).

During this survey, selected finds were lifted when archaeologists felt they were useful as chronological indicators or they could assist in defining the nature of this site. Nine finds were identified as amphorae (DBS-2, DBS-3, DBS-4, DBS-5, DBS-6, DBS-7, DBS-8, DBS-9, DBS-12). According to initial observation, four main amphora types have been distinguished in this selected sample: (1) the Gaza amphora (DBS-2), the basket handled amphora (DBS-12), LR1 amphora (DBS-6, DBS-9) and LR13 amphora (DBS-4. DBS-5, DBS-7). A sherd of a clay cooking pot (DSB-1) was also identified, while three bronze nails, one complete and the other two fragmentary, which were also lifted (DBS-10) (Figures 17 and 15). All finds were noted, described, photographed and declared to the Archaeological Museum of Episkopi. The area was extensively surveyed and the number of amphora shoulders and rims were counted equating to 781 in total, reflecting a fairly substantial cargo for ships of this period. Examples of the amphorae were lifted for further analysis, which is still on-going (Figure 18).

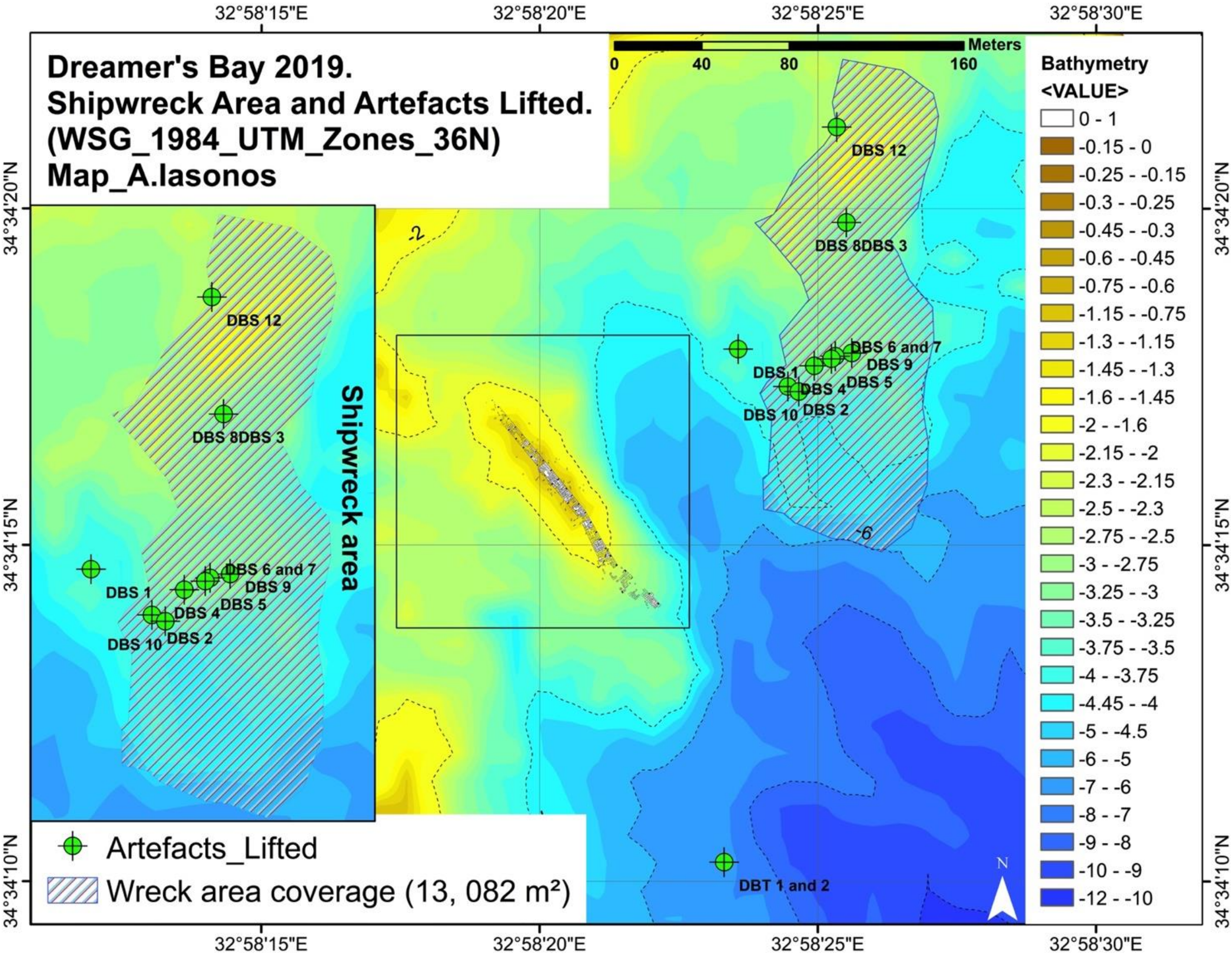

Figure 17: Distribution of ceramics on the seabed in the vicinity of the breakwater that were lifted (A. Iasonos)

Figure 18: Neck and handle of LR13 amphorae recovered from the area of the shipwreck - DBS-4

Discussion and Conclusions

The big result of the 2019 season was confirmation that the eastern concentration of largely homogenous ceramics located on an elevated, rocky outcrop to the east of the breakwater and the sheltered channel, was indeed a shipwreck. Dating to the end of the 6th – beginning of the 7th century AD, as confirmed by ceramics expert Dr Stella Demesticha of the University of Cyprus, the extensive remains of broken amphorae were identified scattered over an area of approximately 130,000sqm, concreted to the rocks and caught in gullies. The area was extensively surveyed and the number of amphora shoulders and rims were counted equating to 781 in total, reflecting a fairly substantial cargo for ships of this period.

Thus, we are now even more confident in our interpretation that the shipwreck post-dates the destruction of the breakwater, as elements of the cargo, notably the Aswan columns that now number five in total, all lie to the east of the breakwater and either lie on top of the breakwater rubble or are associated with the shipwreck. The theory remains that the ship inadvertently hit the destroyed breakwater, which by this stage was not visible lying just below the surface of the water, and eventually wrecked to the east, depositing elements of its cargo en route.

Whilst we await the radio-carbon analysis that will hopefully confirm the date of the destruction of the breakwater, we can confirm that a large tsunami wave brought about its eventual demise. Prior to this event we can envisage ships mooring in the lee of the breakwater, in the eastern channel, also identified this season, where deeper, calmer waters could be sought out providing shelter to ships at anchor. Further anchor finds and extensive areas of ceramics on the seabed, as well as the tile wreck that were located in the deeper offshore waters that lead to the approaches to the channel, confirm this interpretation. These finds note more intense traffic in this area as ships tried, and in some cases failed, to reach sheltered waters of the anchorage in lee of the breakwater. Further investigation of these offshore finds and more extensive survey is recommended for any future surveys, perhaps with the use of marine geophysical remote sensing equipment.

Acknowledgements

The project team would like to express its gratitude to the Republic of Cyprus Department of Antiquities and the UK Sovereign Base Areas Administration and 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, Demetra Aristotelous and the staff of Kourion Museum.

SBAA officials, notably Antonis Antoniades, also provided indispensable assistance in preparing and running the expedition, an effort also relying on support from DIO 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 Snaith 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. 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.

Lastly, thanks goes to the entire team of the 2019 underwater survey, including our RAF support colleagues, for all their hard work and patience. Thank you specifically to Miltiadis, Maria and Achilleas for their help with preparation, logistics and data processing, image generation and report writing. Thanks is also extended to Brian Richards for his financial and practical support on the ground. And finally, thank you to our funders the Honor Frost Foundation for all their support.

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