Article

THE GE.N.ESIS PROJECT
Georeferenced Depiction and Synthesis of Marine Archaeological Survey Data in Greece

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Abstract

Through the GE.N.ESIS project, the Hellenic Ephorate of Underwater Antiquities (EUA) is introduced to a digital tool for visualisation and synthesis of underwater archaeological data. A marine geoarchaeological survey was conducted at the Methoni underwater archaeological site (Greece) in the summer of 2012 utilising geophysical instruments. The acquired data together with archival archaeological data was managed through a Geographical Information System (GIS). The survey results present the ruins of a submerged prehistoric settlement, the Methoni ancient harbour and submerged breakwater, wrecks, cannons and artefacts/features – all of which are of potential archaeological interest. The project outcomes provide the genesis of a new baseline capability for the cultural management of the Greek archaeological sites.

Résumé

Dans le cadre du projet GE.N.ESIS, l'éphorat grec des antiquités sous-marines (EUA) est présenté via un outil numérique de visualisation et de synthèse des données archéologiques sous-marines. Un levé géo-archéologique marin a été réalisé sur le site d'archéologie marine de Méthone (Grèce) au cours de l'été 2012 à l'aide d'instruments de géophysique. Les données acquises ainsi que les données archéologiques d'archives ont été gérées *via* un système d'information géographique (SIG). Les résultats du levé présentent les ruines d'une zone de peuplement préhistorique submergée, l'ancien port de Méthone et des brise-lames, épaves, canons et artefacts/éléments submergés – tous d'intérêt archéologique potentiel. Les résultats du projet fournissent la génèse d'une nouvelle capacité de base pour la gestion culturelle des sites archéologiques grecs.

Resumen

Gracias al Proyecto GE.N.ESIS, le ha sido presentada al "Hellenic Ephorate of Underwater Antiquities" (EUA) una herramienta digital para la visualización y la síntesis de datos arqueológicos submarinos. Un levantamiento geoarqueológico marino fue efectuado en el sitio arqueológico submarino de Methoni (Grecia) durante el verano del 2012, utilizando instrumentos geofísicos. Los datos adquiridos, junto con los datos de los archivos arqueológicos, fueron administrados a través del Sistema de Información Geográfica (SIG). Los resultados del levantamiento presentan las ruinas de un emplazamiento prehistórico sumergido, el antiguo Puerto de Methoni y el rompeolas sumergido, restos de naufragios, cañones y artefactos/objetos, todos ellos de un interés arqueológico potencial. El resultado del proyecto proporciona la génesis de una nueva capacidad de referencia para la gestión cultural de los sitios arqueológicos griegos.

INTRODUCTION

Methoni is a Greek seaside town at the south-western extremity of the Messenia Peninsula (***Fig.1***), also known as Pylia Region. There is archaeological evidence supporting that the human presence in the area which nowadays forms the Methoni Bay, dates back to the Bronze Age (Spondylis, 1996).

***Figure 1**. Pylia Region in Greece and the Methoni Bay (ESRI, 2012)*

In the historical periods that followed, the vigorous activities of the local population and the naval battles fought off Methoni were prominent themes through the literature. The harbour of Methoni was strategically significant (Biris, 2002) and this is evident from the successive improvements of the initial fortification of the ancient town which took place following the second Messenian War and the town's independence around 369 B.C. Methoni's strategic role through the centuries is evident from the repeated predatory raids/expeditions of Romans, Venetians, Turks and the French in the area from the 12^{th} to the 19^{th} century. Its importance is mainly evident through the existence of its harbour dating from the Archaic Period of Ancient Greece according to Homer's Iliad (UoA, 2012) and the successive improvement works on the harbour's breakwater (Lianos, 1987) by some of the above mentioned expeditionary forces. Although in the 18^{th} century the capacity of the harbour was enough to accommodate 7 or 8 galleys (Lianos, 1987), nowadays its breakwater is submerged lying just below the sea surface and the harbour has not been used commercially since a new breakwater was constructed in the 19^{th} century closing its entrance (***Fig. 2 and 3***).

***Figure 2**. The town of Methoni, the fortification of the ancient town, the ancient submerged breakwater and the latest breakwater which closes the entrance of the ancient harbour.*

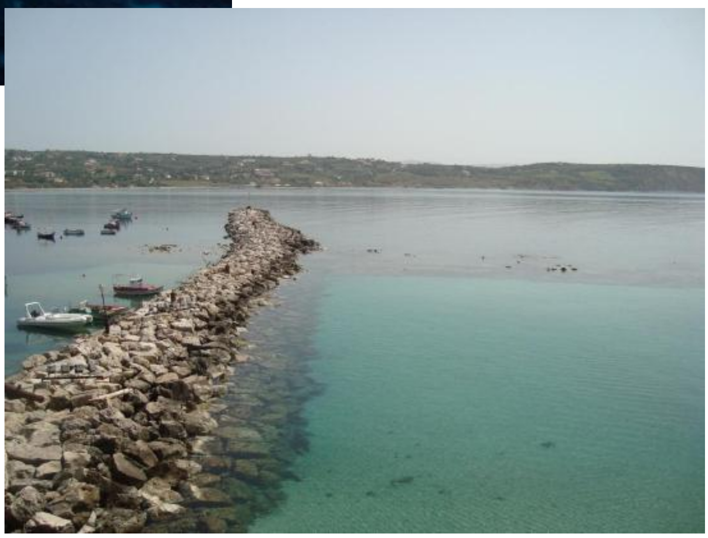


***Figure 3**. The 19^{th} century breakwater over the (nowadays submerged) ancient breakwater.*

Since 1993, the archaeological surveys and excavations undertaken by the Hellenic Ministry of Culture / Ephorate of Underwater Antiquities (EUA) confirmed the glorious historical past of Methoni, bringing to light numerous antiquities at the site. Prehistoric settlement ruins have been discovered lying on the seabed at a depth of 3.5-5m (***Fig. 4***). Together with parts of a medieval coastal stone fresh-water pipeline, they have been documented with the use of land survey methods. A number of wrecks, pottery, a prehistoric stone anchor (***Fig. 5***) and other antiquities have also been discovered in the same area revealing the maritime roots of the local population through the millennia (Spondylis, 2000).

Previous to the summer of 2012 and from pure archaeological surveys, no marine geophysical survey had ever been conducted off Methoni. All governmental survey records concerning Methoni and other underwater sites were archived in either paper form or simple electronic means in no specific format (Spondylis, 2011). Hence, the Greek government archaeologists could only make archival site investigations from distinctive sources of conventional data (maps / architectonic plans) with very few options of further data correlation spatially referenced. Further, it was difficult to analyse survey data provided by external partners in sophisticated formats, mainly because of format incompatibility with existing EUA IT suites or inefficiency in spatial correlation of existing data with the data provided.

Figure 4*. Ruins of a square building at the prehistoric submerged town of Methoni.*

Figure 5*. Prehistoric stone anchor, discovered at Methoni Bay in 2000.*

The GE.N.ESIS Project (**GE**oreferenced depictio**N** and synth**ESIS** of marine archaeological survey data in Greece) introduced the Ephorate of Underwater Antiquities (EUA) to a digital management tool for visualisation, synthesis and analysis of underwater archaeological data. Within the objectives of the project were (a) the conduct of a marine geophysical survey of the ruins of the prehistoric submerged town of Methoni, the submerged breakwater of the town's ancient harbour and potentially of other local underwater antiquities and (b) the visualisation, georeference, synthesis, analysis and management of existing archival archaeological data and survey data acquired during the survey using a GIS.

The information presented in the following sections includes a brief background of the EUA's underwater geo-archaeological surveys and site management, the methodology implemented for the survey, the survey and the project results, leading to the recorded features of potential archaeological interest and a spatial synthesis and depiction of results through a GIS. Discussed will be issues of further scientific concern which qualify and quantify the data reliability and support the interpretation of results. Finally, conclusions and recommendations for further research and project development will be addressed. Further information about the project can be found on the web at www.methoni-genesis.blogspot.com.

BACKGROUND

Underwater Archaeology and Marine Geophysical Surveys in Greece off Methoni

The EUA is the governmental agency for marine archaeology in Greece. It was founded in 1976 and together with the Hellenic Institute of Marine Archaeology are the only bodies that systematically conduct pure marine archaeological surveys in Greece. However, in the light of the particularities of underwater archaeological investigations, the need for integrated scientific collaboration during surveys was early identified and Spondylis (1996) had early addressed the need for multi-scientific research to be conducted off the southwest coasts of Greece.

Since 1976, the EUA in collaboration with other research Institutes, industrial partners and universities, has undertaken numerous surveys sponsored by the survey collaborators off the Greek coasts where remote sensing techniques and often state-of-the-art geophysical instruments were utilised. Despite ongoing discussion amongst geologists and archaeologists about the reasons that led the prehistoric town of Methoni being submerged (Spondylis, 1996), until this project, no geophysical survey had been conducted off Methoni.

GIS in Maritime Archaeology

GIS have growing applications in maritime archaeology (Green, 2004). They allow the display, synthesis and analysis of archaeological and relevant data in geographical space and in such a form that spatial and/or chronological trends of a site can be visualised (NAS, 2009). Layering of ortho-images and datasets from sonar traces or archaeological records is a typical GIS application. A fieldwork oriented GIS can be interfaced with geophysical and positioning systems, to allow survey planning, the provision of real-time positioning information during data acquisition phase and pure archaeological data recording (3H Consulting, 2012). Moreover, GIS facilitates the determination of legal aspects during surveys through the monitoring of archaeological site boundary delimitation. Most significantly, GIS can be used as a data manipulation tool for digital storage and database creation as well as a decision support tool for site and holistic cultural heritage management. The EUA has neither implemented an office-based nor a real-time data monitoring/collection GIS, so even when EUA survey partners use one for data acquisition, the post visualisation and analysis of data is inadequate or non-existent.

Legislation – Legal Issues

The Nautical Archaeology Society (2009) provides a good guide for a study on International Law concerning underwater archaeological surveys. Greek Legislation is applied according to the Greek Law No 3028/2002 (''On the Protection of Antiquities and Cultural Heritage in general'') and relevant Governmental Directives for licensing issues. The participation of the EUA in all maritime archaeological surveys off the Greek coasts and literally the direction of all surveys by the EUA are legal prerequisites. Ilias Spondylis was assigned by the EUA as the Survey Director Archaeologist.

METHODS

Preparatory Tasks

Locating resources for the project was a major factor for the best possible project outcome. Staffing the project adhered to the general rules of Green (2004). Apart from the author, the participation of Gwyn Jones (Plymouth University, MSc Hydrography programme Leader) as Project Supervisor and Konstantinia Tranaka, a professional administrator and nurse, provided enhanced expertise for handling sophisticated geophysical hardware/software and dealing with Health and Safety issues. The EUA granted the provision of the Director Archaeologist, divers and a coxswain for the survey boats.

Aris Paleokrassas contributed to the project as a marine surveyor. Financial resources were secured by the Plymouth University funding scheme and the author's personal budget.

All assets used are presented in the next sections.

A preliminary site reconnaissance took place in Methoni in early April 2012 for familiarisation with the site, to undertake coastlining and for definition of minimum depth inside the ancient harbour ensuring the safety of boat operations. Since the ancient harbour is now enclosed, a passage had to be located over the submerged breakwater crest (***Fig. 6***) so that the survey boat could enter the harbour with a safe clearance depth under its keel.

Figure 6. *Preliminary underwater reconnaissance of the harbour's breakwaters. A measuring pole was used for detection of a point of maximum depth over the submerged breakwater and the definition of minimum depth inside the ancient harbour.*

Figure 7. *Laboratory tests.*

Laboratory tests (***Fig. 7***) were conducted during early June 2012 to familiarise the operator with the survey equipment and software and to investigate methods for very-shallow-water towfish deployment. Sea trials were conducted in Plymouth Sound during June 2012. The aim was to simulate the imminent survey tasks expected at the site, so that problems related to the actual survey and its specifics could be identified at an early stage. The objectives of the sea trials were to set up the survey instruments for sea (***Fig. 8***), to test very-shallow-water deployment techniques of sidescan sonar and magnetometer towfishes (***Fig. 9, 10***) and to evaluate acquired data samples for definition of the optimum towing technique. Towing the towfishes by the stern with a float rigidly attached on top of them proved to be the optimum deployment method (***Fig. 10a***) at that stage.

Figure 8. Magnetometer setup afloat.

Figure 9. *Investigation of optimum ultra shallow water deployment technique for towfishes : Testing the attachment of a towfish on a custom-built catamaran at Plymouth Sound.*

Figure 10. Investigation of optimum ultra shallow water deployment technique for sidescan towfish.

Left (a): *A float rigidly attached to the towfish.* ***Right (b):*** *A float attached to the towfish cable*.

System checks were conducted prior to mobilisation overseas to verify good operational condition and integration of all survey instruments. The Hemisphere Crescent VS110 GPS was initially chosen for positioning. It utilises EGNOS differential corrections and according to ESSP (2012a), the expected horizontal accuracy over the Methoni site area should be in the order of 3m (95% of the time). However, during the system checks it became apparent that Open Service differential corrections were not available for prolonged periods due to Signal-In-Space (SIS) outage for both EGNOS PRNs (120, 126). The history of SIS outages highlighted a recent period of significant signal instability (ESSP, 2012b). In the light of this fact, the use of the C-Nav 2050G DGNSS was decided. After software updates for the C-Navigator I unit and firmware updates for the receiver unit, the reception of RTG (C1) corrections marked the end of system checks.

All the surveying equipment was mobilised early July 2012 across Europe by car. The project team settled in a Ministry of Culture guesthouse at the Pylos fortress 10km away from Methoni.

Reconnaissance

During the period between the team settling in and the start of the fieldwork, reconnaissance took place in Methoni ashore, underwater and afloat. Although it was conducted in a rather informal way, the team discovered a cannon (***Fig. 11a***) probably linked to a wreck which was simultaneously discovered nearby (***Fig. 12***). Another cannon had been discovered by a local resident in the same area a few days previous (***Fig. 11b***).

Figure 11. Cannons on the seabed of Methoni Bay.

Left (a): The cannon that was discovered by the team.
Right (b): The cannon that was discovered a few days before the start of fieldwork.

Fieldwork

The fieldwork took 7 days between the 11th and 27th of July 2012. Sidescan sonar, magnetometer and sub-bottom profiler were used for the survey, providing a wide range of remote sensing techniques to be implemented for the underwater investigation of the site and the potential of data correlation for artefact identification. The first phase of the fieldwork (sidescan sonar and magnetometer survey) was conducted utilising a 5.50m RHIB provided by EUA. For the second phase (seismic survey) the EUA mobilised a 6.85m RHIB from Athens to Methoni.

Four areas off Methoni (***Fig. 13***) were identified to be surveyed: (a) area ‘A’ for the visualisation of the submerged prehistoric settlement ruins and its sub-seabed profile, the estimation of its potential extent under and over the seabed and for artefact detection and identification (b) area ‘B’ for the visualisation of the submerged ancient harbour and breakwater as well as for artefact detection and identification (c) area ‘C’ due to the recent findings on the seabed (a wreck and two cannons), for artefact detection/identification both on and under the seabed and (d) area ‘D’ for artefact detection only under the seabed due to low equipment availability at the final stage of the project.

Figure 12. Cannonballs on top of the ballast load of a wreck.

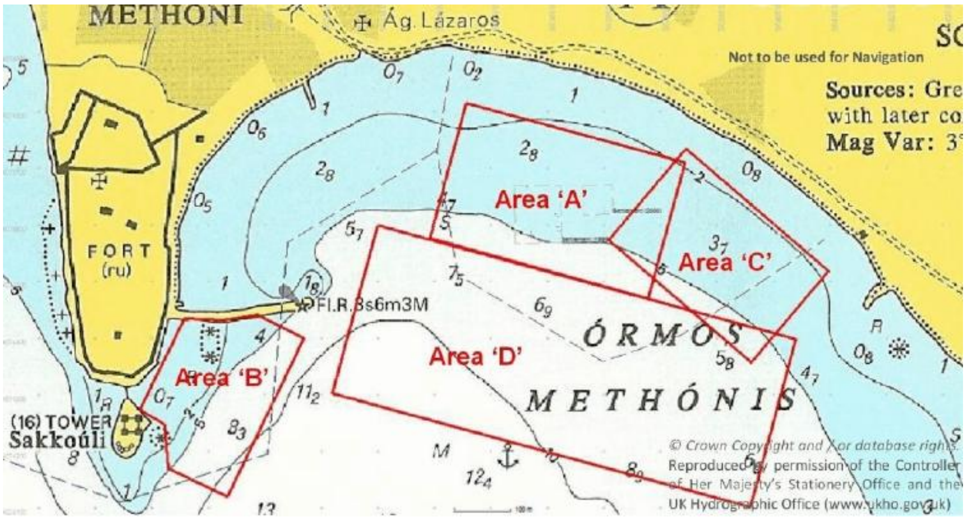


Figure 13. The four survey areas off Methoni.

For data acquisition, processing and rendering, the following geodetic parameters were used: For Horizontal control, UTM Grid/Projection (34N, 18-24E zone) and ITRF2005 Datum (ITRF2005 coordinates coincide with WGS84 coordinates at the decimetre level (ITRF, 2012)). Vertical control was not applied since no bathymetric survey was conducted and the maximum tidal range for the nearby Kalamata port is 0.58m (HNHS, 1991). The observed tidal range during the survey period never exceeded 0.15m (IOC, 2012).

For positioning information the C-Nav® Precise Point Positioning (PPP) System was chosen (sourced by Plymouth University). It is a dynamic DGNSS which provides worldwide positioning of decimetre level accuracy (C&C Technologies, 2012). Its 2050G receiver integrates a 24-channel, dual frequency GPS receiver, a 2-channel Satellite Based Augmentation System (SBAS) receiver and a C-Nav Correction Service L-Band receiver. The raw data latency is less than 20ms and the receiver outputs up to 5Hz raw measurement data in the standard configuration.

The *C-Nav world DNGSS division* of C&C Technologies, Inc. provided free worldwide access to the C1 Correction Service for the project through Plymouth Univesity, hence distribution of satellite based differential GNSS corrections with no additional equipment required (reference/base stations).

The C-Nav Correction Service has 99% availability and EGNOS Open Service corrections can also be accessed. The C-Navigator I Control and Display unit was used as a quality control tool for monitoring performance, data quality and accuracy of the receiver.

The GeoAcoustics SS941 dual frequency Sidescan Sonar Transceiver combined with the Model 159D dual channel towfish were sourced by Plymouth University and used for artefact detection and seabed feature mapping. The SS941 Transceiver operated at 410 KHz was triggered externally and the operational parameters were controlled remotely by the Coda DA1000 acquisition system. The acquisition range was 32-38m. The 159D towfish was initially deployed by the stern of the RHIB having a float attached to it, but soon a noisy data acquisition became apparent and the towfish was deployed from the bow (***Fig. 14***) resulting in improved data acquisition.

Figure 14*. The GeoAcoustics sidescan sonar towfish deployed by the bow of the survey boat.*

The Geometrics G-882 Cesium magnetometer, provided by Plymouth University, was utilised for artefact magnetic detection (***Fig. 15***). Being small and lightweight, it provided flexibility for the RHIB survey operations. The G-882 performs at an absolute accuracy of better than 3nT throughout range and its typical operating sensitivity for the actual survey sample rate (10Hz) is better than 0.002 nT P-P (Geometrics, 2012). The towfish was deployed by the RHIB stern having attached a float on top of it. During and after the magnetometer survey, all vessels anchored in the area were positioned so as their magnetic anomalies could be identified and excluded from the dataset during post-process.

For the seismic survey, the GeoAcoustics GeoPulse Pinger was provided by Akti Engineering. It is a flexible sub-bottom profiler (SBP) allowing operation as an 'over-the-side mount' system onboard small boats (***Fig. 16***). The system utilises the Model 5430A Transmitter (which controls the output power, frequency and transmit repetition rate), the Model 5210A Receiver and the over-the-side Transducer Mount Model 132B which houses a four transducers array. The SBP was operated at a 3.5 kHz central frequency and at a variable output power according to the depth and sub-seabed structure. Areas 'A', 'C' and 'D' were investigated by the SBP.

Figure 15. The Geometrics G-882 magnetometer.

Figure 16. System checks of the GeoAcoustics GeoPulse Pinger.

For magnetometer data acquisition, processing and helmsman's guidance along navigation lines, the Site Searcher software was used, provided by 3H Consulting Ltd. The HYPACK® MAX software was used for navigation planning, helmsman's guidance and recording control during the seismic survey, sourced by Akti Engineering. Geodetic transformation parameters of both systems were found to be coincident maintaining seamless datasets. For sidescan sonar data acquisition, processing and SBP data processing, the Coda DA1000 hardware and the Coda GeoSurvey software were used, both sourced by Plymouth University. The SonarWiz Map suite, sourced by Akti Engineering, was used for seismic data acquisition integrated with the HYPACK® MAX Software.

Following the geophysical survey, a precise positioning task was conducted. Two wrecks, two cannons and various artefacts were precisely positioned. For this task, a diver had to attach a float to one edge of a line and hold the other edge on top of the point to be recorded while keeping the line under tension to achieve verticality. Simultaneously, a snorkeler had to attach the C-Nav antenna on top of the float and keep it there until the position was recorded (***Fig. 17***).

Post-survey Tasks

The survey team returned to the UK either by road or air transportation. The survey instrumentation was demobilised largely by freight service provided by Teletrans SA without charge and partly by private car / road. After returning back to the UK, the **GE**o-referenced depictio**N** and synth**ESIS** (GE.N.ESIS) of marine archaeological survey data was conducted utilising the Site Recorder (SR) software sourced by 3H Consulting Ltd. SR is a GIS suite used for integration of information either recorded during an archaeological survey or post synthesised. It combines mapping, finds database, survey processing program, dive log and image management tools (3H Consulting, 2012).

Figure 17. Precise positioning of a wreck.

RESULTS

Sidescan Sonar Survey

Table 1 (see p. 25-27) presents a selection of detected small scale features of potential archaeological interest through sonograph imagery. Feature dimensions are given as horizontal by vertical length and numbering retains the originally logged values. Mosaics of acoustical seabed imagery of survey areas and imagery of large scale features are presented through the synthesis of archaeological data in the following paragraph. The sidescan sonar data post-process procedure included manual sea-bed tracking corrections, navigation editing, and Time Variable Gain adjustments.

Magnetometer Survey

Following the 1st-stage magnetometer data post-processing (normalisation and filtering), magnetic anomaly plots were mapped using the GIS. ***Fig. 18*** and ***19*** present the magnetic anomaly plots in the vicinity of the submerged settlement (area 'A') and the ancient harbour (area 'B') on a different basemap. Strongest anomalies are referred to deeper red and green data samples/points.

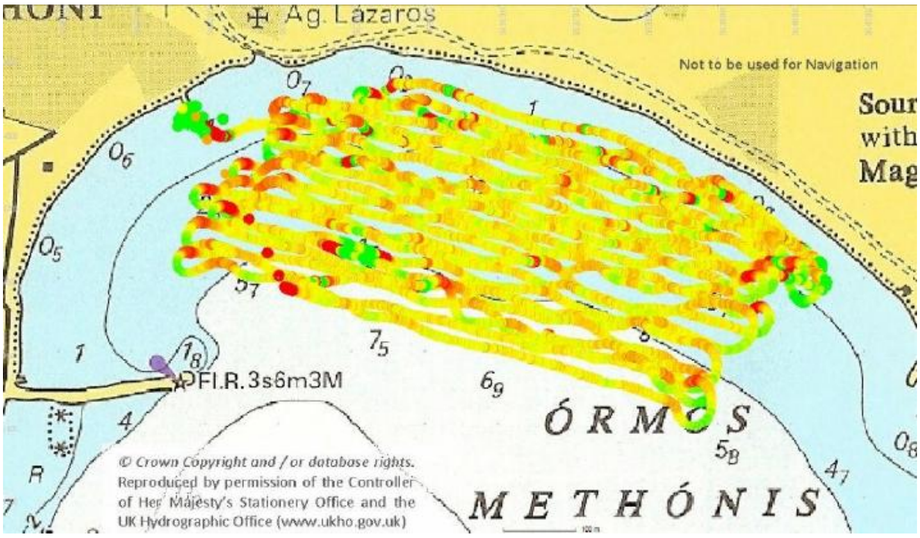


Figure 18. Magnetic plot of area 'A' after 1st stage data post-process (SR screen dump).

Figure 19. An introduction to data synthesis: Magnetic plot of area 'B' (the ancient harbour and the submerged breakwater) on a Google Earth basemap (SR screen dump).

Table1. Selection of detected small scale sidescan sonar features.

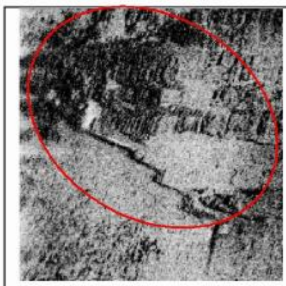
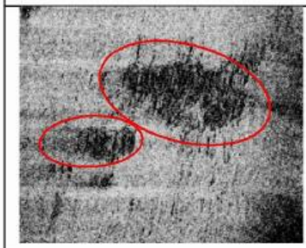
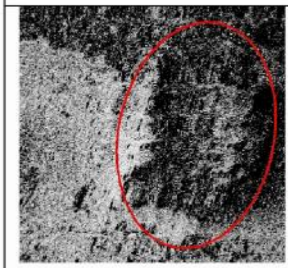
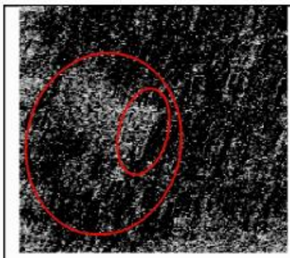
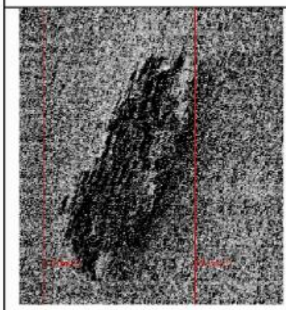
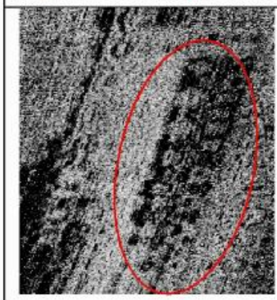
	Name: SSS.1 Description: Wreck Dimensions: 30x7m Comments: (a) Seabed scours are readily apparent along its keel (b) Associated with magnetic anomaly and SBP.21 feature (c) Precisely Positioned by DGNSS
	Name: SSS.2 Description: Large and small ellipsoid scattered features Dimensions: 13x6m and 5x2.5m Comments: (a) Associated with magnetic anomaly (b) Possibly wreck
	Name: SSS.6 Description: Rectangular settlement ruins Dimensions: 10x14m Comments: (a) Settlement ruins not previously recorded (b) Heaving effect is readily apparent
	Name: SSS.7 Description: Asymmetric features Dimensions: 3.5m (the linear sub-feature in the small red ellipsis) Comments: Settlement ruins scattered
	Name: SSS.14 Description: Ellipsoid scattered material Dimensions: 7x14m Comments: N/C
	Name: SSS.15 Description: Symmetrical semi-buried feature Dimensions: 7x13m Comments: (a) Possibly semi-buried wreck

Table1. Selection of detected small scale sidescan sonar features.

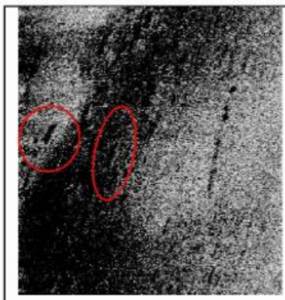
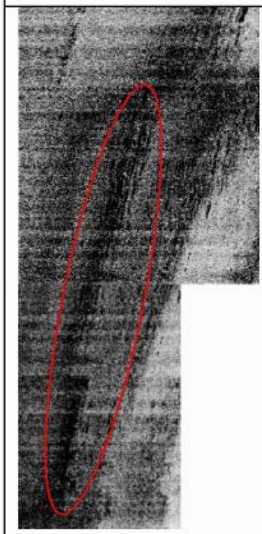
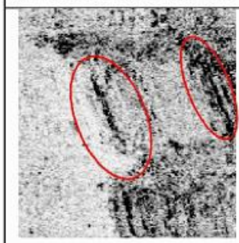
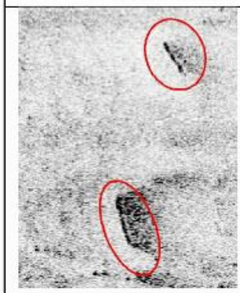
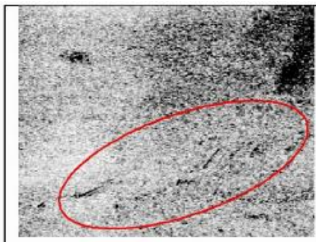
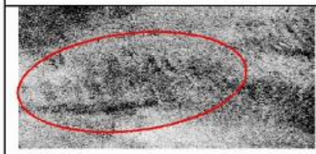
	Name: SSS.19, 20 Description: Two cannons Dimensions: 1.7m (inside the red circle), 2m (inside the red ellipsis) Comments: (a) Both precisely positioned (b) The large scale backscatter coincides with wreck debris
	Name: SSS.23 Description: Scattered debris of a wreck and ballast stones including cannonballs Dimensions: The ballast stones 9m, while the total extend of the wreck is 10x20m Comments: Wreck and artefacts were all precisely positioned
	Name: SSS.30 Description: Symmetrical semi-buried feature Dimensions: 11m Comments: (a) Possibly semi-buried wreck (b) A scour along a linear feature (possibly the keel) is visible
	Name: SSS.31 Description: Linear settlement ruins (walls) Dimensions: 6m each Comments: Not recorded in the past
	Name: SSS.33 Description: Two linear features Dimensions: Top one 1m, bottom one 4.5m Comments: (a) In close proximity to the cannons (b) Not identified

Table1*.* Selection of detected small scale sidescan sonar features *(continuation).*

	Name: SSS.34 Description: Linear artefacts Dimensions: 1m each Comments: (a) Metallic artefacts associated with a wreck and the cannons (b) Precisely positioned (c) Associated with magnetic anomalies
	Name: SSS.39 Description: Semi-buried symmetrical feature Dimensions: 20m Comments: (a) Associated with magnetic anomaly (b) Possibly semi-buried wreck

During the 2nd-stage data post-processing, the magnetic profiles of survey areas were created after further normalisation of data by filtering excessive yaw effect, instrument noise and turning points (***Fig. 20, 21***). Subsequently, wherever necessary, magnetic anomaly maps of the above mentioned areas were created following a 3rd-stage data post-process, namely parasite/contamination removal (***Fig. 22***). In the following maps, all magnetic anomaly map projections are perspective and Grid North coincides with y (Northings) axis. The Kriging data interpolation method was used for the magnetic model creation.

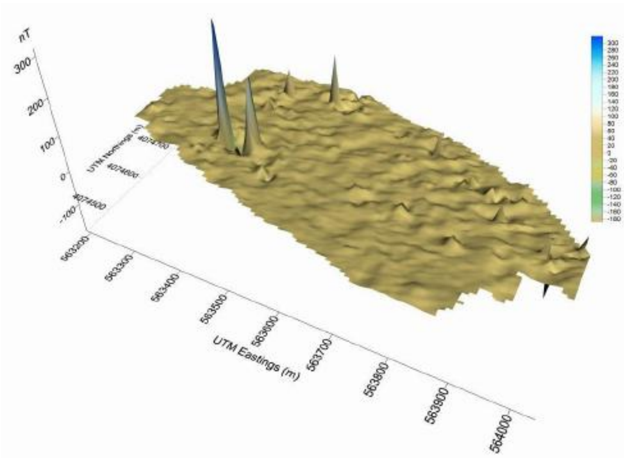


Figure 21*. Magnetic profile of survey area 'A' after 2nd-stage data process. The two large spikes correspond to anomalies caused by the keels of sailing vessels at anchor.*

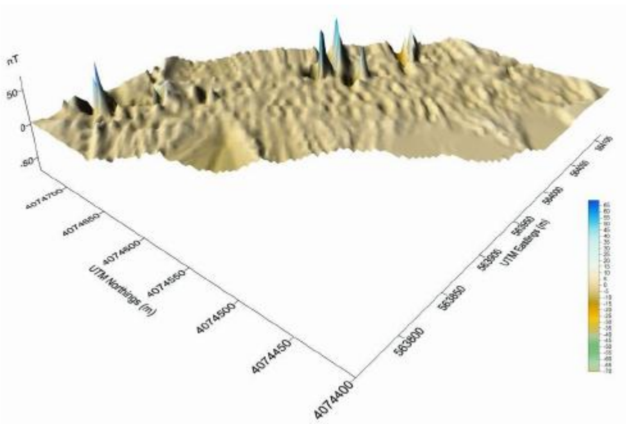


Figure 20*. Magnetic profile of survey area 'C' after 2nd-stage data process. The large spikes at the northeast extremity of the area were caused by cannons, wreck artefacts and unknown features. Unknown features also caused the spikes at the north-west extremity of the area.*

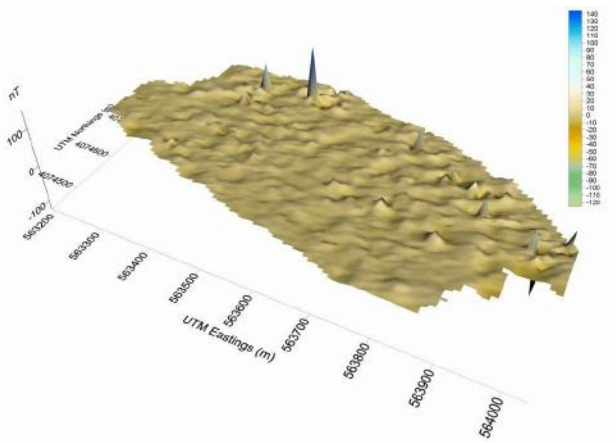


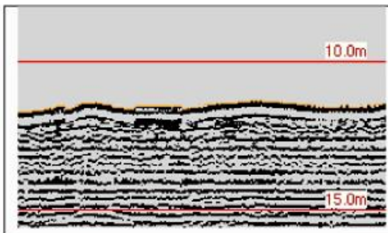
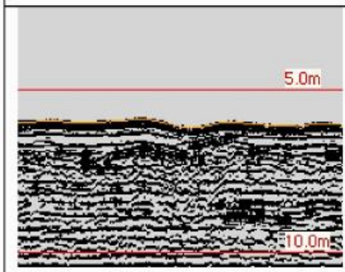
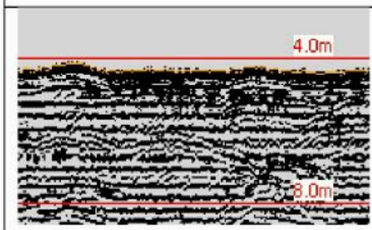
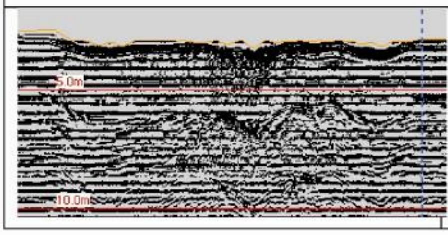
Figure 22*. Magnetic profile of survey area 'A' after 3rd-stage data process. Among others, the two spikes caused by vessels at anchor are filtered.*

Seismic Survey

In this section, selected subsea-bed features detected during the survey and deemed to be of potential archaeological interest, are presented. For the SBP data post process, sub-bottom sections around potential targets were created after sea-bed tracking and applying a separate set of 3-zone (water column zone, seabed zone and sub-seabed zone) time varying frequency filters to the data for each section.

In the following list of SBP features (***Table 2***), extended profiling sections were not possible to be attached. All sections run from West (left) to East (right) and depth values are below sea surface.

Table 2. Selection of detected small scale SBP features.

	Feature: SBP.02 Acoustic / feature description: Buried reflector Dimensions: 2m length Depth: 12m absolute, 0.3m below seabed Comments: N/C
	Feature: SBP.07 Acoustic / feature description: Partly buried wooden wreck Dimensions: 2.2m length Depth: 6.3m absolute, 0.5m below seabed Comments:(a)Associated with SBP.21, SSS.1 features (b) Associated with magnetic anomaly (c) Precisely positioned
Feature: SBP.11 Acoustic / feature description: Strong reflectors on and under seabed – Settlement ruins Dimensions: 139m overall Depth: 6m absolute, 0-0.5m below seabed Comments: (a) Associated with sidescan features and magnetic anomalies. (b) Relevant geological background doesn't exist	
	Feature: SBP.13 Acoustic / feature description: Surface and sub-surface reflector Dimensions: 4.3m Depth: 4.4m absolute, 0-0.5m below seabed Comments: Associated with magnetic anomaly
Feature: SBP.14 Acoustic / feature description: Strong and extended surface and sub-surface reflectors – Settlement ruins Dimensions: 51m overall Depth: 4m absolute, 0-1m below seabed Comments: Extension to the already known settlement ruins	
	Feature: SBP.22 Acoustic / feature description: Wreck Dimensions: 9.6m Depth: 3m absolute, 0-1.5m below seabed Comments: (a) Associated with magnetic anomaly (b) Precisely positioned

Synthesis of Marine Archaeological Data

In this section, selected data elements of the synthesised digital GIS project are presented, highlighting the potential of findings' evaluation through data synthesis. The following project elements/datasets where synthesised through the GIS as geographical information layers: Navigational charts, aerial orthophotos, coastline boundary (sourced from the Hellenic Navy Hydrographic Service), Google Earth imagery, archaeological site and survey area boundaries, survey lines, sidescan sonar mosaics, magnetometer data, precise positioning information, architectonic plans, position of anchored vessels during the survey and detected sidescan sonar and SBP features. ***Fig. 23*** depicts the synthesis of post-processed magnetometer data in the area 'C' and positioning information of a wreck and two cannons (derived during the precise positioning task). ***Fig. 24*** shows the synthesis of post-processed magnetometer and sidescan sonar data in the same area. The two cannons are visible, as well as the extent of the wreck and the strong backscatter from the cannonballs. ***Fig. 25*** depicts the same findings, post-processed magnetometer data superimposed on a marine chart basemap, a SBP survey line and the sub-seabed profile of the wreck along the line.

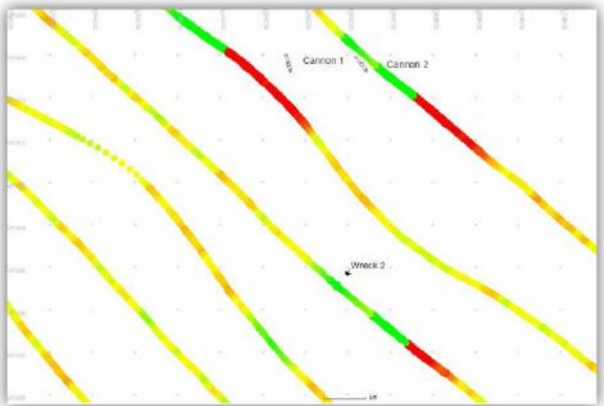


Figure 23. *Synthesis of post-processed magnetometer data and positioning data of two cannons and a wreck.*

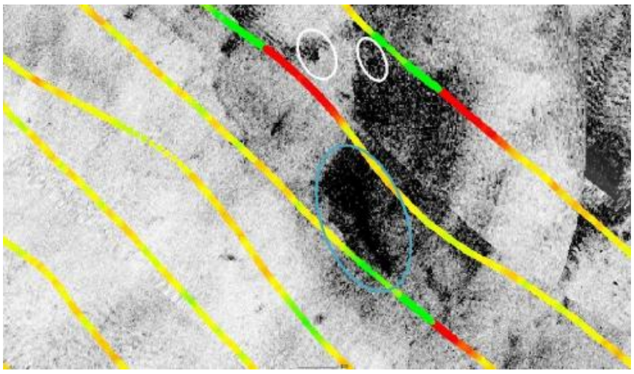


Figure 24. *Synthesis of post-processed magnetometer and sidescan sonar data. The blue ellipsis includes a wreck and the two white ones two cannons within area 'C'. Strong backscatter within the blue ellipsis is caused by cannonballs.*

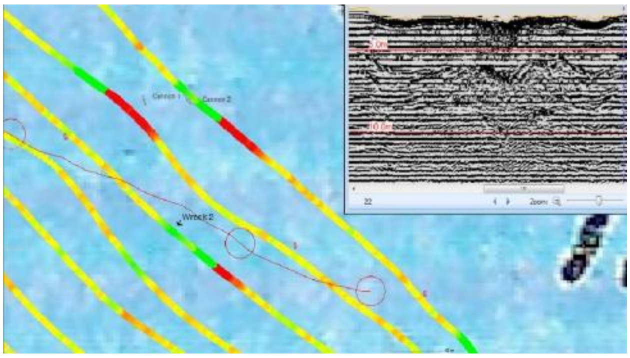


Figure 25. *Synthesis of precise positioning data (cannons and wreck) in the Area 'C', SBP and magnetometer data (survey line and wreck profile) superimposed on a chart.*

Fig. 26 presents the synthesis of sidescan sonar data of the ancient harbour and the submerged breakwater, archaeological site delimitation data (site boundaries) and coastline information. Clearly defined are the extent of the submerged breakwater and the shape of the harbour entrance of which nowadays is closed. Sand depositions are visible all over the harbour seabed. The west breakwater rocky slope is steep and its shape seems to be well preserved, while the east rocky slope is gentle and its stones are showing marks of inconsistency. Interesting geological and habitat features are evident east of the submerged breakwater where hard sediments and sea grass exist. ***Fig. 27*** and ***28*** refer to the same area (in the vicinity of the submerged prehistoric settlement) and highlight the potential of data correlation through the synthesis of data from existing architectonic plans, magnetometer data, precise positioning data of a wooden wreck, SBP survey lines and sidescan sonar mosaic. Magnetic anomalies are evident over the wreck and the settlement ruins. Clearly defined is the extent of the north block of settlement ruins while the ruins of the south blocks are rather spread over the area to an extent greater than what is recorded till now. In the sidescan mosaic, a wreck is readily apparent as well as a number of small scale features.

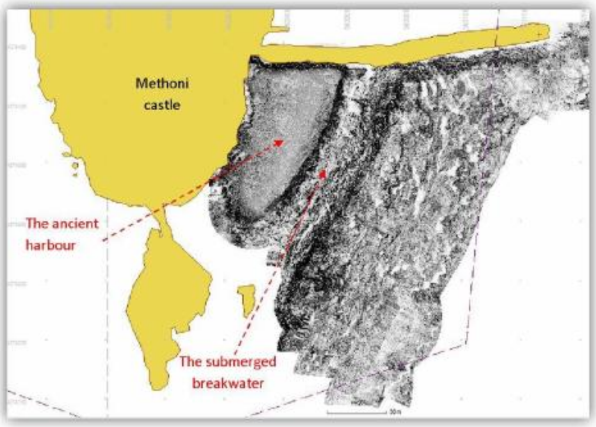


Figure 26. Synthesis of sidescan sonar data (mosaic of the ancient harbour and the submerged breakwater), archaeological site delimitation data (the violet dashes form part of the site boundaries) and coastline information.

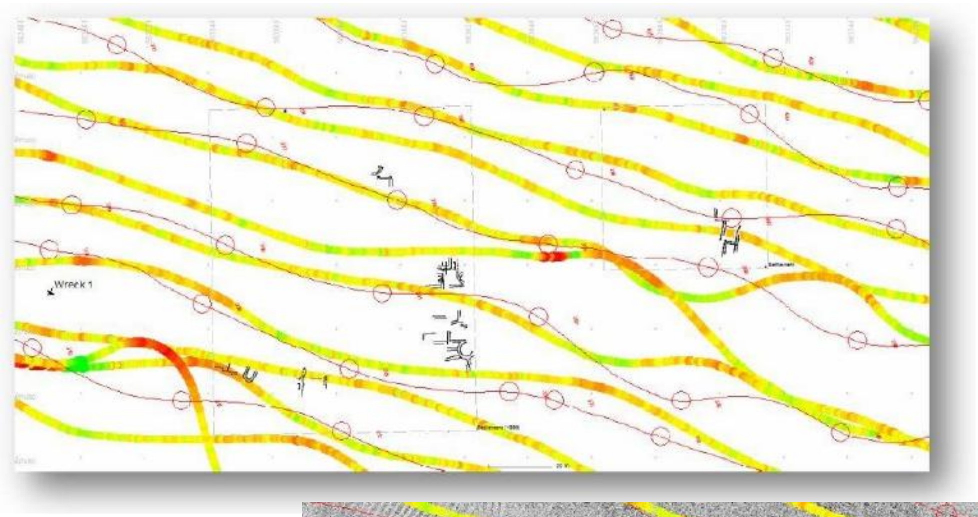


Figure 27. Synthesis of data in the vicinity of the settlement ruins from existing architectonic plans, magnetometer data, precise positioning data (wreck 1) and SBP survey lines. The potential of data correlation is clear.

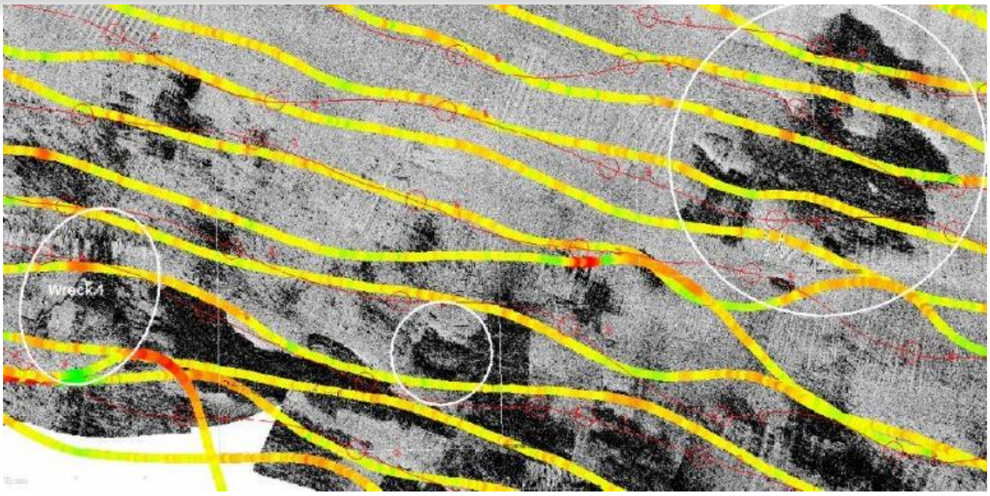


Figure 28. Synthesis of data in the vicinity of the settlement ruins from existing architectonic plans, magnetometer data, precise positioning data (wreck 1), SBP survey lines and sidescan sonar mosaic. Large scale features are evident (wreck 1 in the white ellipsis and settlement ruins in the white circles).

DISCUSSION

The archaeological site of Methoni lies in the shallow waters of the homonymous bay and is exposed to heavy waves of almost all directions due to wave diffraction. Consequently, the wave energy along the coasts is high. The wave energy turbidity combined with the littoral drift action causes sediment transport and deposition towards the north-west part of the bay, as well as erosion of the east coast and the shallow patches of seafloor. The revelation of the two cannons and even the stones on top of one of them (Fig. 11) are indicative of the seabed erosion. Indicative of the sand transport along the surf zone and the consequent covering and uncovering of the settlement ruins is the fact that the same blocks of ruins, depicted at different data acquisition periods, do not spatially match. This offset cannot be explained solely by limitations of the survey system positional accuracy.

The positional accuracy of the integrated sidescan sonar system is considered at a 1.5m level. Although the daily checked decimetre accuracy of the C-Nav DGNSS, in situ measurements (running survey lines in opposite directions over a distinctive feature) highlighted a 1.5m horizontal accuracy. The accuracy degradation was caused by yaw/pitch/roll effects of the towfish not being adequately filtered by the navigation smoothing algorithm of the processing software together with the variation in the apparent bearing of targets. This variation was caused by fluctuation of water temperature due to water column patches of inhomogeneties (sand) that provoked fluctuation of transmitted sound amplitude and phase (Urick, 1983). To verify the system positional accuracy, observed positions of features during the sidescan survey were checked against their derived positions from precise positioning. The horizontal accuracy close to the breakwater slope is considered further degraded due to ranging distortion (Russell-Cargill, 1982). The positional accuracy of the integrated magnetometer system is considered at a 3.5m level, estimated through in situ measurements (running survey lines in opposite directions over a distinctive ferrous feature). Towfish layback issues are believed to have largely contributed to the stated accuracy due to boat yawing and engine shut-offs. To verify the horizontal accuracy, observed positions of features during the magnetometer survey were checked against the derived positions from precise positioning.

The horizontal accuracy of SBP integrated system within the archaeological site is considered at a 1m level due to roll/pitch motion of the survey boat.

During the first day of fieldwork, the shallow waters of Methoni Bay proved to be noisier than those of Plymouth Sound. Hence, a by-the-bow deployment of the sidescan towfish was tested and applied. Although this alteration decreased the sidescan sonar susceptibility to noise, the excessive pitch motion of the boat caused heaving effects to be evident throughout the sidescan sonar dataset and especially across the area 'C'. These effects are readily apparent especially through the raw sidescan sonar dataset and deteriorated the depiction of small scale features creating an apparent topography through replication of previous and next swath lines (Russell-Cargill, 1982). However, the main consideration during the sidescan sonar survey was acoustic interferences. These were apparent in three forms, namely transducer channel interference (***Fig. 29***), where occasionally a mirror image in sidescan sonar channels is evident, multipath reflection interference (***Fig. 30***), where multiple acoustic signal reflections from the seabed and the sea surface resulted in depiction of non-existing artefacts close to existing ones, and finally noise. The latter is mostly evident in the area 'C'. Through the literature (Blondel, 2009), noise is explained by the dense particle suspension in the water column, air bubbles in the surf zone, interference fringes, sea temperature inversion and speckle. ***Fig. 31*** is an example of problematic data due to a combination of interference effects namely multi-path reflection interference (false targets), air bubbles in the surf zone (parasite backscatter close to the transducer) and speckle or temperature inversion (shoal like patches in the data). Since part of the area 'C' together with all other survey areas were surveyed the previous days or the same day without such problems but using lower sonar range, it is believed that reasons for these effects were the sea conditions and the relatively increased sonar range that was used for achieving a good data coverage in area 'C'. These effects were dealt with through wide stencilling and gain histogram manipulation / TVG equalisation during sidescan data post-process.

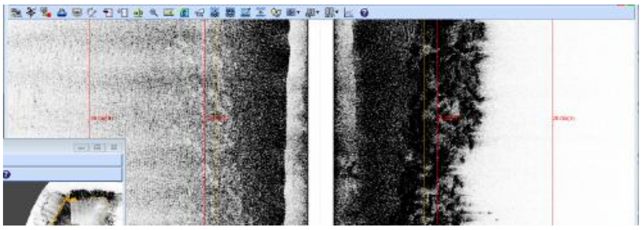


Figure 29. Sidescan sonar transducer channel interference effect. A mirror image of the ancient breakwater from the starboard to the port channel is clear (Coda screen dump).

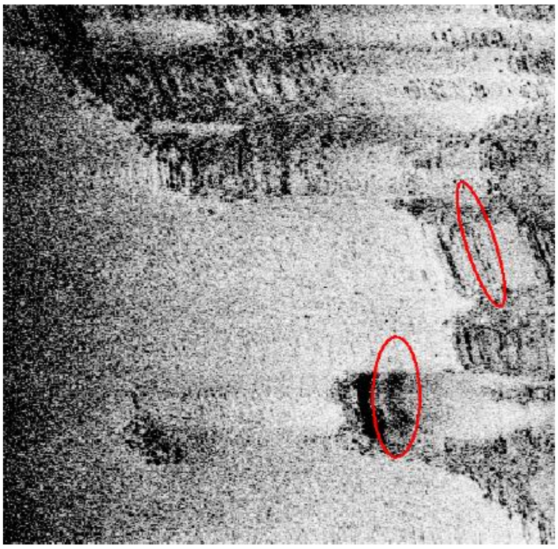


Figure 30. False sidescan sonar artefacts due to multipath reflection effect.

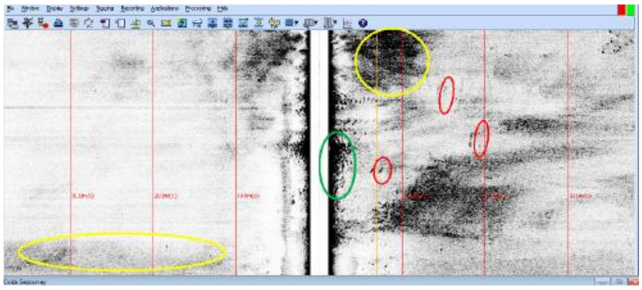


Figure 31. Coda screen dump showing problematic sidescan sonar data due to multipath reflection interference (false targets in red circles), air bubbles in water column (parasite backscatter close to the transducer in the green circle) and speckle or temperature inversion (shoal like patches in the data where they do not really exist, in the yellow circles).

The magnetometer was also affected by the shallow water environment. The seafloor contamination, the regional influences from anchored vessels and the movement of the sensor due to turbulence / boat wake (Green, 2004) led to the collection of a noisy dataset. However, after a 3-stage data post-process, potential targets are distinctive. The GeoPulse SBP, when operated in water depth less than 3m, definitely reached its operational limitations. The SBP recordings were found to be readable up to a minimum water depth of 3m and the maximum seabed penetration was about 15m depending on Power and Recording Length settings. The seabed and sub-seabed investigation, on the base of the geological background, confirms the existence of the submerged prehistoric settlement and highlights its wider extent. The walls of the settlement as recorded through the sidescan dataset, compared with their depiction through the existing architectonic plans, seem to be widely scattered due to the wave/ longshore drift energy or human activities.

Fig. 32 shows the scouring effects of sea current energy around the ruins which degrade their physical support. ***Fig. 33*** shows not only the presence of anchored vessels inside the officially declared archaeological site but especially on top of a wooden wreck.

CONCLUSIONS

The Hellenic Ephorate of Underwater Antiquities (EUA) now has a digital tool for the sustainable management of the Methoni underwater archaeological site, through the visualisation of synthesised geo-archaeological information. Moreover, the Ephorate has a full report of features of potential archaeological interest within the site. Apart from small-scale artefacts, highlighted are the submerged breakwater of the ancient harbour and the ruins of the submerged prehistoric settlement of Methoni. According to the project results, the settlement ruins are severely scattered due to environmental and possibly anthropogenic factors and many of the already known settlement walls are buried while new ones are revealed due to sediment transport. The EUA may evaluate the project results and implement the proposed management suite on the Methoni underwater archaeological site and even on all of the Greek underwater archaeological sites, setting the basis for a holistic management of the underwater cultural wealth. Furthermore, the suite can be mobilised onboard the survey boats so as to provide the EUA staff, information about the spatial distribution of underwater antiquities on the seabed, thus reducing the time spent on a site underwater. Additionally, the suite facilitates the determination of legal aspects during archaeological surveys providing site boundary monitoring.

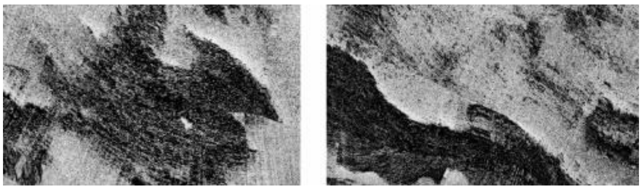


Figure 32. Sidescan sonar mosaic of settlement ruins showing halos around the ruins and close to the coast.

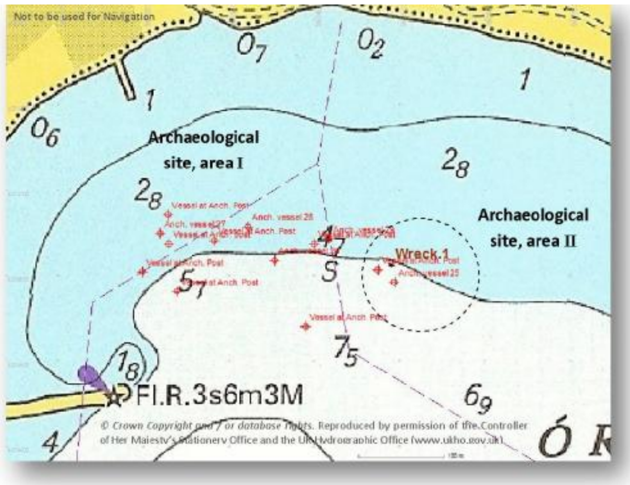


Figure 33. SR screen capture showing the presence of anchored vessels (red crosses) inside the officially declared archaeological site (bounded by the coast and the violet lines) and especially on top of a wreck (black dashed circle) during the survey.

The GE.N.ESIS project, as a new start for Greek maritime archaeology, has the potential for further development. A thorough study and correlation of the numerous recorded features/artefacts in the Methoni Bay may provide the EUA with a priority list of features to be further investigated for years to come. This study will have even better results if further data post-processing is conducted. For the sidescan sonar dataset, further filtering, gain histogram equalisation, reflection removal and additional process applications can improve information about a target's 3D dimensions and its potential of being artefacts. The theoretical investigation of recorded profiles / time series of magnetic anomalies and the removal of magnetic regional variations may improve information about a target's depth, size, weight and description. A further insight to the sub-bottom sections can provide a clearer estimation and even a map of the settlement extent and evidence for the geological evolution that caused the settlement submersion. A combined study of the above mentioned datasets will boost the archaeological knowledge of the Methoni site.

At a more technical level, the investigation of optimum towfish deployment techniques according to various dominating factors, as well as the investigation of interference factors and optimum sonar parameterisation in the ultra-shallow water environment may provide useful results for future surveys. A further multibeam echo-sounder and a high-resolution sidescan sonar survey of the site would provide the EUA with 3D and updated bathymetric information as well as updated seabed imagery which would facilitate the monitoring of natural processes / erosion patterns. This would enhance the estimation of the site evolution and the promotion of an efficient site preservation management. It is recommended that the Hellenic Ministry of Environment, Energy and Climate Change, together with the Hellenic Navy and the EUA, implement a Delimitation Scheme for Marine Archaeological Sites for the protection of underwater antiquities off the Greek coasts. Information about the archaeological site boundaries and any navigational restrictions can be released through the nautical charts. Finally, the EUA is recommended to publish a Governmental

Directive providing data submission guidelines for Project Managers conducting externally commissioned projects involving GIS, so that data submitted to the EUA can be beneficial for the evolved GE.N.ESIS project.

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BIOGRAPHY

Panagiotis Gkionis has been working for the Hellenic Navy for 18 years. Following training at the Hellenic Naval Academy, he embarked on his seagoing career as a Deputy Navigating Officer in 1998. For the next 14 years he found himself within a wide range of warfare appointments onboard Hellenic frigates and gunboats, qualifying as a Navigating Officer and Operational Training Officer. He took up his current appointment as an Assistant Head of the Research and Planning Department onboard the Hellenic Navy Hydrographic Service, following the completion of an 'MSc Hydrography' programme in 2012. *(tragion@gmail.com)*

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