UNIVERSITY OF PATRAS	**MARINE REMOTE SENSING SURVEY IN SAIDA, LEBANON** SURVEY PERIOD OCTOBER 2017	SUPPORTING MARITIME ARCHAEOLOGY IN THE EASTERN MEDITERRANEAN HONOR FROST FOUNDATION

MARINE REMOTE SENSING SURVEY IN SAIDA, LEBANON

SURVEY PERIOD: OCTOBER 2017

FIELD WORK REPORT

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1. INTRODUCTION

This report describes the field work of a marine remote sensing survey, which was carried out at the coastal zone of Saida, in Lebanon.

The survey was planned and carried out between 1st and 20th of October 2017, by the Laboratory of Marine Geology and Physical Oceanography of the University of Patras Greece under the directorship of Dr. Claude Doumet-Serhal and Dr. Eric Gottwalles.

The Saida marine remote sensing survey is an ongoing research project aiming to evaluate the evolution of the coastline configuration at the region of Saida over the last glacial-interglacial cycle and to detect and map potential targets of archaeological interest. For the accomplishment of the above aims the remote sensing survey acquired detailed echo-sounding data for the mapping and reconstruction of the seafloor topography, profiling data for the definition of the sub-bottom seismic stratigraphy and the detection of potential archaeological buried targets and scan sonar data for the mapping and reconstruction of the seafloor morphology and detection of potential archaeological targets lying on the seafloor. Furthermore, the surveying included visual inspection of specific sites of the seafloor considered as promising targets of archaeological interest and for ground trothing of side scan sonar imagery.

2. SURVEY DESIGN

The remote sensing survey of Saida was organized and conducted into three distinct phases. This methodological scheme has been proved effective in the underwater surveying of large areas of archaeological interest and includes:

- **PHASE A'**: The first phase corresponds to the surveying and mapping of the seafloor using multi beam, side scan sonar and sub-bottom profiler systems.
- **PHASE B'**: The second phase includes the preliminary processing of the acquired data sets. The purpose of this phase was to evaluate the most interesting areas ("hot spot" areas) and to detect and locate potential targets for further investigation. During the field work the first and second phases were almost time-parallel thus gaining essential time for the surveying.
- **PHASE C'**: During the third phase visual inspection conducted on specific sites on the seafloor obtained from the results of the 2nd phase. An underwater towing camera hovered over selected locations and the targets were identified on the video camera.

3. PHASE A': MARINE REMOTE SENSING SURVEY

The field work employed (i) a multi-beam interferometric echosounder ITER and an single beam echo-sounder for the acquisition of bathymetric data sets, (ii) a side scan sonar for the examination of the seafloor texture and the detection of possible targets of archaeological importance and (iii) a sub-bottom profiler for the determination of the seafloor stratigraphy and the detection of possible buried targets of archaeological importance.

The survey was conducted on board the vessel "Adonis" which was modified to meet the specifications of the remote sensing survey (Fig. 3.1). The positioning and navigation conducted with a Hemisphere VS101 GPS system capable of accuracy of approximately 0.2 m. All instruments were connected to the navigation and positioning system enabling the georeferencing of all the acquired datasets.

During the surveying all the instruments were operating simultaneously. The speed of the vessel during the acquisition of the data sets was around 3knots, providing high acoustic sampling. The marine geophysical data sets acquired from a dense grid of 219 track lines (Fig. 3.2). The track lines were parallel and perpendicular to the present shoreline. The distance between the tracklines was approximately 100m, except of the area of the Zireh Island. There the grid was denser and the distance between the track lines was 20 to 50m (Fig. 3.3).

Fig. 3.1. *The vessel "Adonis" which was used for the survey equipped with (a) the subbottom profiler (over-the-side), (b) the interferometric multibeam echosounder and (c) the side scan sonar system.*

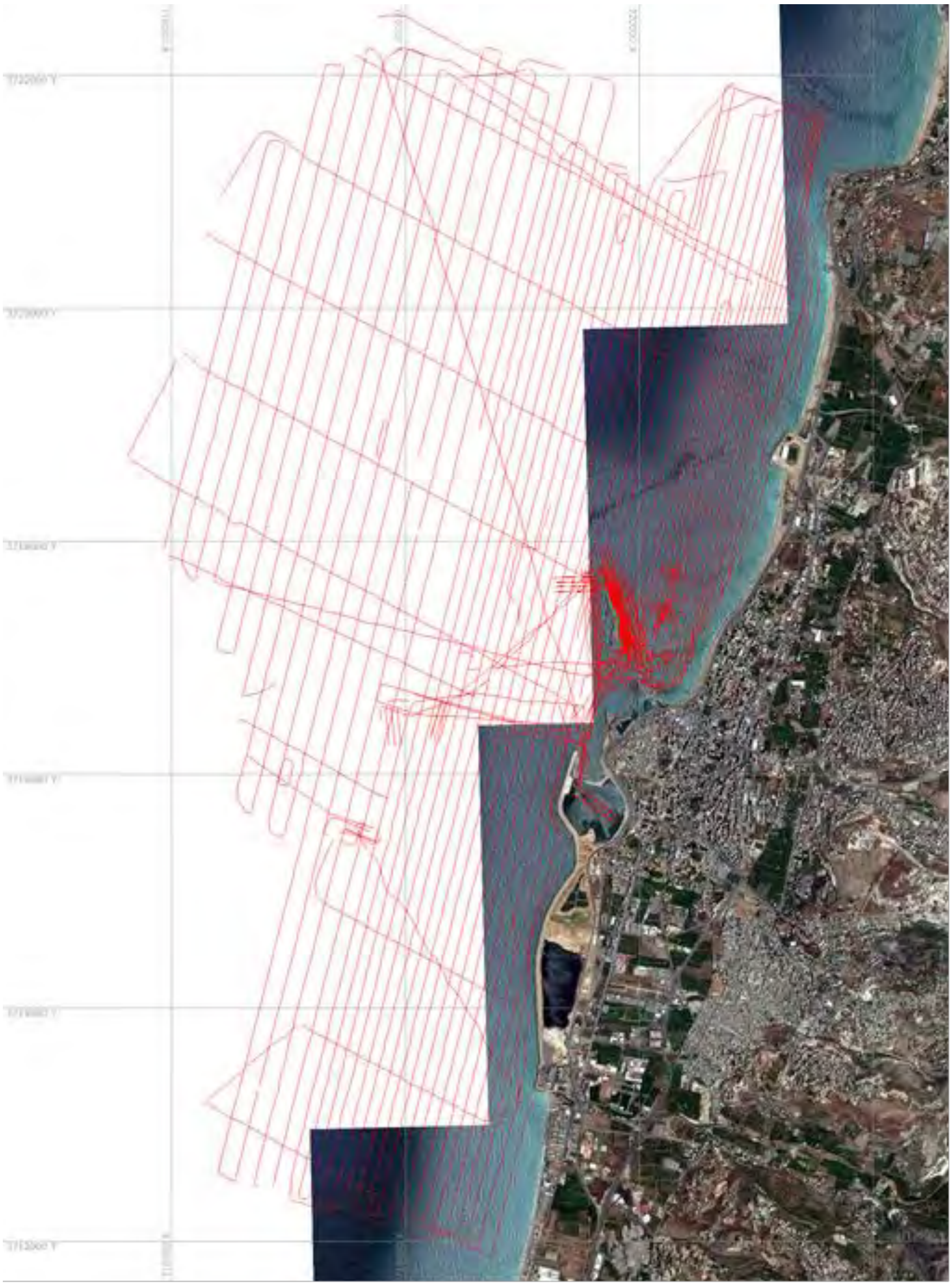

Fig.3.2. *Map of the survey area showing the ITER Systems BathySwath1 interferometric multi beam echosounder, Chirp subbottom profiler and SideScan Sonar survey tracklines.*

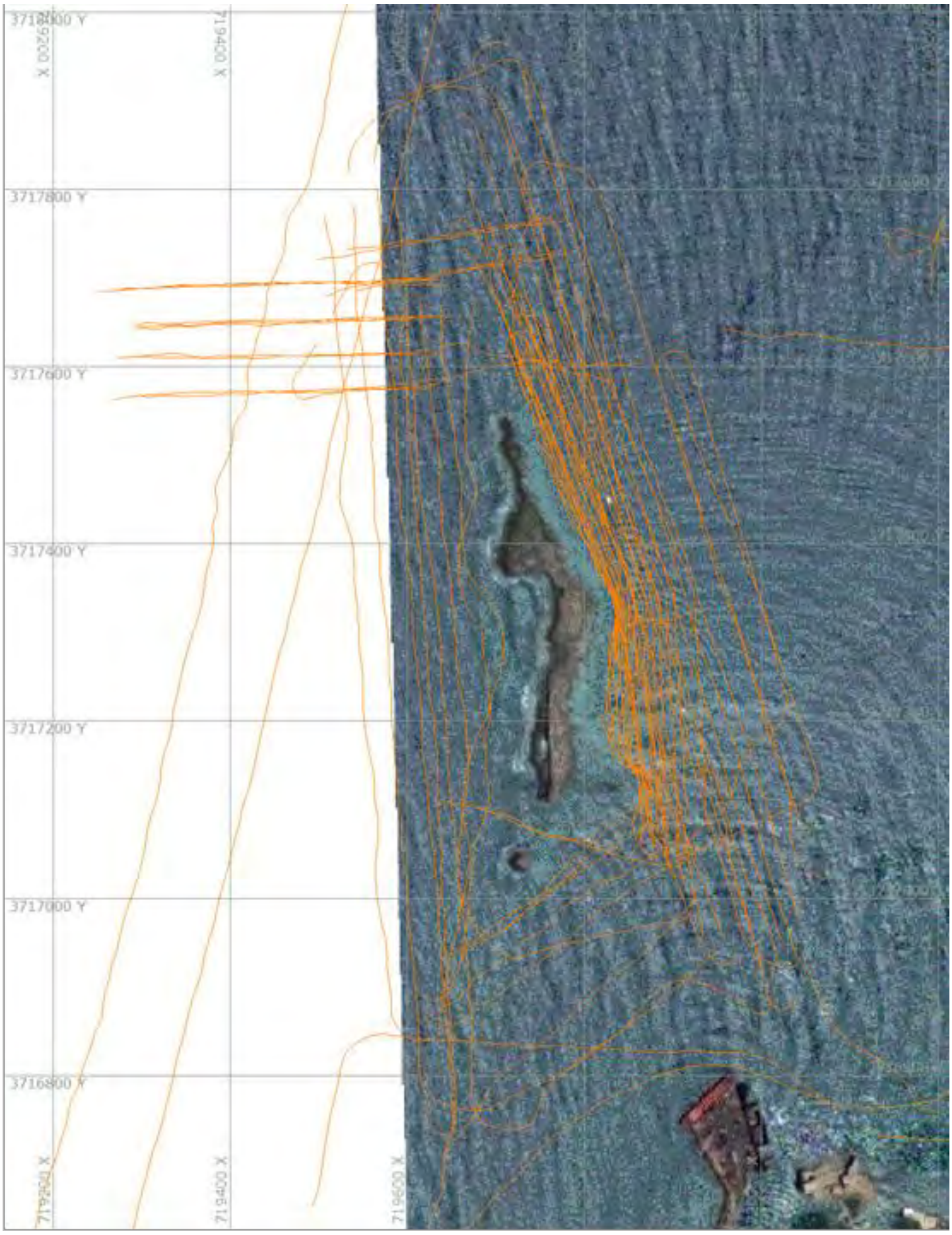

Fig. 3.3 *Map depicting the tracklines conducted around Zireh island*

3.1. Subbottom profiling survey

The sub-bottom profiling survey utilized a Chirp type Geopulse profiler. This profiler system emits a combination of medium to high frequency acoustic pulse in the form of acoustic conical beams providing a geological profile of the sub-bottom beneath the path over which the system is towed. The Chirp type profiler produces seismic data of shallow penetration but of high resolution.

The Chirp system operated during the survey consisted of:

- An O.R.E. Model 138C over-the-side Transducer Mounting (Fig. 3.1.1).
- Waterproof digital profiler electronics bottle (Fig.3.1.1).
- GEOPULSE model 5430P digital recording station for the collection and processing of the seismic profiles (Fig.3.1.2).

For the acquisition of the profiling data the SonarWiz 5 software was used.

During the survey the profiler acquired 219 lines of seismic reflection profiles having a total length of 503 km (Fig.3.2, 3.3). The profiling conducted with a Time Base (T.B.) of 0.10 sec and a 0.1-msec pulse providing a vertical resolution better than 0.3 m.

During the surveying the capacities of this system proved effective in the detection and mapping of the seafloor stratigraphy, the evaluation of the sedimentary deposits and the recording of underwater markers of palaeoshorelines and buried potential archaeological sites.

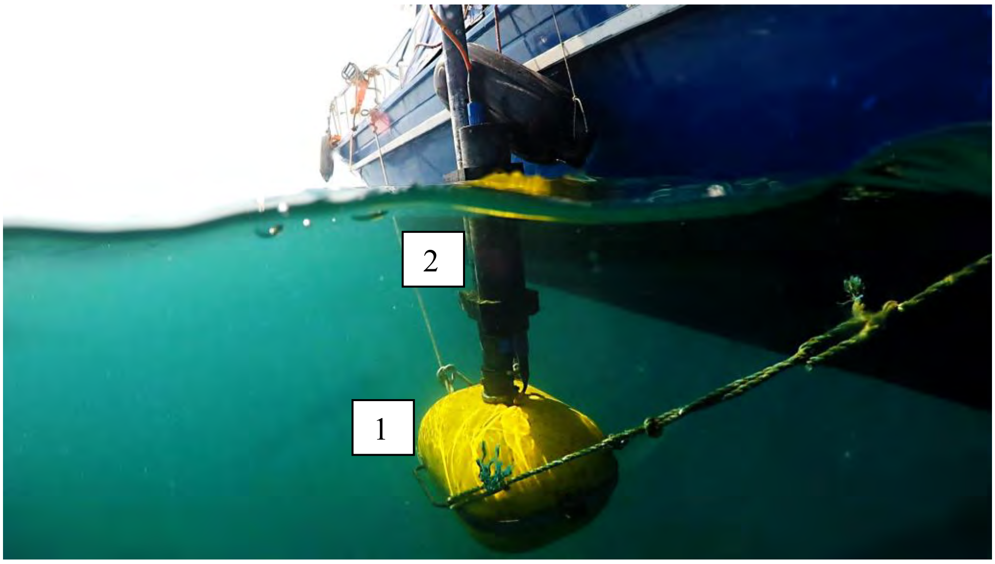

Fig.3.1.1. *O.R.E. Model 138C over-the-side Transducer Mounting (1) and waterproof digital profiler electronics bottle (2).*

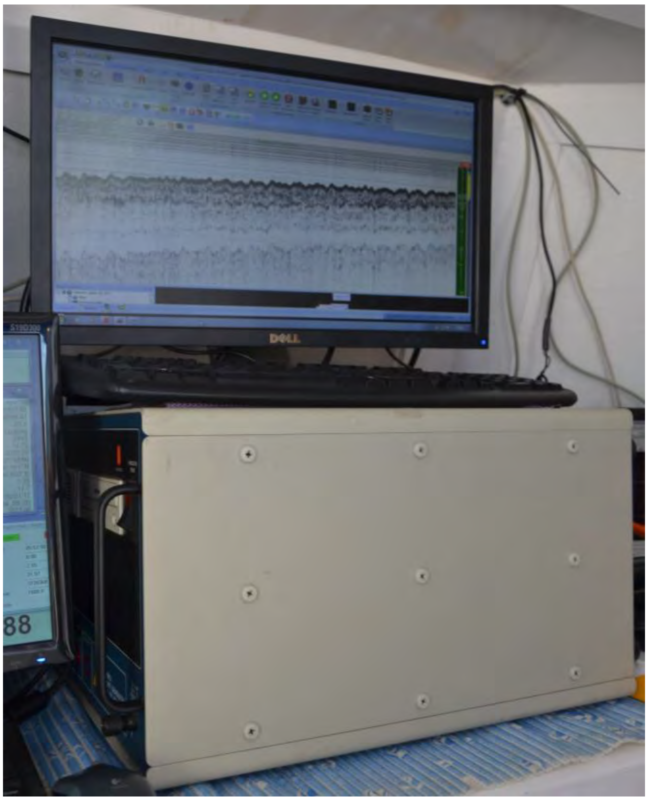

Fig. 3.1.2. *GEOPULSE model 5430P digital recording station.*

3.2. Bathymetric surveying

The bathymetric surveying employed a multi-beam interferometric echosounder (Fig.3.2.1) and a single beam echosounder (SBES).

The multi-beam interferometric echosounder was a BathySwath1, ITER System consisted of: (i) two (2) transducers, which were attached to the mounting pole that was tied up to the bow of the ship, and (ii) the digital recording unit. BathySwath1 uses a wide swath width with operational depth ranging from 0.2 m to 100 m. The capacities of this system are effective in the surveying of shallow depths providing high speed in surveying with resolutions up to 2 cm.

The single beam echosounder employed in the survey was a dual frequency ELAC 4200 MK2 echosounder (Fig. 3.2.2). This system operated to provide calibration and validation data sets for the multibeam echosounder data, increasing thus the quality of the echo-sounding data sets.

For the acquisition of the bathymetric data sets the Bathyswath Swath Processor and the HYPACK 2014 software were used. Bathymetric data sets acquired from an area of about 30 km^2.

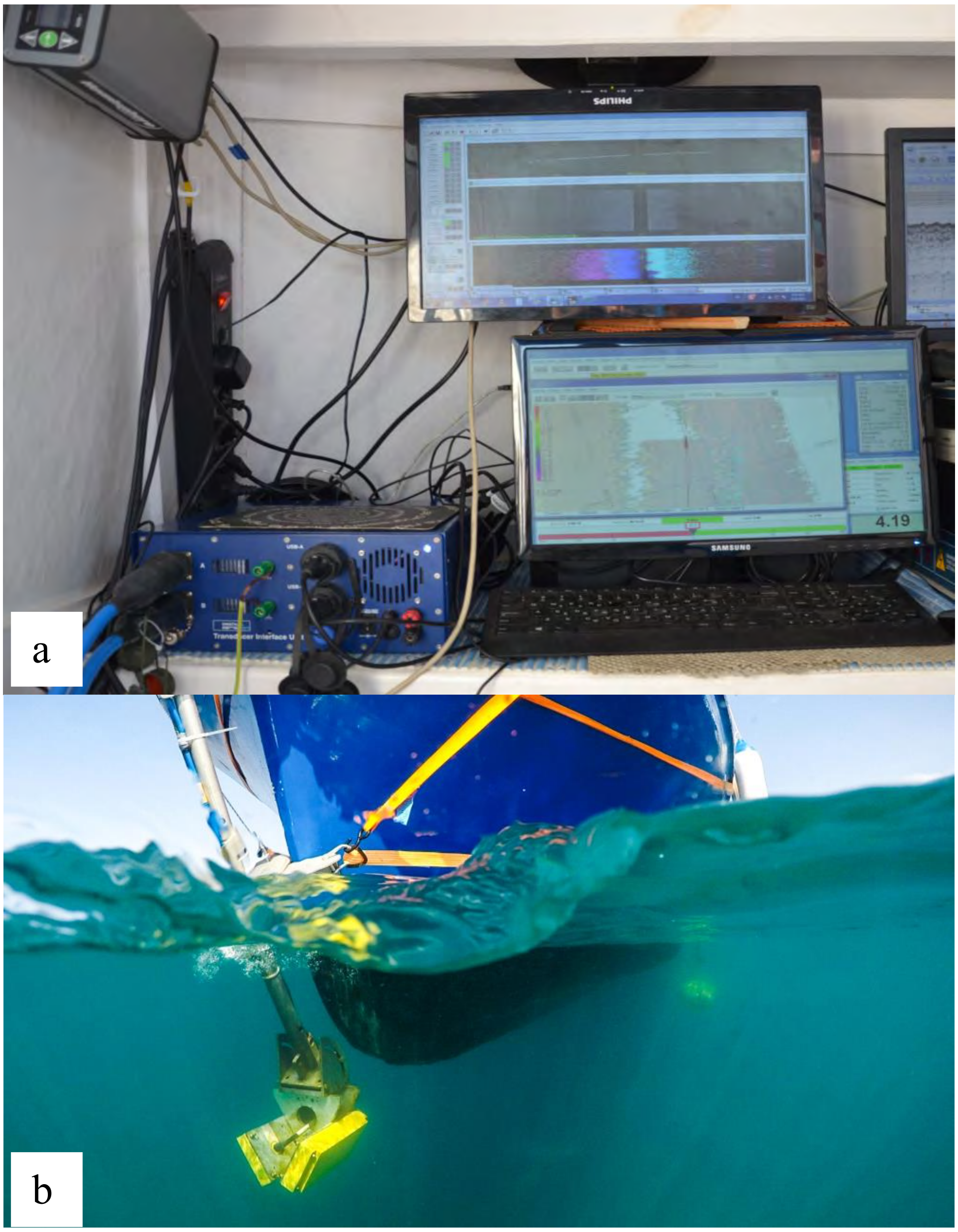

Fig. 3.2.1. *The digital recording unit (a) and the transducers (b) of the ITER Systems BathySwath1 interferometric multibeam echosounder.*

Fig. 3.2.2. *ELAC 4200 MK2 single beam dual frequency echosounder.*

3.3. Side Scan Sonar surveying

The side scan sonar emits fan-shaped acoustic pulses down toward the seafloor. The intensity of the acoustic reflections from the seabed is recorded providing information for the texture and the relief of the seafloor. The survey at Saida utilized an EG&G 272 TD side scan sonar consisted of:

- A dual frequency (100 and 500 kHz) towfish EG&G 272TD (Fig. 3.3.1.).
- kevlar cables 50, 150 and 200 m.
- digital recording unit Edgetech 4100 topside (Fig. 3.3.2.).

During the side scan surveying the lane spacing provided always a 50 % range overlap. The towfish height above the seafloor ranged between 10 and 50 % of the slant range. During the survey the operational frequencies were 100 kHz and 500 kHz, in accordance to the side scan sonar surveying protocols. The 100 kHz frequency is effective in the investigation of the seafloor texture at large surveyed areas but the 500 kHz frequency is effective in the investigation of specific areas of interest providing higher resolution. During the operation of the 100 kHz frequency the slant range of the system set at 75m and during the operation of the 500 kHz frequency it set at 50m. The total area insonified by the side scan sonar system summed up to 30 km^2. The nearshore area of the Zireh Island was mostly insonified by 500 kHz in order to achieve high resolution data sets (Fig.3.3).

For the acquisition of the side scan sonar data the "EDGETECH Discover 4100P software was used.

Fig.3.3.1. *The EG&G 272 TD side scan sonar*

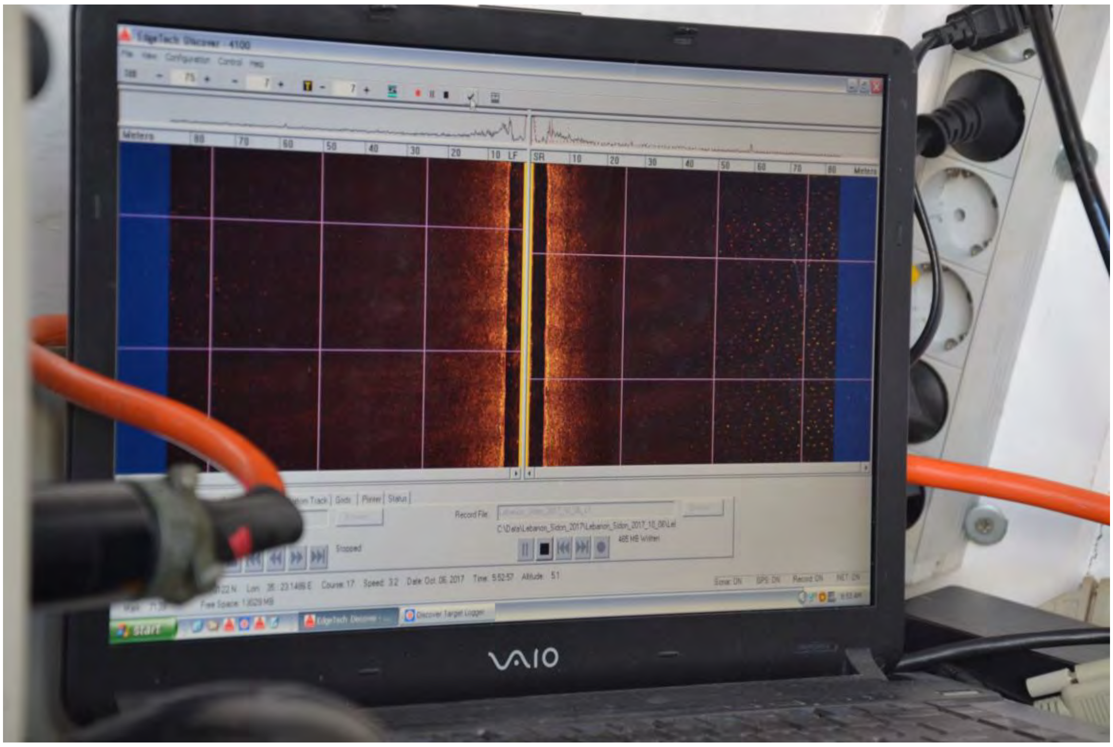

Fig.3.3.2. *The Side Scan Sonar digital recording unit.*

4. PHASE B': PRELIMINARY *SSS* AND *SBP* DATA PROCESSING

This chapter provides the results of the preliminary processing of the data sets. As mentioned previously, the purpose of this phase which conducted during the field work was to provide an overview of the seismic stratigraphy and the geomorphology of the studied area and to evaluate the most promising areas and sites of archaeological interest aiming to a more targeted research. It should be mentioned that this type of processing did not incorporate a large number of time-consuming techniques which usually assist to a robust mapping and interpretation of the remote sensing data sets.

A very preliminary processing of the bathymetric data was carried out using the software HYPACK 2014. Based on the preliminary bathymetric data sets the seafloor in the surveyed area deepens gently from the coastline seawards reaching a water depth of around 12 m (Fig. 4.1). This pattern appears modified in the area between the Zireh island and the coastline of Saida. There, northerwards of the island, a narrow zone of shallow waters up to 9 m is formed almost perpendicular to the island and to the coastline of Saida. This zone together with the island configures a shallow basin –like seafloor between the island and the present coastline with water depths up to 12 m.

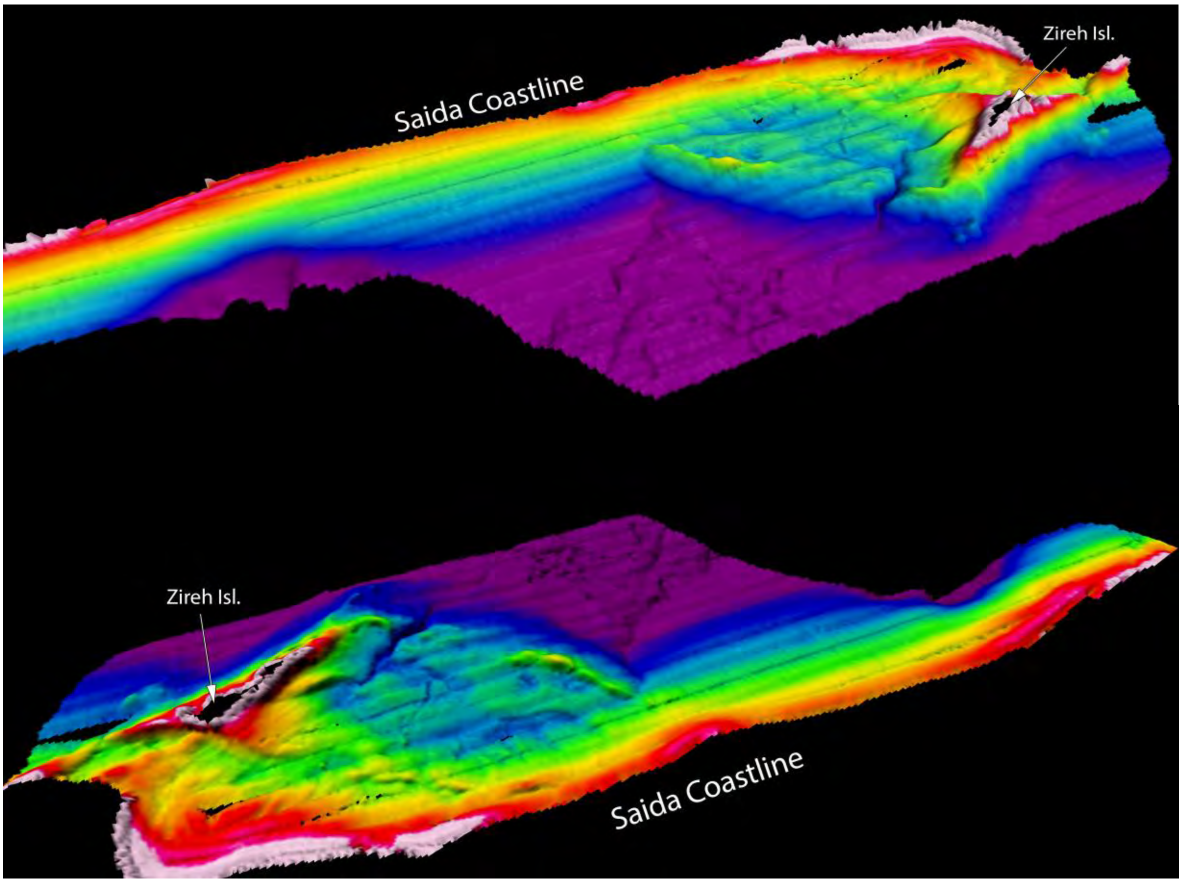

Fig. 4.1. *Unprocessed bathymetric maps of the area of Zireh Island.*

The preliminary processing of the seismic profiles undertaken by the SB-Interpreter software. The collected profiles from the investigated area usually show the recording of a seismic unit which it corresponds to sedimentary deposits, to overlie a seismic unit that it was interpreted as the acoustic basement (Fig. 4.2). The thickness of the sedimentary deposits ranges a lot throughout the surveyed area and this unit includes sites with acoustic anomalies which could be of natural origin (i.e. fluid escapes) and or probably of artificial origin (Fig. 4.2). The acoustic basement forms almost a wide plateau with depths up to 12 m below the present sea surface. The Zireh island is a part of this plateau (Fig. 4.3). In addition, a channel-like morphological feature, which is running perpendicular the coastline of Saida, divides the plateau into two parts.

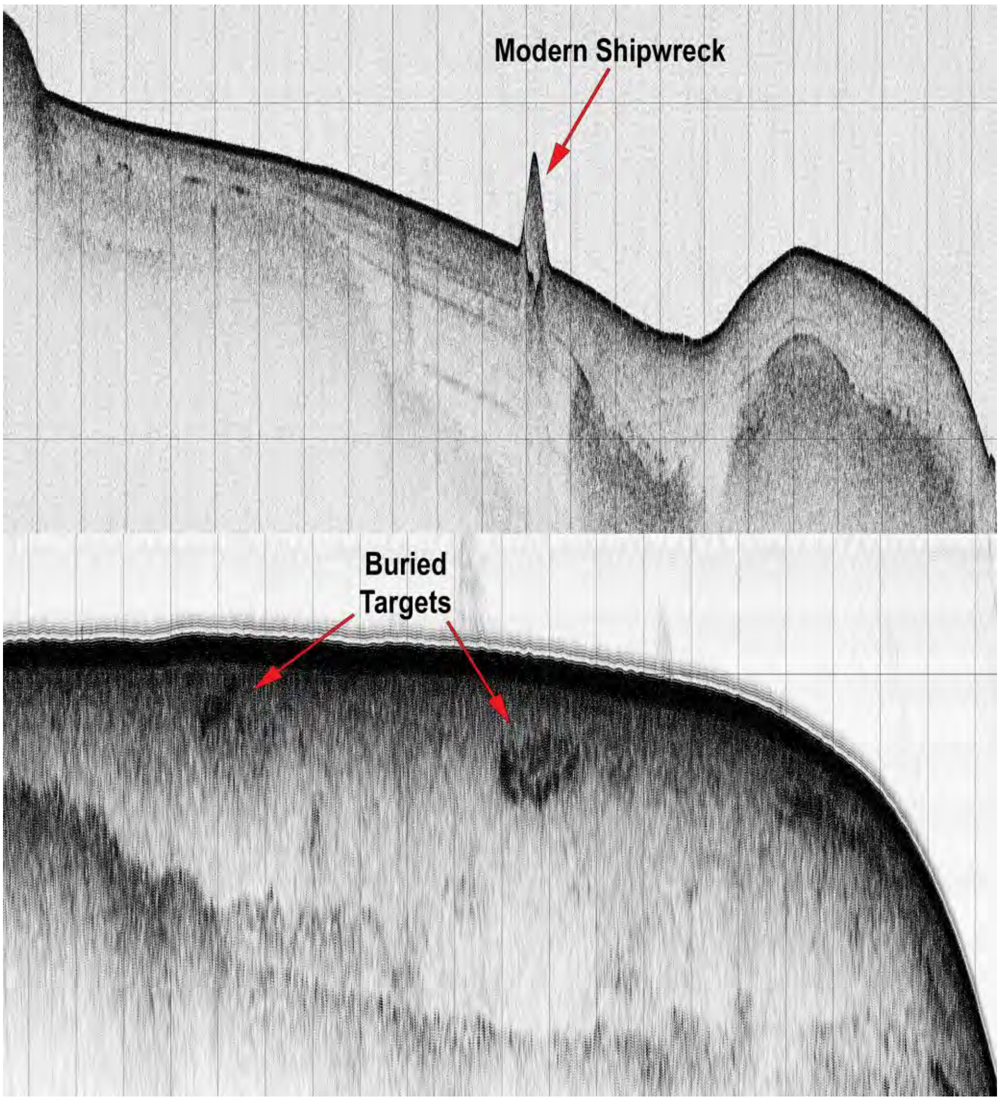

Fig. 4.2. *Seismic (Chirp) profiles showing the upper unit as almost transparent acoustically unit to overlie a strong reflector which corresponds to the top of the acoustic basement. The red arrows show acoustic anomalies above the sea floor and within the upper unit that most probable correspond to surficial and buried targets.*

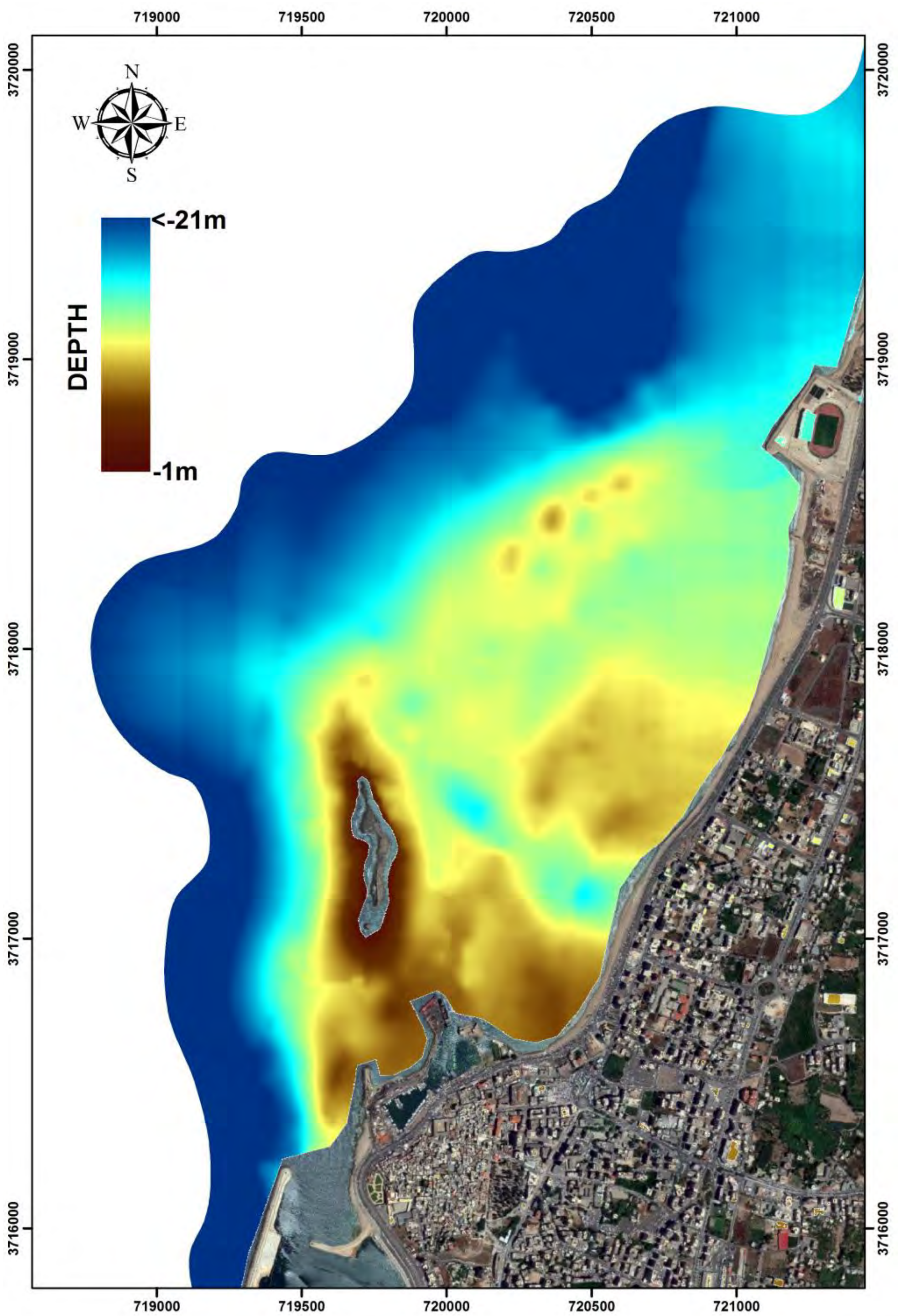

Fig.4.3. *Preliminary map showing the elevation of the top of the acoustic basement below the present sea level, around Zireh Island.*

The processing of the side scan sonar data undertaken by the Triton ISIS software. The sonographs present wide areas of low to medium reflectivity corresponding to the seafloor sedimentary cover (Fig. 4.4). Areas of acoustic anomalies were detected. The seismic profiles collected from these areas were examined in an effort to evaluate the origin of these anomalies (natural or artifact). The comparison distinguished the sites of acoustic anomalies linked to rocky outcrops. The majority of these cases recorded on sonographs as areas of high reflectivity at the nearshore areas.

All other sites of acoustic anomalies were evaluated based on their acoustic signature and shapes as targets of natural origin (i.e. pockmarks: craters in the seabed caused by fluids (*gas and fresh water*) erupting and streaming through the sediments; Fig. 4.5) or artificial origin (i.e. of potential historical and archaeological targets (Fig. 4.6). Efforts were made in some of the later cases of acoustic anomalies to be investigated further by visual inspection.

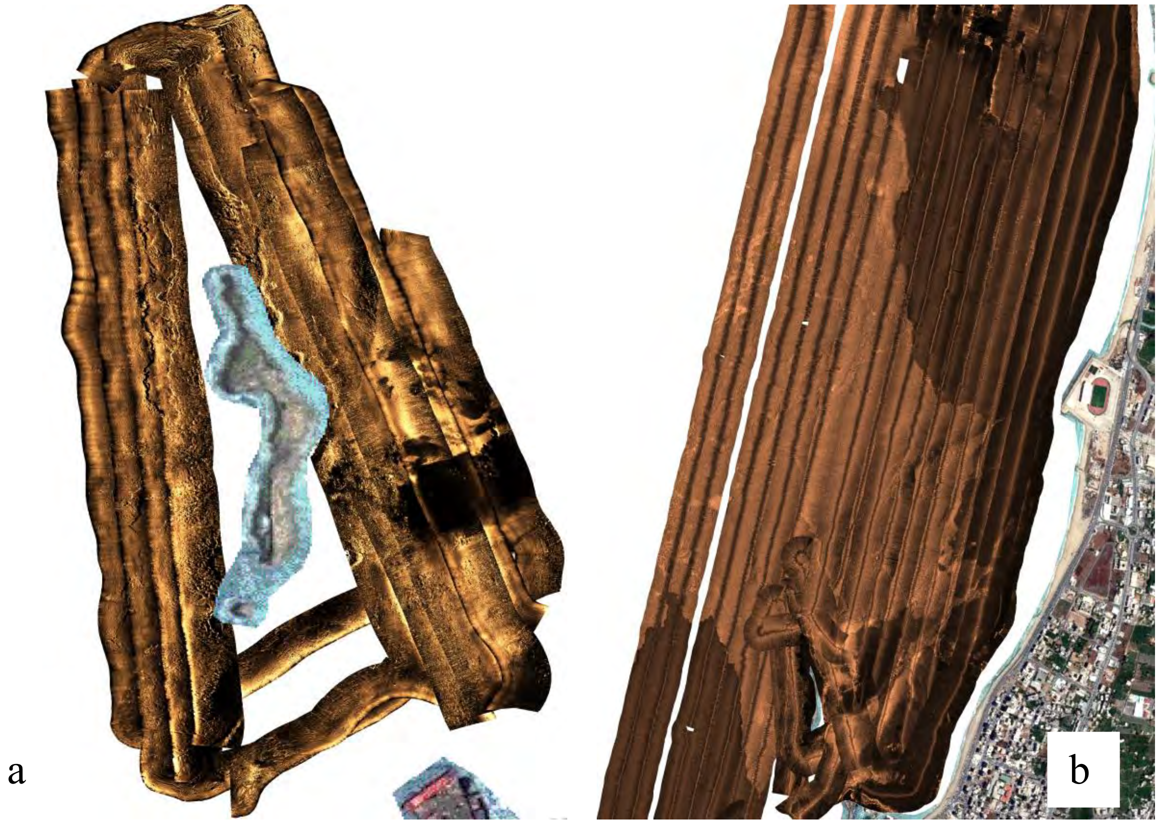

Fig.4.4. *Sonograph mosaics of the area around (a) Zireh island and the shallow water of (b)Saida.*

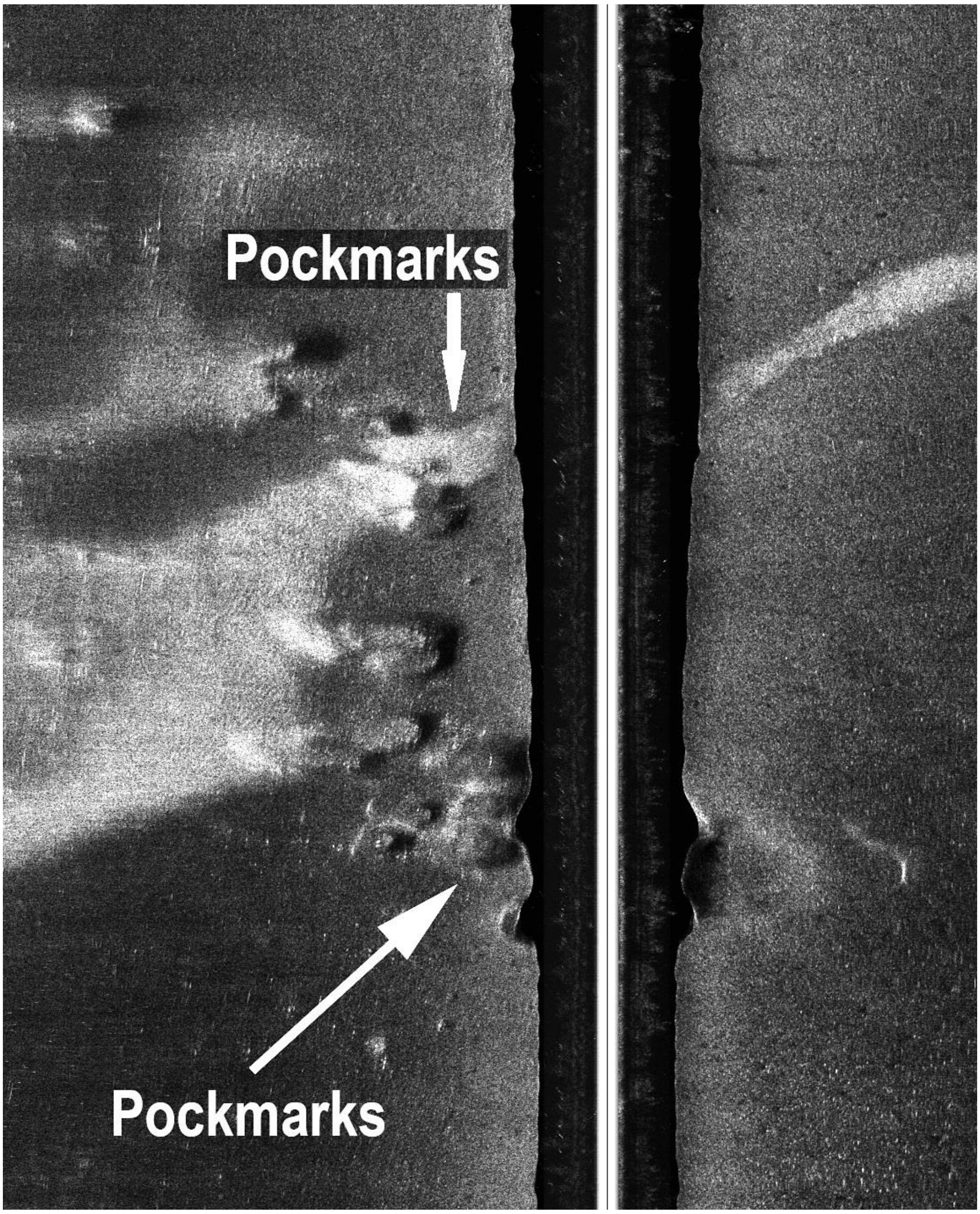

Fig.4.5. *Side Scan Sonar sonographs showing features of the seafloor of natural origin (pockmarks).*

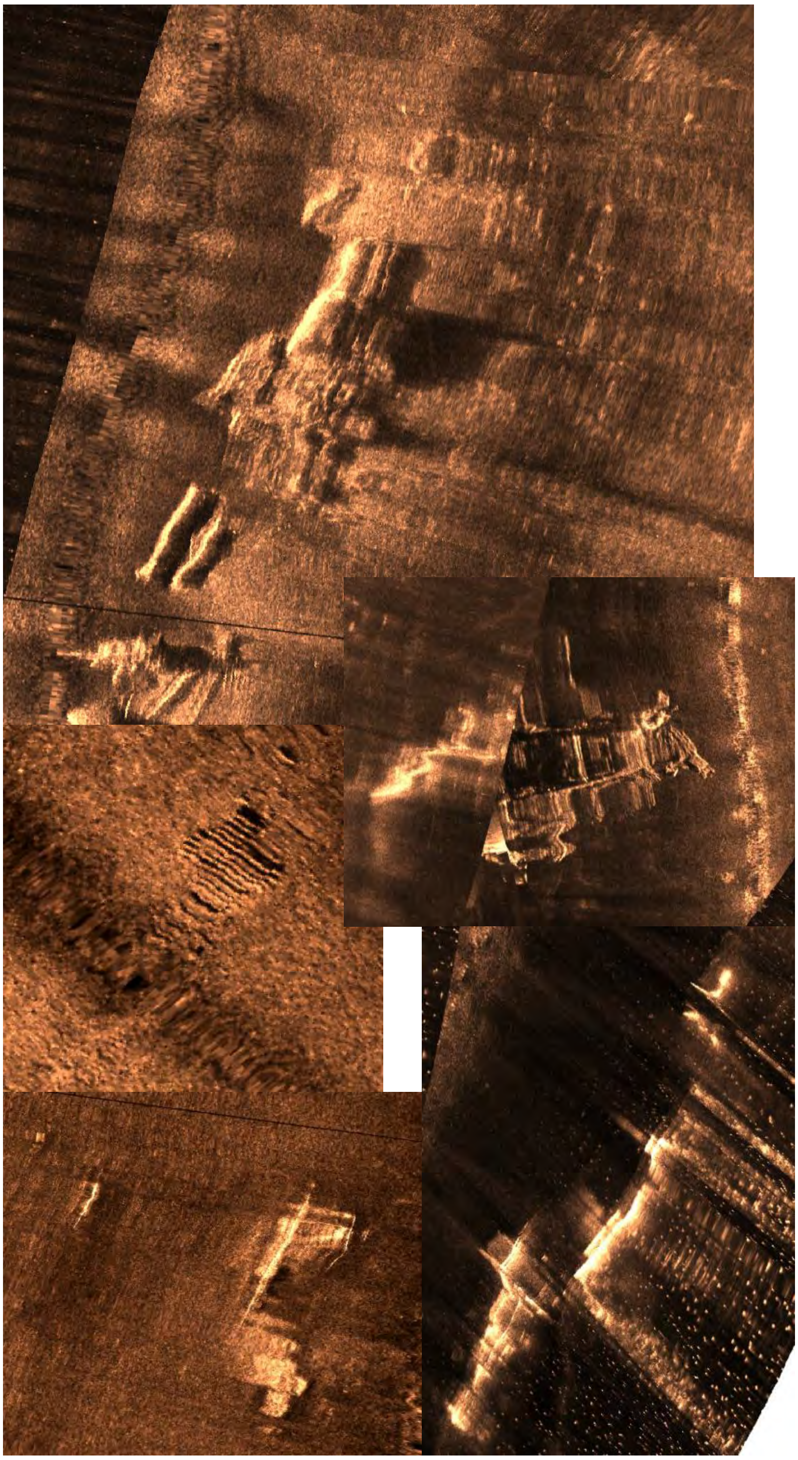

Fig.4.6. *Side Scan Sonar sonographs showing features of the seafloor of artificial origin (historical shipwrecks).*

5. PHASE C': GROUND-TRUTHING SURVEY

The ground-truthing survey was carried using a Sea Viewer underwater towed camera (Fig. 5.1.)

After the preliminary evaluation of the collected marine remote sensing data (Phase B'), a full day was devoted to ground truthing. The lines were planned and conducted, in order to record and identify features that were detected lying on the sea floor and representative natural features of some specific seafloor types (Fig. 5.2.).

Fig.5. 1. *The Sea Viewer underwater towed camera*

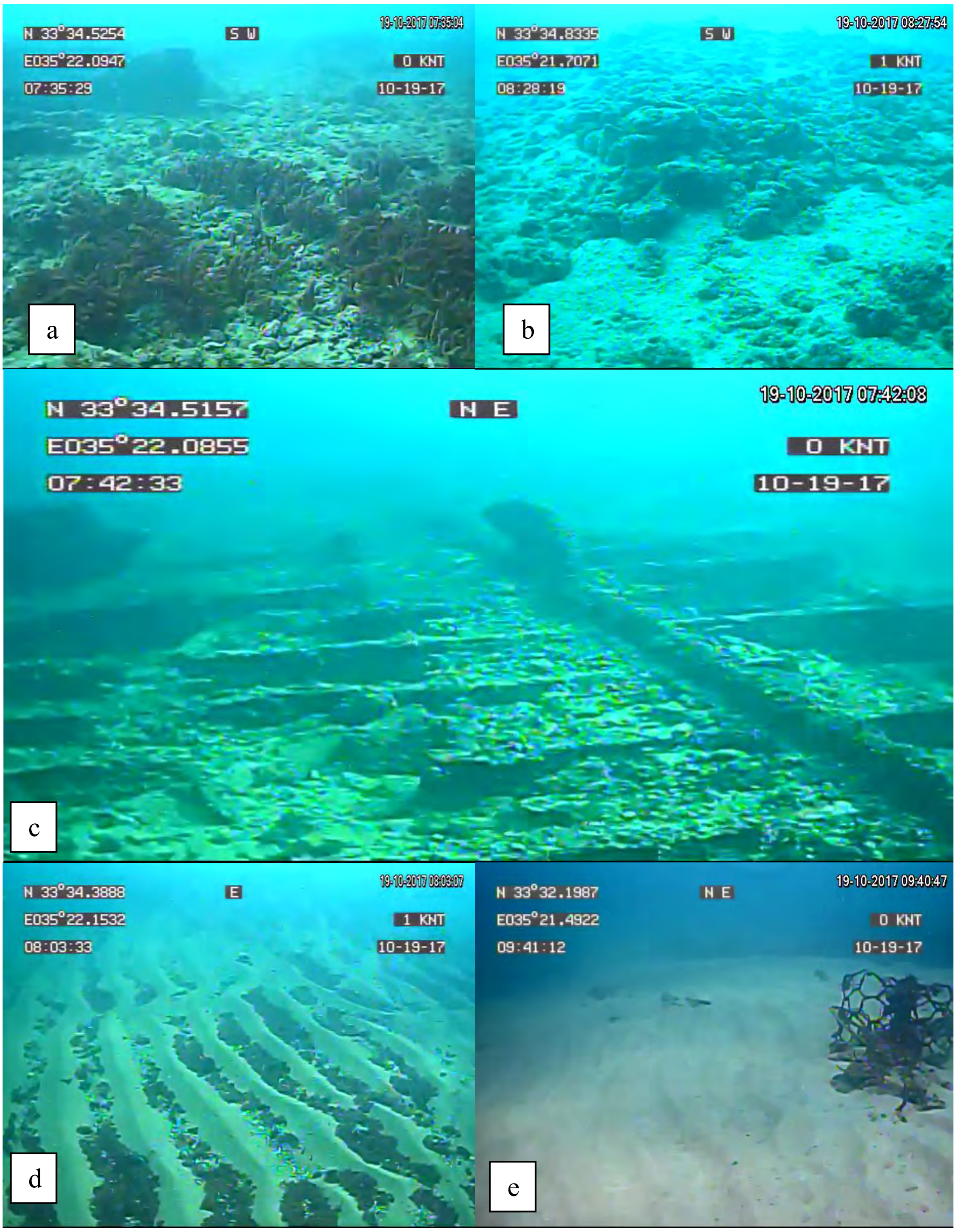

Fig.5. 2. *Images of natural (**a**, **b** and **d**) and manmade (**c**:historical shipwreck, **e**: iron nets) features of the bottom as captured by the Sea Viewer underwater towed camera.*

6. Current Situation and short-term planning

The next phase of the marine geophysical project in Saida includes processing and interpretation of the acquired seismic, bathymetric and bottom morphology data aiming to the evaluation of the evolution of the coastal zone of τhe studied area and the detection of buried or surficial targets of potential archaeological importance.

In particular an emphasis will be given on the processing and interpretation of the data collected in the area enveloping Zireh Island. Zireh Island is of great importance for the palaeogeographic reconstruction of the coastline of ancient Saida.

7. SCIENTIFIC PERSONNEL

The scientific - researching personnel participated in the field activities in Saida (Lebanon), during the survey period of October 2017, was:

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- **Christodoulou Dimitris**, PhD, research assistant
- **Fakiris Elias,** PhD, research assistant
- **Georgiou Nikolas**, MSc, PhD candidate
- **Dimas Xenophon**, MSc, PhD candidate

8. ACKNOWLEDGMENTS

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We would like to kindly thank Dr Eric Gottwalles, underwater archaeologist, affiliated researcher at Holy Spirit University of Kaslik (Beirut, Lebanon). Without his help, this survey could not have been carried out. Thanks also go to Osman El Bizri, the captain of the "*Adonis*" vessel, and Mario Kozaily for their great assistance in the field work.