MARINE REMOTE SENSING SURVEY IN SAIDA, LEBANON

SURVEY PERIOD: OCTOBER 2018

FIELD WORK REPORT

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October 2018

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1. INTRODUCTION

This report describes the field work of the second period of the marine remote sensing survey, which was carried out at the two ports and the coastal zone of Saida in Lebanon.

The survey was planned and carried out between 30th of September and 10th of October 2018, by the Laboratory of Marine Geology and Physical Oceanography of the University of Patras, Greece, under the directionship of Dr. Eric Gottwalles.

The Saida marine remote sensing survey is an ongoing research project designed:

- to detect targets (surface and subsurface) of potential archaeological interest,
- to obtain detailed bathymetry of the two ports of Saida and around the area of Zireh Island,
- to define the subbottom stratigraphy of the recent sediment sequence, and
- to define the evolution of the coastline configuration at Saida over the last 18000 yrs BP based on the mapping of palaeoshorelines features and the seismic stratigraphy of the seafloor.

2. SURVEY DESIGN

The systematic remote sensing survey of the seafloor of Saida was segmented into three distinct areas.

- **AREA A'**: The first area is the old fishing port of Saida and the area around the Sea Castle.
- **AREA B'**: The second area is the newly built commercial port of Saida located southern of the old fishing port.
- **AREA C'**: The third area is located between Zireh island and the mainland of Saida and around the Zireh island.

The segmentation of the surveying areas was planned in order to construct a methodological approach that combines the cost-effective tool to rapidly survey areas of archaeological and historical interest while making the most out of the limited survey time. The areas of the two ports of Saida, the one newly built and the old fishing port, were systematically surveyed in order to detect any potential target of archaeological interest for further investigation and to collect data for the complete reconstruction of the coastal zone of Saida during the last 18.000 years. Additionally, in continuation of the first survey, which was carried out during the October of 2017, the shallow coastal zone of Saida and the area around Zireh island was prospected in a more systematic manner compared to that of first survey period. The objective of this part of the survey was to maximize the data quality on those areas which are considered of great archaeological importance.

3. FIELD WORK AND SURVEY METHODOLOGY

Field activities in Saida coastal zone, during October 2018 survey period, included:

- the detailed bathymetry of the two ports, the area around Zireh and the coast of Saida,
- the morphology of the seafloor,
- the study of the seabed seismic stratigraphy.

The main objective of the survey was to detect targets, either buried under the seafloor or lying on top of it, of potential archeological importance and to detect submerged palaeoshorelines and other morphological features which are indicators of the sea level changes over time.

The marine remote sensing survey was carried out using: (i) an Innomar SES-2000 light plus Sub-Bottom Profiler and Dual-Frequency Sidescan Sonar and (ii) an ITER Systems BathySwath1 interferometric multi beam echosounder. A Hemisphere VS101 GPS system with accuracy of approximately 0.2 m was used for the navigation and the positioning of the vessels.

During the survey period, a total of 679 survey tracklines were conducted having a total length of 189 km and resulting in an area coverage of about 1.1 km^2. (Table 3.1., Fig. 3.1.).

Table 3.1.

Equipment	*frequencies/ beam*	*Total Tracklines*	*Total length of tracklines (km)*	*Total Coverage Area (km^2)*	*Total Data amount (Gb)*
Bathyswath	***224 kHz***	***621***	***188.8***	***1.1***	***62.9***
SBP	**12-15 kHz**	***679***			
Side Scan Sonar	**250-410-600 kHz**	***517***			

Fig. 3.1. Map showing the survey tracklines in the total survey area.

3.1. Survey Vessels

In order to meet the objectives of the survey two motorboat vessels were used. The vessel "Nedah" was used for the areas inside the two ports. The small size of the vessel, combined with the great maneuverability, made it ideal for surveying the narrow, extremely confined and crowded areas of the two ports.

The vessel "Adonis" was used for surveying the open-water area between Zireh island and Saida coastline. The vessel's stability and length have been proved ideal for this specific area in order to overcome the wave regime of the area and to collect the best quality of the data. Both of the vessels were suitably modified to meet the specific needs for the remote sensing survey (Fig. 3.1.1).

Fig. 3.1.1. (a) The vessel "Nedah" which was used for surveying the two ports areas and (b) the vessel "Adonis" which was used for the survey of the coastal zone of Saida and around Zireh island.

3.2. The Bathymetric survey

The bathymetric survey was carried out simultaneously with the subbottom profile survey using a Multi-beam interferometric echosounder ITER Systems BathySwath1 (Fig. 3.2.1).

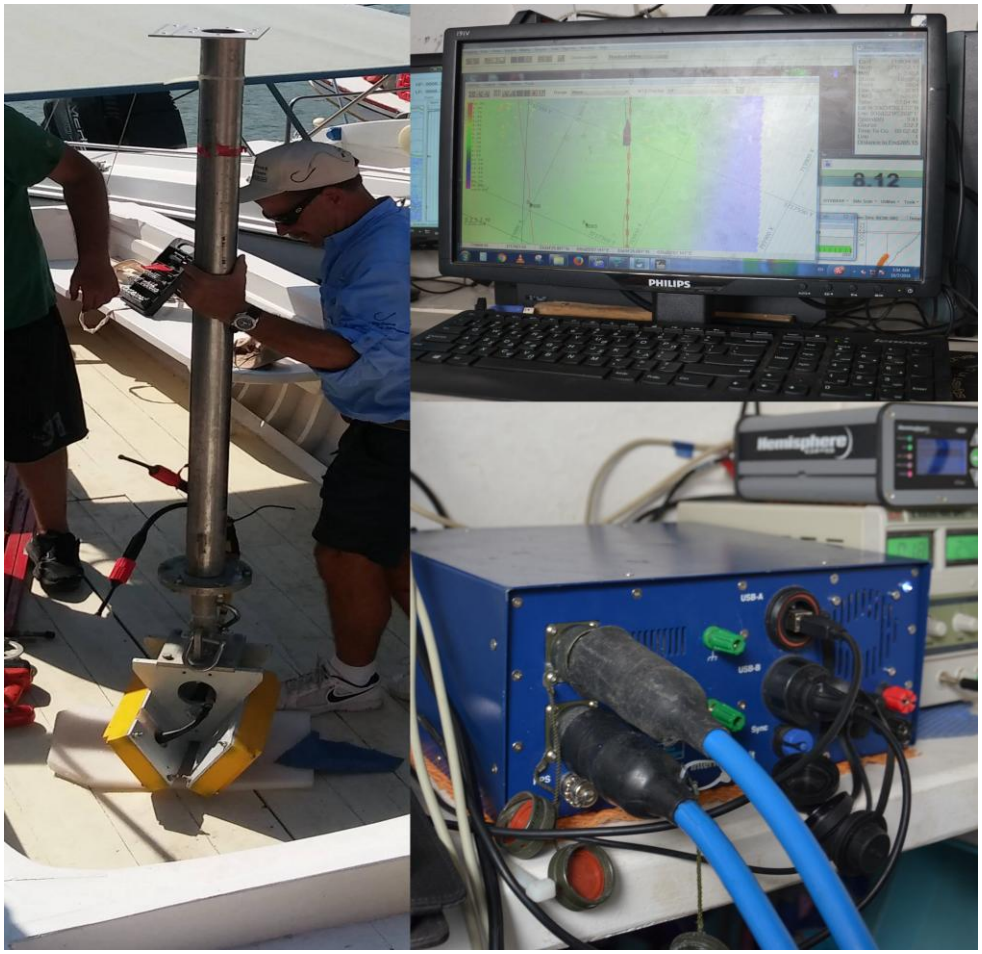

Fig. 3.2.1. The transducers (a) and the digital recording unit (b) of the ITER Systems BathySwath1 interferometric multibeam echosounder.

The ITER Systems BathySwath1 interferometric MultiBeam Echosounder consists of: (i) two (2) transducers, which were attached to the mounting pole that was tied up over the side of the vessels, and (ii) the digital recording and display unit. BathySwath1 uses wide swath widths that increases survey speeds significantly, especially in shallow water. This is due to the fact that the swaths cover an area of 150

m of slant range, with operational depth ranging from 0.2 m to 100 m and accuracy of 2 cm.

The SES 2000 Light Plus sonar bathymetrical data (Fig. 3.3.1.) was used for calibration and validation of the multibeam echosounder data.

The bathymetric survey was carried out in order to obtain detailed bathymetric data in the area around Zireh Island and inside the two ports in order to construct a detailed bathymetric/geomorphological map. This map is crucial for the palaeogeographic reconstruction of the coastal zone of Saida and the detection of targets existing on the seafloor of the ports and around Zireh Island.

3.3. Sub-bottom Profiling survey

The Sub-bottom Profiling survey at Zireh and two ports area was carried out using a SES 2000 Light Plus-Innomar parametric sub-bottom profiler (Fig 3.3.1.). This parametric Sub Bottom Profiler is characterized by its unique ability of operating on extremely shallow waters (0,5m depth) retaining extremely high resolution. The profiler emits an extremely narrow conical wave which is consisted of two different frequencies. The high frequency wave (85- 115 kHz) is ideal for the detection of the bottom and the extraction of bathymetrical data. The low frequency wave (4- 15 kHz) allows the identification of very thin (vertical resolution of 5cm) sedimentary strata with a penetration of up to 40m bellow the seafloor (depends of the seafloor texture) and targets of very small size buried inside the sediments.

The system consists of:

- The SES 2000 Sub- Bottom Profiler over the side mounting system (Fig 3.3.1.)
- The Digital Recording and Data Displaying station for the collection of the seismic profiles (Fig 3.3.1.).

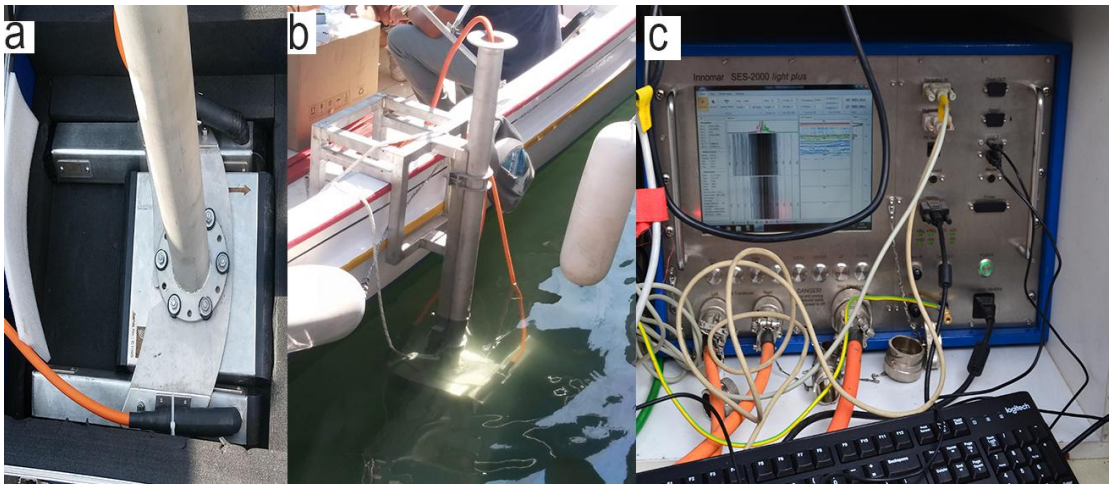

Fig. 3.3.1. (a) The Innomar's SES 2000 Light Plus System which was used for the needs of the survey, (b) the over-the-side mounted transducers on the research vessels and (c) the digital data recording and displaying unit.

The objective of the subbottom profiling survey was to define the seismic stratigraphy of the very shallow areas of the ports and around Zireh. In order to achieve this objective, the frequency was alternated between 12 kHz for the area around Zireh and 8, 10, 12 to 15 kHz for the ports areas in order to reach the combination of the highest resolution while retaining the deepest penetration.

3.4. The Side Scan Sonar survey

The Side Scan Sonar survey was carried out simultaneously with the bathymetric and the Sub bottom profiling survey using Innomar –SES 2000 Light Plus side scan sonar (Fig.3.3.1.).

The Side Scan sonar survey aimed at: (i) the mapping of the geomorphological and textural features of the seafloor and (ii) the detection and positioning of targets which may represent man-made features lying on the seafloor. The side scan sonar system emits acoustic pulses providing a plan view seafloor acoustic image. The main advantage of a side scan sonar system is the ability to survey wide seafloor areas at a greater "over the ground" speed.

The side scan sonar system consists of:

- The SES 2000 Side Scan Sonar which operates in three frequencies (250, 410 and 600 kHz) (Fig.3.3.1.).
- The Digital Recording and Data Displaying station for the collection of the side scan sonar sonographs(Fig 3.3.1.).

The Innomar's SES 2000 Side Scan Sonar has the ability to simultaneously operate and collect data in two different frequencies. The survey of the area was carried out using 250 kHz, 410 kHz and 600 kHz frequencies in order to reach the highest achievable spatial resolution. The trackline spacing was such that the seafloor area covered between two lines was overlapped by 75% at the areas of the ports and more than 50% around Zireh Island.

A significant number of surface targets and features has been detected and recorded.

4. SURVEY AREAS

During the marine remote sensing expedition in Saida, on October of 2018, the total survey area was segmented into three (3) distinct sub-areas (A, B and C).

4.1. Area A: The old fishing port of Saida.

The first priority area was the old fishing port of Saida. The old port area was surveyed in extremely high detail using all the available instruments (Table 4.1.1., Fig. 4.1.1.).

Table 4.1.1.

Equipment	*frequencies/ beam*	*Tracklines*	*Total length of tracklines (km)*	*Total Coverage Area (km^2)*
Bathyswath	***224 kHz***	***257***	***43.7***	***0.03***
SBP	**12-15 kHz**	***285***		
Side Scan Sonar	**250-410-600 kHz**	***153***		

The survey tracklines were conducted on a primary axis of SW to NE direction for the inner port following the main axis of the port and in a S-N direction in the outer port. In addition, several W-E tracklines were acquired in both areas of the port. The spacing between the lines was about 5m. During the survey period, a preliminary processing of the data was carried out in order to evaluate the quality of the data and to detect any areas that would require further inspection. Based on those, in some specific areas, like the inner port, the passage between the outer and the inner port, the center of the outer port and the areas around the Sea Castle the survey trackline spacing was 1m or less (Fig 4.1.1.).

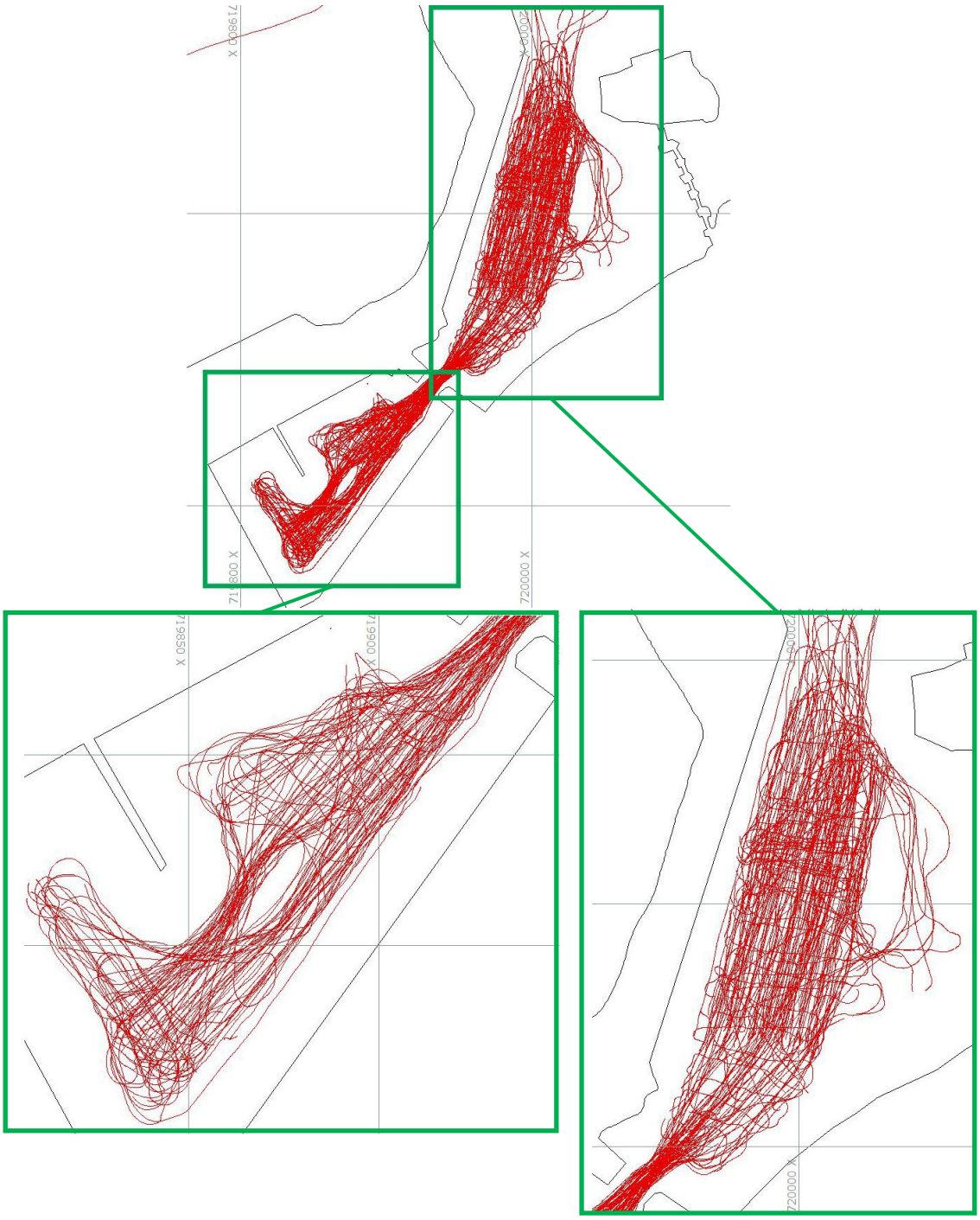

Fig 4.1.1. Maps showing the extremely dense grid of survey tracklines inside the old fishing port of Saida.

The Bathymetric Survey was carried out covering 35m on each side of the tracklines. Figure 4.1.2 shows the preliminary bathymetric map of the old fishing port of Saida, based on unprocessed bathymetric data.

The Side Scan Survey was carried out covering 25m on each side of the track line with frequencies of 250, 410 and 610 kHz in order to achieve the highest resolution. The preliminary side scan sonar mosaic exhibits targets on the seafloor of potential archaeological and historical importance (Fig. 4.1.3.).

The Sub Bottom Profiler survey tracklines were acquired four times using four different frequencies each time (8, 10, 12 and 15 kHz). This multi-frequency approach allows the highest penetration through the low frequencies and the highest possible resolution through the high frequencies (Fig 4.1.4).

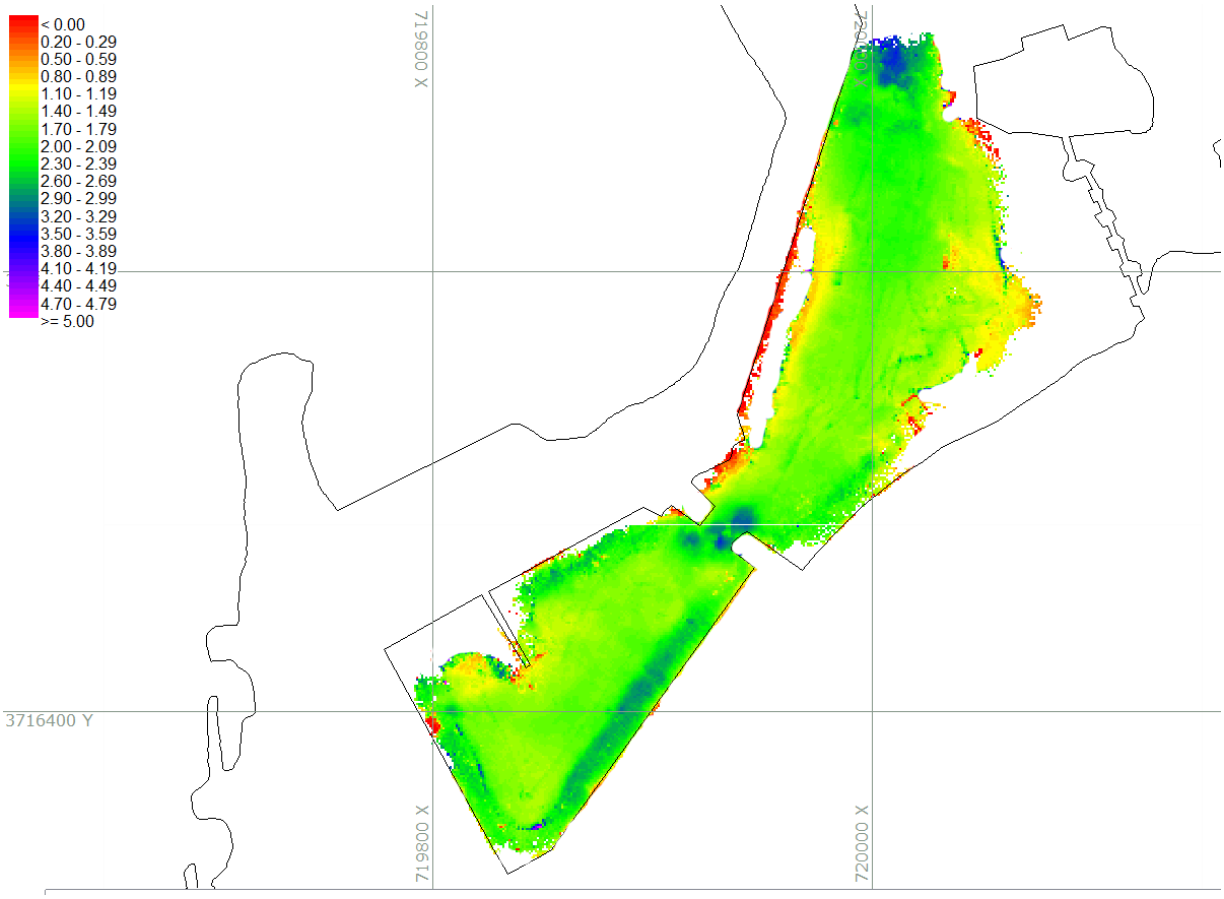

Fig. 4.1.2. Unprocessed bathymetric map of the old fishing port of Saida.

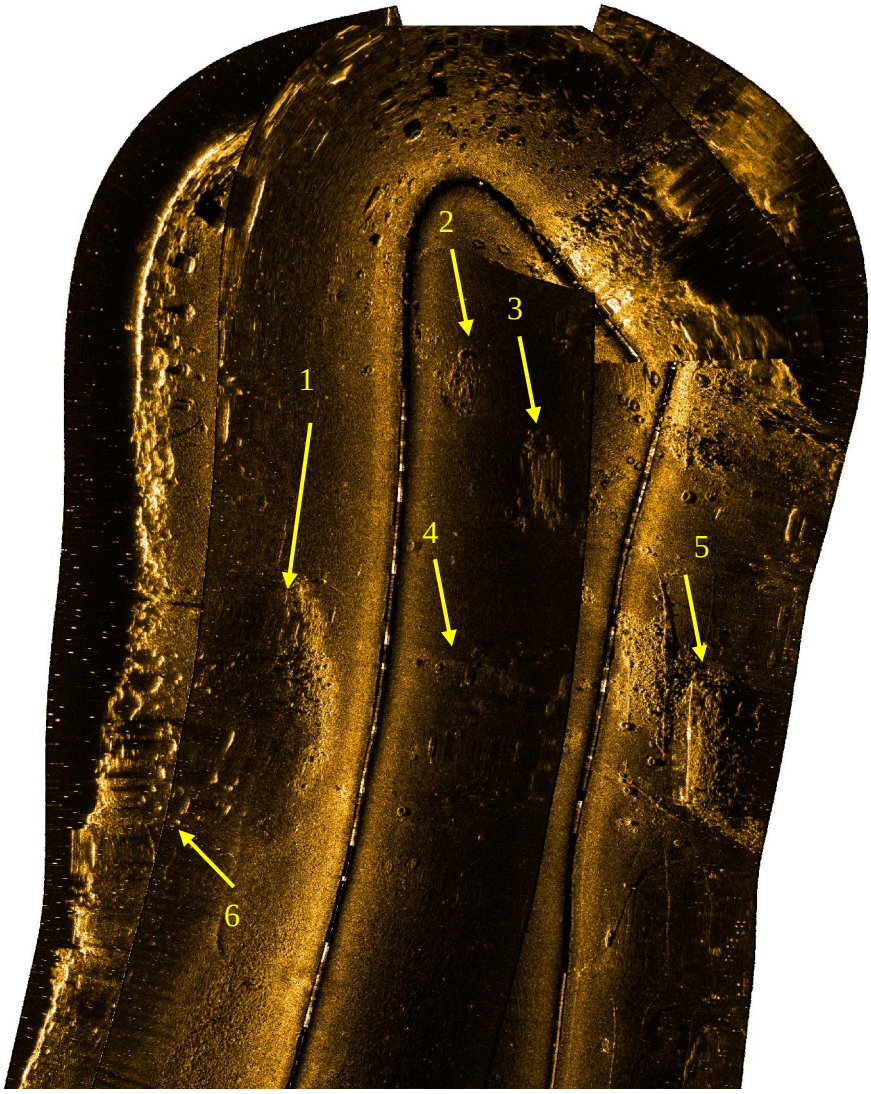

Fig. 4.1.3. Preliminary side scan sonar mosaic showing targets (1-6) of potential archaeological and historical importance in the outer part of the old fishing port of Saida.

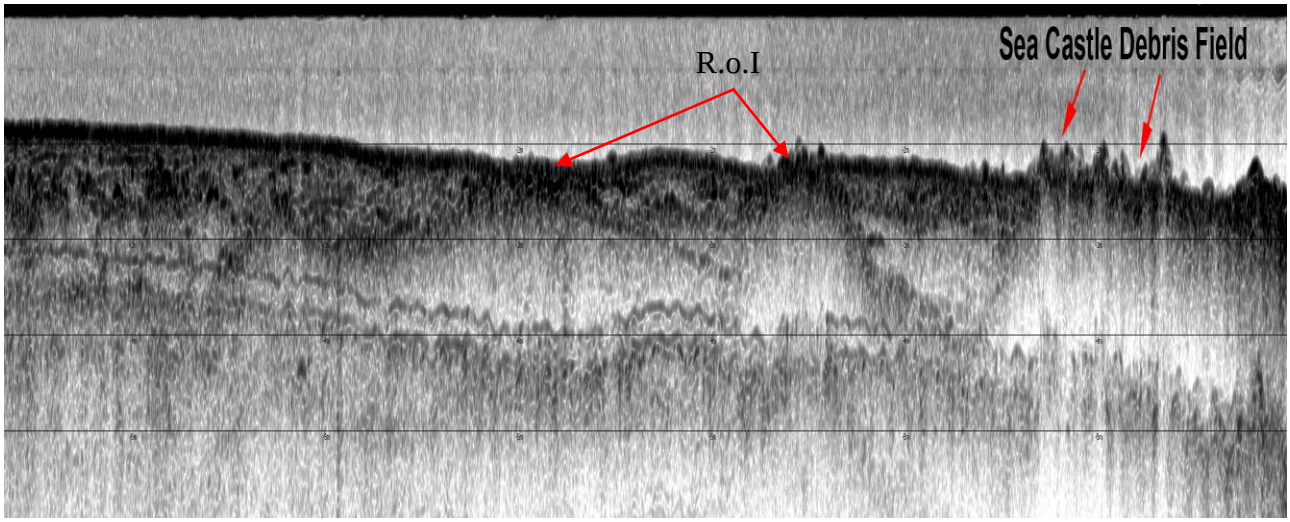

Fig. 4.1.4. Unprocessed extremely high resolution seismic profile showing the debris field around the Sea Castle and two regions of interest (R.o.I) inside the outer part of the old fishing port of Saida.

4.2. Area B: The new port of Saida.

The second priority area was the newly built commercial port of Saida. The new port area was surveyed in detail using all the available instruments (Fig. 4.2.1., Fig. 4.2.1.).

Table 4.2.1.

Equipment	*frequencies/ beam*	*Tracklines*	*Total length of tracklines (km)*	*Total Coverage Area (km^2)*
Bathyswath	***224 kHz***	***88***	***28.7***	***0.23***
SBP	**10-12 kHz**	***88***		
Side Scan Sonar	**250-410-600 kHz**	***88***		

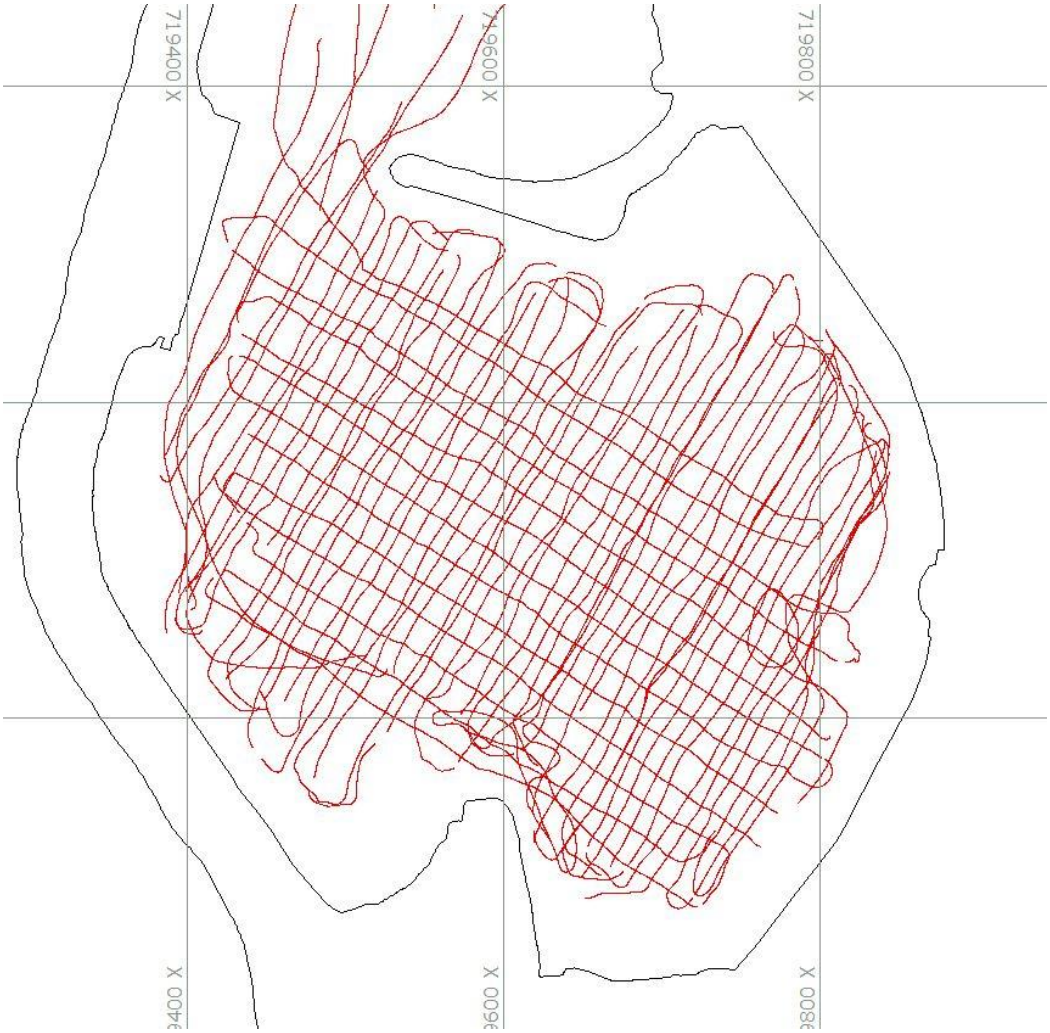

Fig. 4.2.1. Map showing the dense grid of survey tracklines inside the new port of Saida.

The Bathymetric Survey was carried out covering 35m on each side of the tracklines. Figure 4.2.2 shows the preliminary bathymetric map of the new port of Saida, based on unprocessed bathymetric data.

The side scan sonar survey was carried out using frequencies of 410 and 600 kHz, simultaneously to the sub bottom profiling the bathymetric surveys. Preliminary interpretation of the side scan sonar showed man-made targets and natural morphological features (crater-like features) (Fig. 4.2.3.).

Subbottom profiling tracklines, of 12 kHz, were acquired in an NE- SW direction, almost perpendicular to the shoreline with spacing of 20 m (Fig.4.2.1). In

addition, tracklines parallel to the shoreline with spacing of 10 m and frequency of 10 kHz were also carried out in order to serve as tie-line tracklines to the perpendicular grid and to enhance the already dense data grid (Fig.4.2.1 and 4.2.4.).

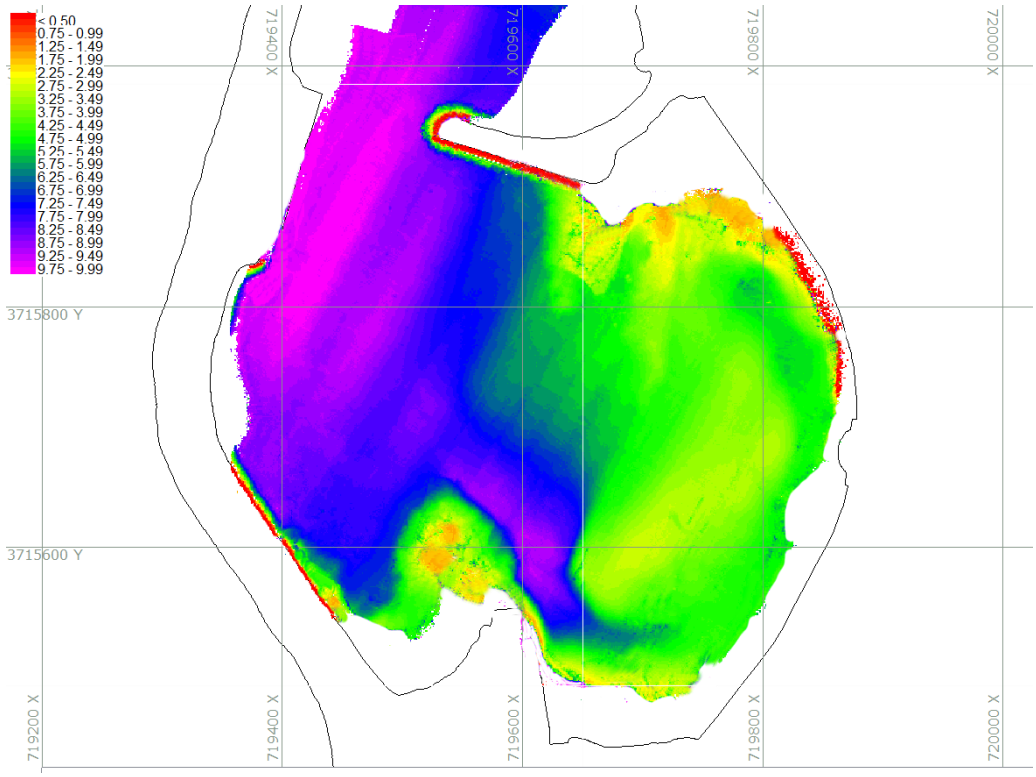

Fig. 4.2.2. Unprocessed bathymetric map of the new port of Saida.

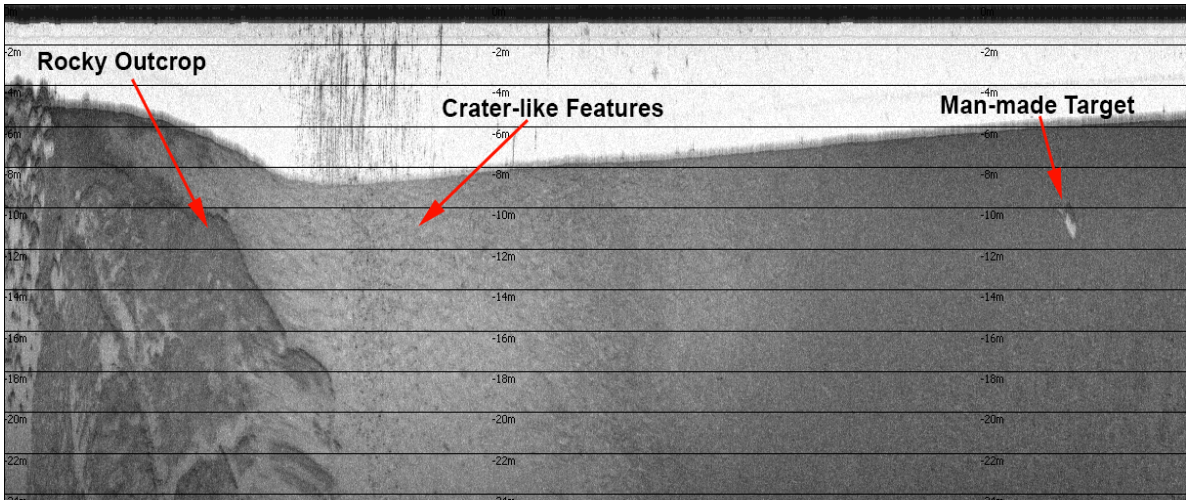

Fig. 4.2.3. Side scan sonar sonograph showing natural and man-made features.

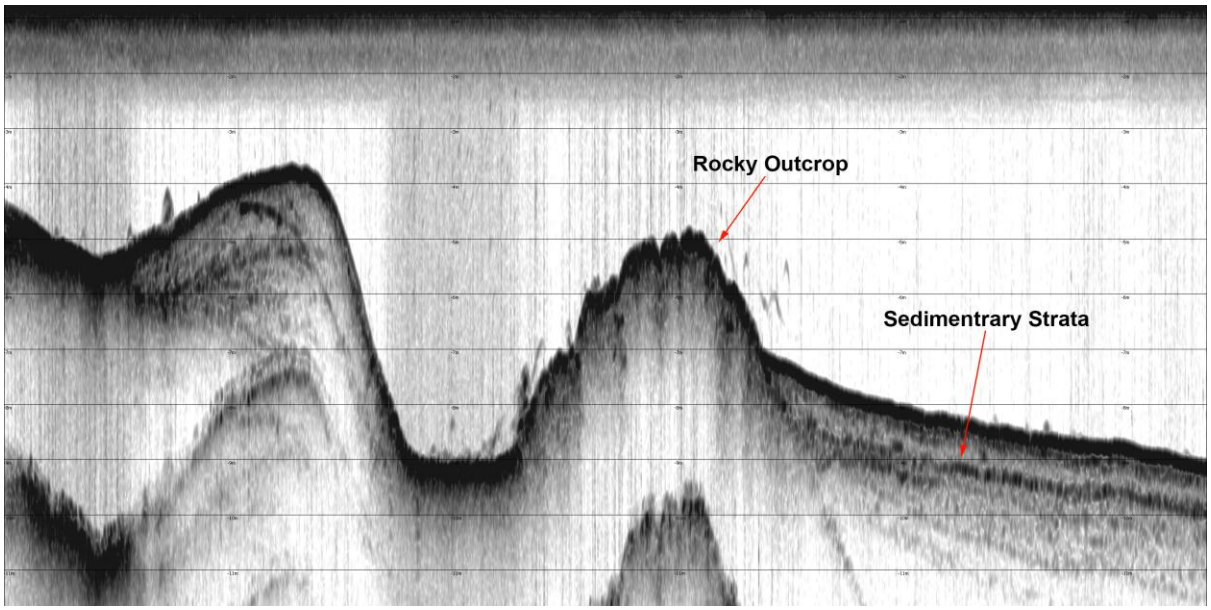

Fig. 4.2.4. Ultra-high resolution seismic profile showing the seismic stratigraphy of the seafloor of the new port of Saida.

4.3. Area C: The Zireh Island – coastal zone of Saida.

The third priority area was the area around Zireh island and between the island and the coast of Saida (Fig 4.3.1.). This area is considered as an area of great archaeological importance since is located between two ancient ports; Saida and Zireh ports. The area was surveyed in detail using all the available instruments (Table 4.3.1. and Fig. 4.3.1.).

Table 4.3.1.

Equipment	*frequencies/ beam*	*Tracklines*	*Total length of tracklines (km)*	*Total Coverage Area (km^2)*
Bathyswath	***224 kHz***	***276***	***116.3***	***0.85***
SBP	**10-12 kHz**	***276***		
Side Scan Sonar	**250-410-600 kHz**	***276***		

12 and 15 kHz frequency subbottom profilling tracklines were acquired in an E-W direction and almost perpendicular to the shoreline with spacing of 10m (Fig.4.3.1). Moreover, in the area around the coast of Zireh, tracklines of S to N direction were conducted with spacing of 2m. In addition, lines parallel to the shoreline with spacing of 5m were acquired in the very shallow water (minimum of 1.5m water depth) near the coast of Saida and around the Sea Castle. Those tracklines were acquired in order to enhance the existing data of survey period of 2017 using the SES 2000 subbottom profiler.

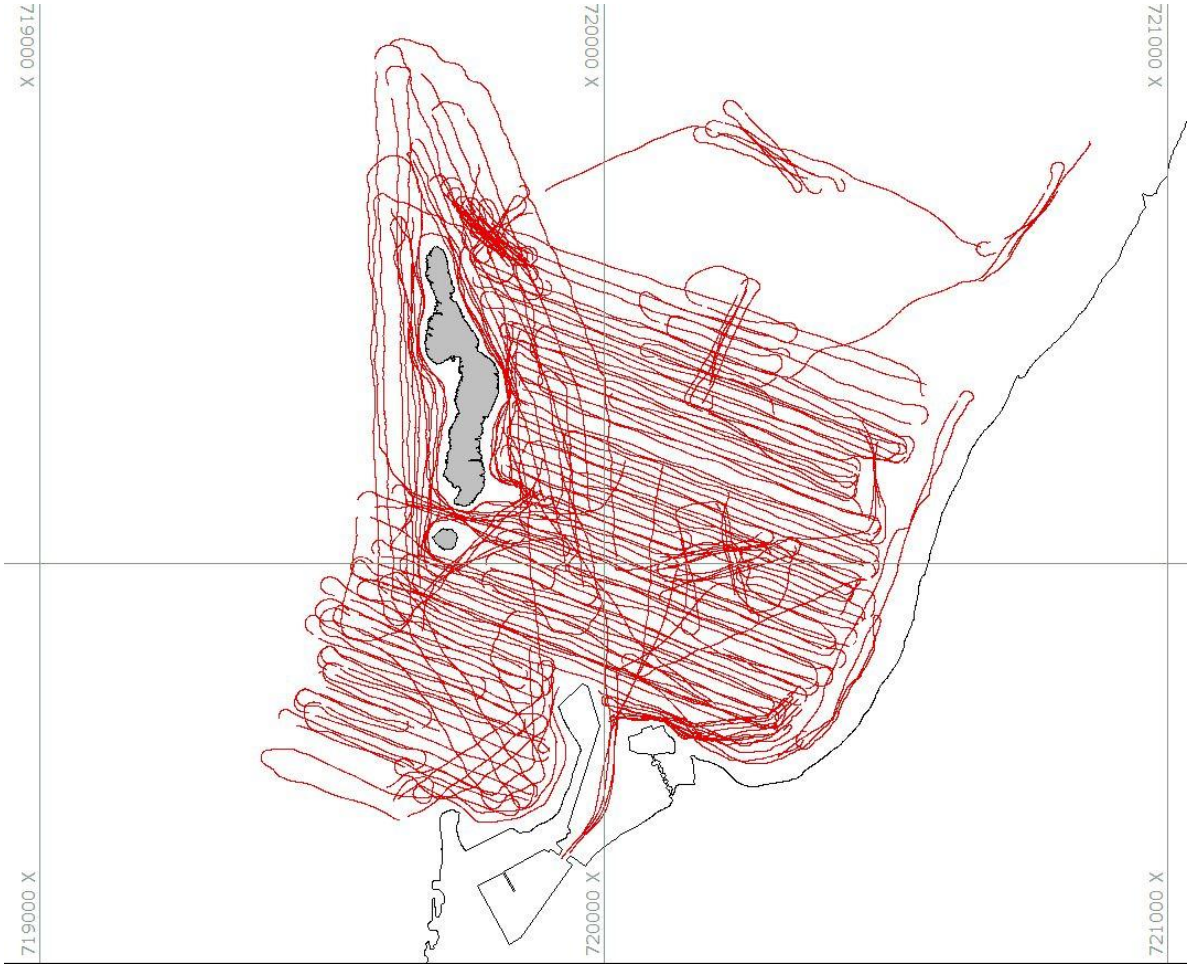

Fig. 4.3.1. Map showing the dense grid of survey tracklines around Zireh island and in the area between Zireh and the coast of Saida.

Simultaneously to the sub bottom profiling and bathymetrical survey of the area, the side scan sonar survey was carried out using frequencies of 410 and 600 kHz (Fig. 4.3.2.). Moreover, supplementary tracklines were acquired at the sites of the modern shipwrecks that have been surveyed during the 2017 survey period. SES 2000 Side Scan - Sub Bottom and the ITER BathySwath1 Systems insonified those shipwreck sites with extremely high resolution providing even more information.

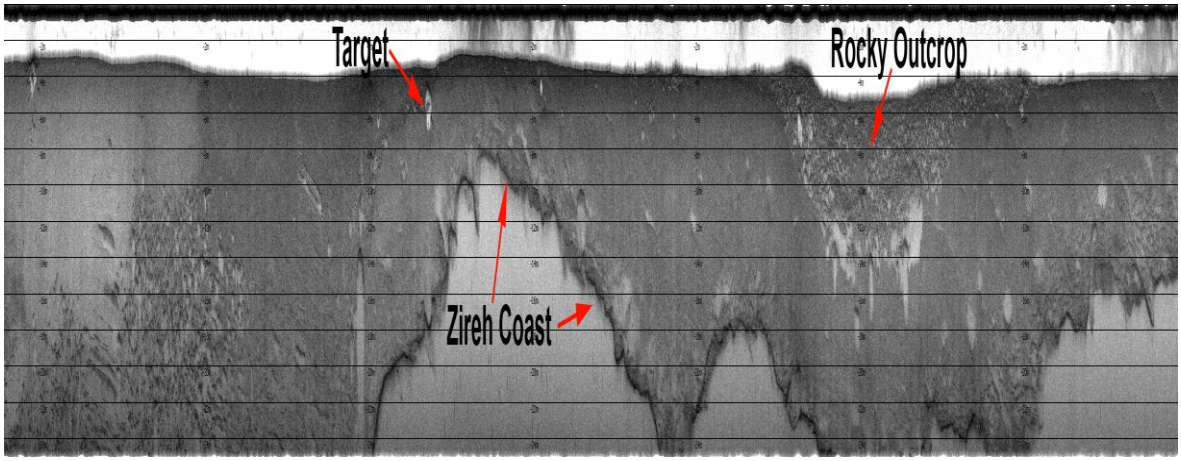

Fig. 4.3.2. Side scan sonar sonograph showing natural and targets of potential archaeological importance close to the eastern coast of Zireh island.

5. SHORT-TERM PLANNING

The next phase of the second survey period (2018) of Saida project 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.

Special attention will be paid to the processing of the old fishing port data set. A preliminary examination of the collected data strongly suggests that the SES subbottom profiling data will allow the palaeogeographic reconstruction of the ancient harbor of Saida.

An emphasis will also be given on the processing and interpretation of the data collected in the area around Zireh Island and between Zireh and Saida coastline. Targets of potential archaeological importance have been detected around Zireh island. Moreover, the area of Zireh Island is of great importance for the reconstruction of the coastline of ancient Saida.

6. SCIENTIFIC PERSONNEL

The scientific - researching personnel participated in the field activities in Saida, Lebanon, during the survey period of October 2018, was:

- **Papatheodorou George**, Professor, Director of the Laboratory of Marine Geology and Physical Oceanography, Department of Geology, University of Patras, tel.: ++302610996275, email: gpapathe@upatras.gr, www.oceanus.upatras.gr
- **Christodoulou Dimitris**, PhD, research assistant
- **Fakiris Elias,** PhD, research assistant
- **Dimas Xenophon**, MSc, PhD candidate
- **Eric Gottwalles,** PhD, underwater archaeologist, Lecturer in Archaeology and Ancient History at Holy Spirit University of Kaslik (USEK), Lebanon.
- **Robyn Pelling,** archaeologist, HFF.

7. ACKNOWLEDGMENTS

The Saida marine remote sensing survey (survey period 2018) was funded by the Honor Frost Foundation. Special thanks go to Dr. Claude Doumet-Serhal for supervising the survey.

We would like to kindly thank Dr Eric Gottwalles, underwater archaeologist. Without his help, this survey could not have been carried out. Thanks also go to Osman El Bizri, captain of the research vessels.