A sub-bottom Profiler and Multibeam echo sounder integrated approach as a preventive archaeological diagnosis prior to harbour Extensions

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Abstract

Before excavations were carried out of the rocks and dredging spoils for extension of the Porto-Vecchio marina in Corsica, France, an investigation was carried out by the Subaquatic Office of the French National Institute for Preventive Archaeological Research. SHOM (Service Hydrographique et Océanographique de la Marine, Ministry of Defence in France), who specialised in Hydrographic and Oceanographic services, recommended that the project team couple the sub-bottom profiler with a multibeam echo sounder.

In preventive archaeology, time pressure is a significant factor in your need to compile a large volume of data. Archives such as archival maps, old spatial data and data from more recent surveys including meta-data from a sub-bottom profiler and multibeam echo sounder, can be superimposed on the dataset of current marine maps after which all statistics can be integrated in a Geographical Information System (GIS).

All of the processed data were exported in QGIS®™. The GIS allowed us to subdivide or categorise the abnormalities according to different parameters. GIS is a meta-data compilation tool—a guide for archaeologists to strategically choose what to excavate.

Keywords

Sub-bottom profiler, multibeam echo sounder, GIS, harbour

Introduction

This investigation was carried out in France, more specifically at Corsica in the Mediterranean, between September 2015 and June 2016, at one end of the bay of Porto-Vecchio including a part of the maritime public domain (Figure 1). The Subaquatic Bureau of the French National Institute for Preventive Archaeological Research carried out the investigation, at the request of the Department of Submarine and Subaquatic Research of the Ministry of Culture. It was carried out before excavation of the rock and dredging spoils in order to extend the marina in Porto-Vecchio. According to Pelgas (2015b: 338), a similar survey was conducted in 2013 in the commercial port at Porto-Vecchio with superposition of different data.

Methodology

With preventive archaeology, limited time is a key factor in the compilation of large volumes of data, so how can this be best organised? Most of the old spatial data could be superimposed onto the dataset of the current marine map and survey, superimposed onto the architect's project plan, and then all could be integrated in a Geographical Information System (GIS, cf. Figure 2). In general, for old maps, transferring them into a GIS is not easy, potentially resulting in significant distortions in measurements due to incompatibilities. In this example of an eighteenth-century map, we already see the Porto-Vecchio harbour; however, the data is more qualitative than quantitative.

The old postcards also provide useful information, showing: a two-masted schooner and an anchored four-masted boat in this part of the bay in shallow waters, dated to the beginning of the last century, probably in the 1920s. This data could be associated only with a reference to the area (raster grid with web link) with the zoom in scale minimal and maximal visibility. Historical data studies including maps can provide information about marine deposits or erosion. Data was compiled and superimposed onto the current marine maps.

Different plotting was incorporated in the GIS using lead lines (fat covered) between 1884 and 1891 by SHOM, in the harbour and the gulf (Figure 3). It provides us with data relating to the seabed's evolution. These bathymetric figures have respectively provided 1291 and 1017 measurements. With the time constraints faced, measurements were of utmost importance using monobeam in 1979 and 1987, with the vertical sounder

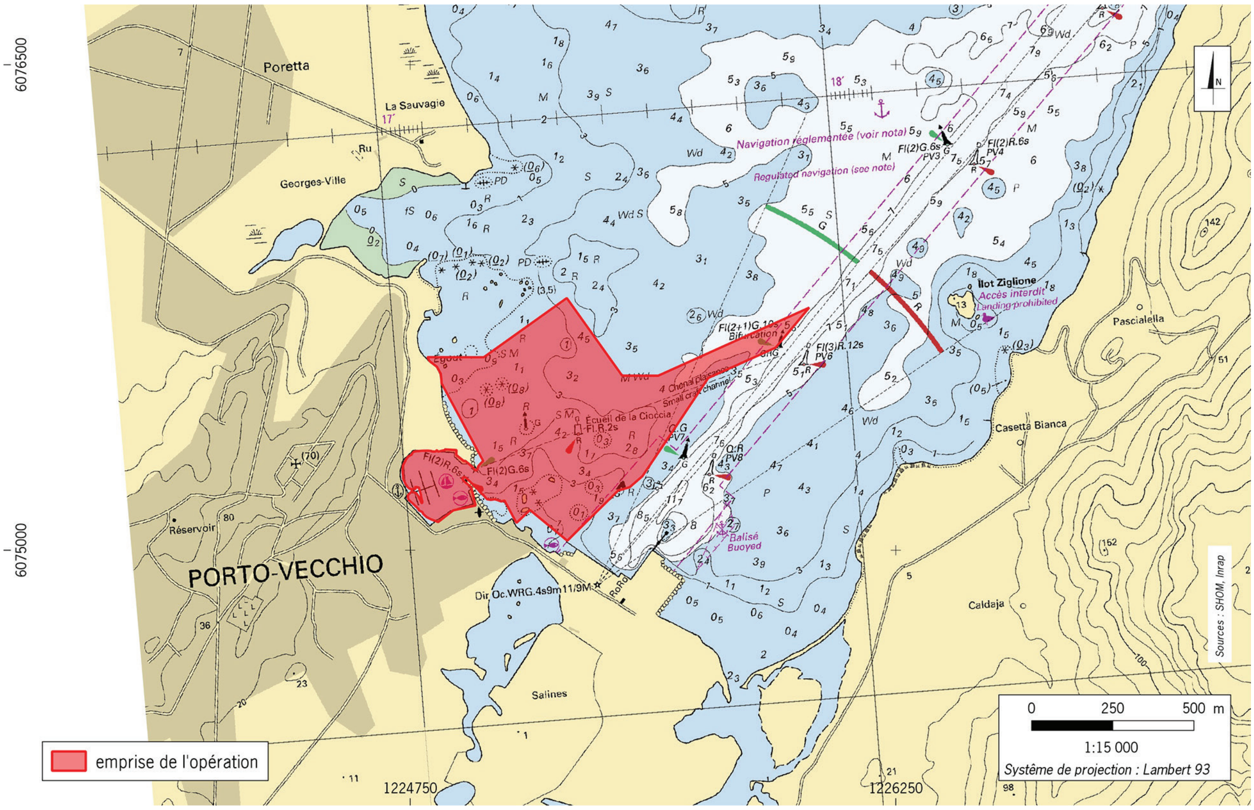

Figure 1. Area under investigation.

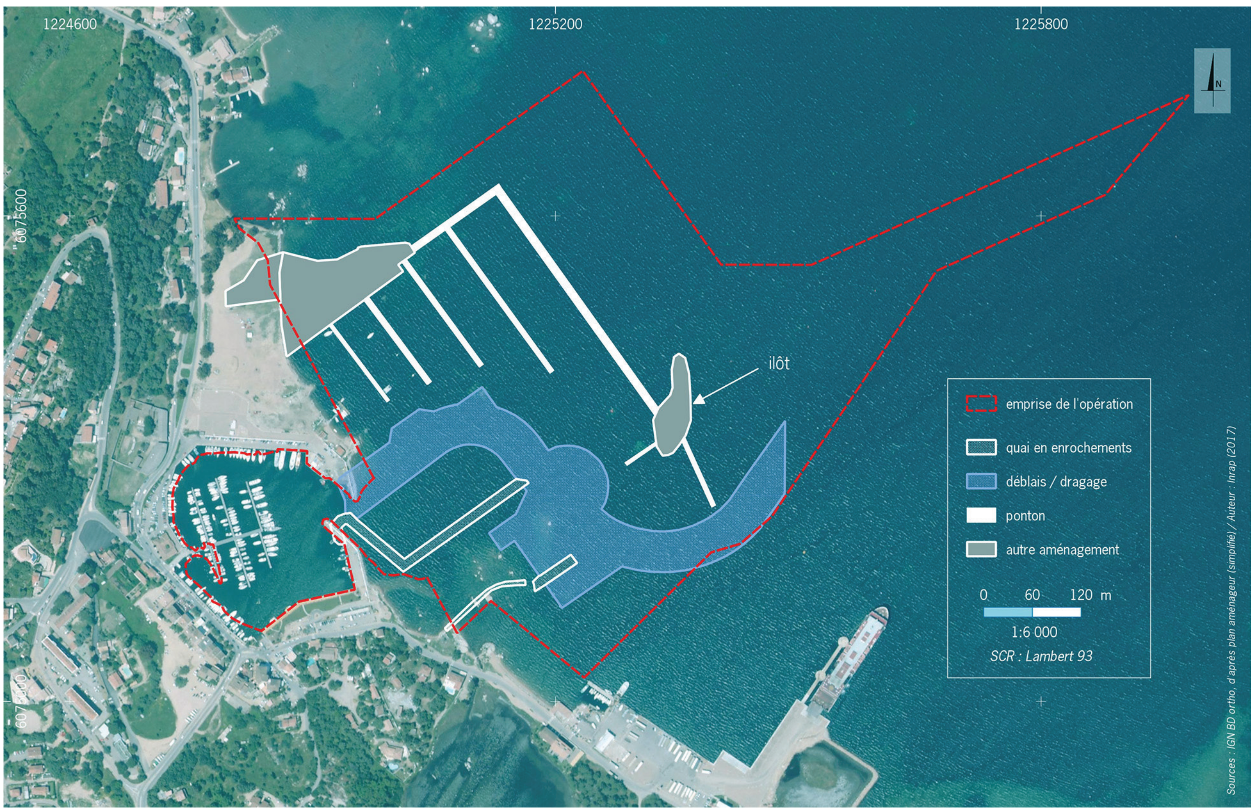

Figure 2. Results of the investigation superimposed onto the harbour development plan.

Figure 3. Lead lines (fat covered) between 1884 and 1891, SHOM data.

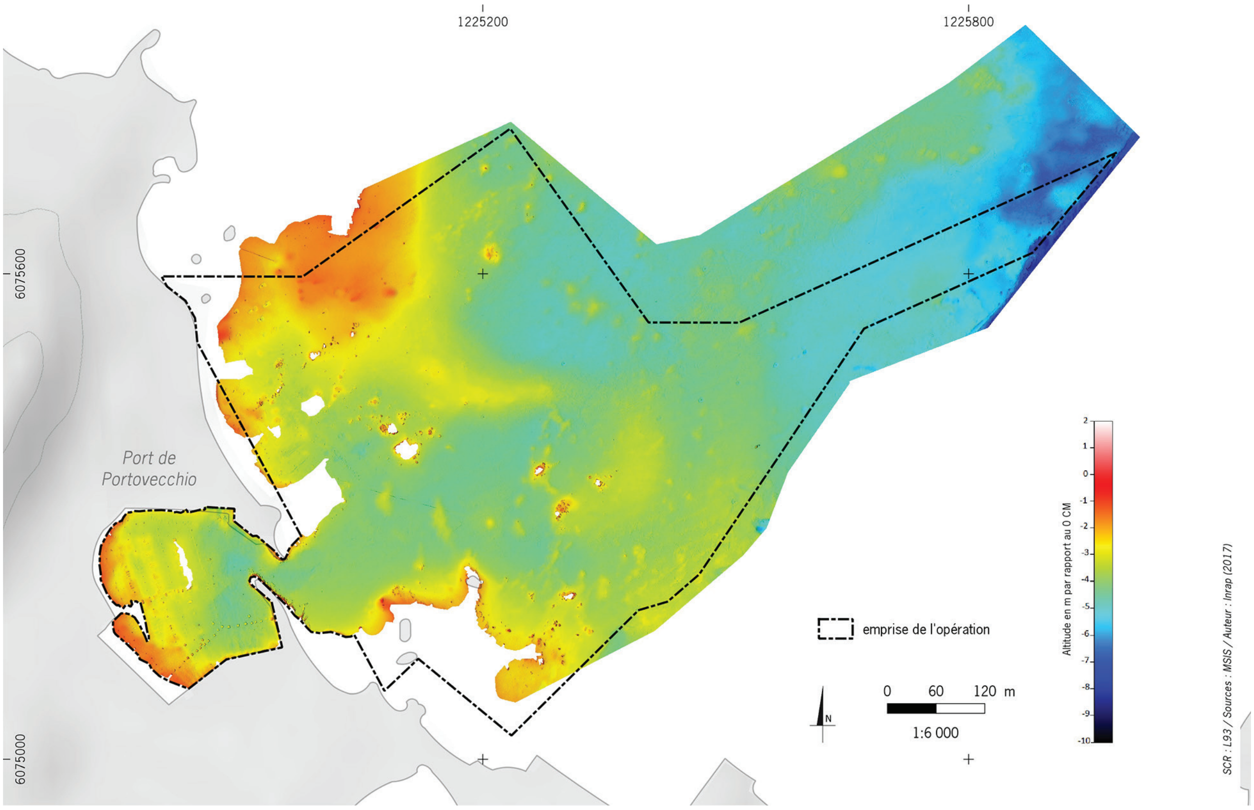

Figure 4. 2015 Mesuris bathymetric map.

DESO20, with 6060 and 9676 measurements within the same area.

One step that produced a significant volume of data was the sub-bottom profiler survey, which has been requested by DRASSM of the Ministry of Culture. However, before this step, according to Pelgas *et al.* (2015a: 89), in order to carry out an effective sub-bottom echo-sounder survey, it is very important to construct a very good quality bathymetric Digital Elevation Model of the area. It is an important preliminary step (Figure 4). Caiti (2009: 149) has already indicated that multibeam allows us to carry out a very accurate plan of an archaeological area.

The metadata files include:

- Position of the different seismic emissions;
- Speed of the vessel;
- The name of each acoustic profiling; and,
- The number of ping emissions.

SHOM, who specialises in Hydrographic and Oceanographic services, recommended coupling the sub-bottom profiler with a multibeam echo sounder. We have used the seabat® 7125 with Teledyne Reson (511 beams on an angle of 160° with a cadence of 40 measurements per second). Data acquisition allows us in this case to obtain up to 25 probe spots per square metre. A reference station was established on land with global system for Mobile Communication 'GSM' liaison with the Global Positioning System 'GPS' on the boat. INRAP collaborated with Mesuris Company to implement an underwater survey using the multibeam echo sounder and the sub-bottom profiler.

The use of the multibeam echo sounder has the advantage of reliable positioning; and, is vertically accurate to +/– 10cm, and horizontally accurate to +/– 2cm. Another advantage is that should the abnormality be covered with sediment after the survey, the reliability of the positioning will increase the likelihood of relocating the anomaly. In the boat, the team has a real-time follow-up of the survey on the screens; and, under the hull, there were tools (multibeam and sub-bottom connected to the inertial central). It is also important to measure the velocity of the acoustic wave in the water, according to the temperature and the salinity.

The seabed detection is carried out by analysis of the beams dispersed in all directions. The reception aerial is made up of transductors that digitise the echoes reflected from the seabed and its features (seabed profile, rocks, etc.). We obtain a matrix containing the depth measurements of the seabed on the acoustic signal received. It is the reflectivity of the samplings, which

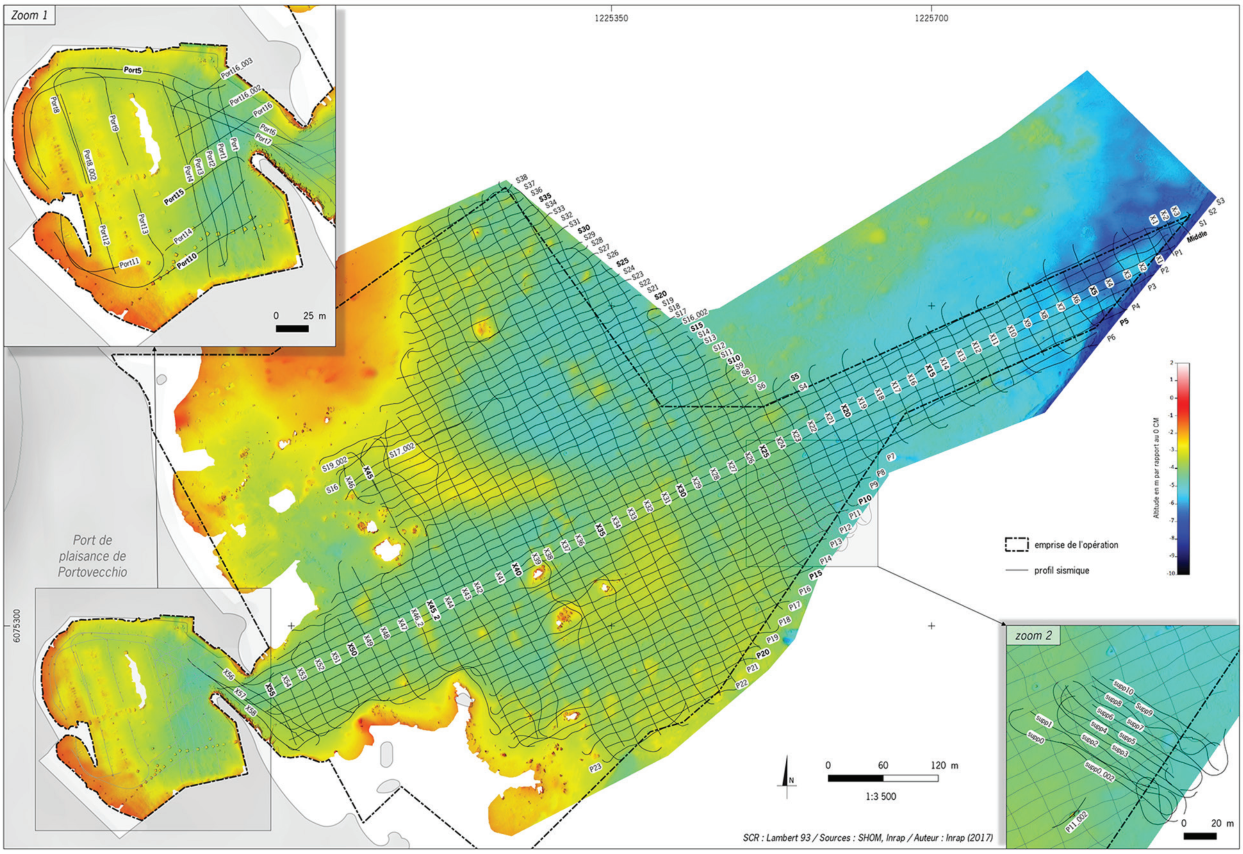

Figure 5. Sub-bottom profiles.

create an acoustic imaging. In the QINSy software™, the probe reserved is an average of the probe data. The bit map density gives us a Digital Elevation Model with centimetric accuracy. The multibeam is connected to the inertial unit, and the GPS (Real Time Kinematic) is connected with the shipping package software QINSy™.

The high definition is obtained by other captors and sensors of the inertial unit, to compensate for the rolling motion, pitching and heaving, and the change of course, in order to ensure the continuity of the direction and position when the GPS signal is temporarily lost. To realise the Digital Elevation Model, we programmed the software package based on the required parameters. In the treatment phase, the QINSy Cloud software™ sorts the valid data and eliminates false data. For each depth range, a colour is associated to enable visualising of the 3D map.

The primary data is presented in .kml and .xtf files, and transformed into ASCII data. The 3D georeferencing carried out with the Fledermaus™ software allows us to analyse the seabed as needed. An open source viewer tool allows us to visualise the 3D map. We can represent the isobaths or not, to appreciate the depths. A geological company, which carried out the seismic refraction survey a few years ago, provided the data, which give us the area and altitude where the rock appears. It also gave us the thickness of the sediment.

The second main step of this survey was the use of the sub-bottom profiler. It is a tool to gain time and to detect what is undetectable by the multibeam. A sub-bottom profile was carried out every 7 to 10m, giving us 163 profiles with redundancy profiles established along different acquisition axes (Figure 5). It is necessary to multiply profiles with different acquisition axes to increase the chance of discovering abnormalities.

This survey was made with the slowest acquisition speed (2 knots), a necessary positioning to superimpose the survey onto the bathymetric DTM. A system attached to the vessel is preferred to a towed system. The sub-bottom raster profiles are represented on the bathymetry. Each profile is named. The superimposing of the echo sounder profiles on the bathymetric data allows setting the reading of the echo sounder profiles. The transducers are electronically controlled by Delph Seismic Acquisition software ™ and read using Delph Seismic Interpretation software ™. Delph Interpretation exported the native data to XTF to SEG-Y file. The frequency of the sub-bottom profiler is between 5 and

Numéro	Commentary
1	stony heap scattered
2	weight tumulus elongated form 8m x 4m
3	rocks area and sand mound
4	weight tumulus ?
5	elongated form 5 m
6	elongated oval form mound
7	weight tumulus ?
8	weight tumulus ?
9	weight tumulus ?
10	weight tumulus ?
11	weight tumulus ?
12	weight tumulus ?
13	weight tumulus ?
14	weight tumulus ?
15	weight tumulus ?
16	weight tumulus ?
17	wreck area
18	wreck area
19	wreck area
D39	anchors dead body or heap chains ?
D80	
G41	probably boulder
M15	bulk 0,4m or coarse sediment accumulation ?
M16	recent wreck ?
M17	
M19	
M20	
M23	
O17	
O18	
O19	
O21	
O22	
O23	
O24	
O25	
O26	
O27	
O28	
O29	
O32	
O33	
O34	
O36	
O38	
O47	
O53	
O65	
O66	
O67	
O68	

D = Waste /M=Weight / O= Object / G = Geologic

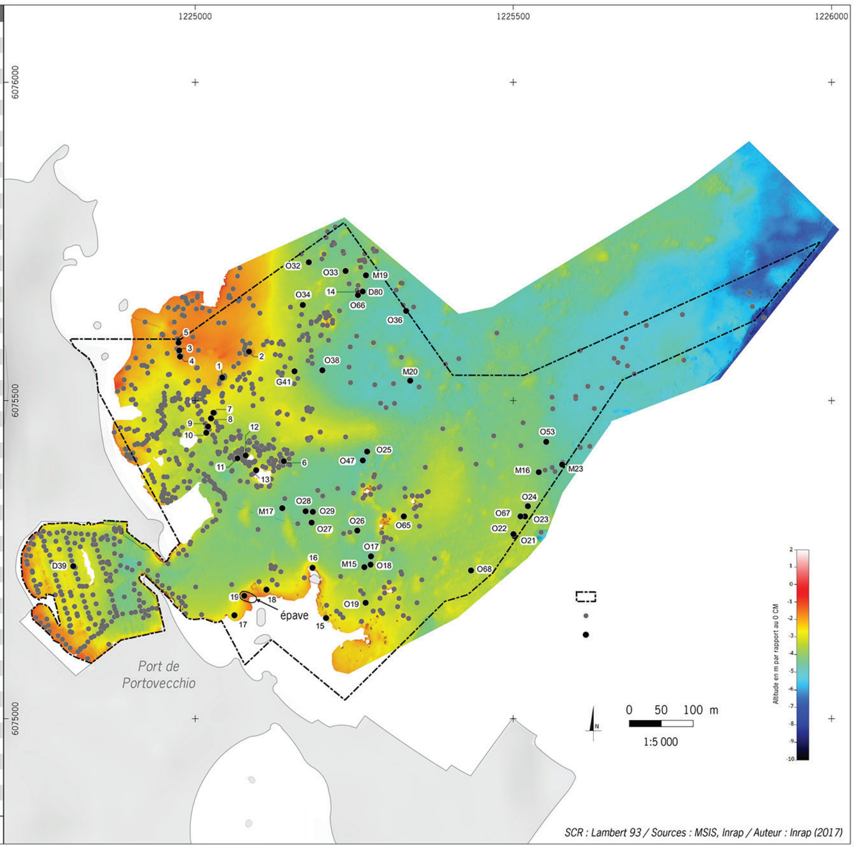

Figure 6. Selected abnormalities.

15kHz for a vertical resolution of less than 10cm and a maximum directivity of 20 degrees. It is readable with other seismic scoring software (Kogeo, an open source software), or in Kingdom seismic and geological interpretation of HIS Kingdom® (purchased software).

The importation of the navigation data in Shape file corresponding to each profile is carried out.

A selected profile can be read, and we can see where the other perpendicular profiles are; and, we can determine the burial depth of abnormalities. All the processed data (Shape file) can then be exported in QGIS®™ (an open source GIS software). We have for each data, the .dbf, .prj, .sbn, sbx, shpp, and .shx files.

Analysis

The GIS allows us to subdivide or categorise the abnormalities according to different parameters. The depth of burial and depth to the water surface will be recorded for each abnormality. The advantage of carrying out the preliminary DTM is to compare some abnormalities and their positioning (Figure 6). The GIS allows us to see structures as a pipe sometimes on the bathymetry, and on the sub-bottom profiles the continuity of the burial pipe.

Abnormalities were selected and sorted in order to be verified soundings (concrete mooring) with water dredge. We have seen vertical positioning 'ultra-accuracy' with a vertical resolution of 7cm and horizontal resolution between 15 and 25cm with 3 knots.

Results

One of the abnormalities was a stone 5cm above the bedrock —a wreck was discovered in an area covered by multibeams: some frames, wooden hull lining girders and metal remains, which possibly covered the hull (unknown today) as well as nineteenth-century artefacts (roof tiles with printed dates). The multibeam picture indicated rock or anthropic abnormality. All the others have given geological results or layers of hardened shells. All information could be exported in the GIS.

Conclusion

GIS is a meta-data compilation tool, but it requires a significant amount of time (several months, in this case, to analyse all files, compile and select). It is a guide for archaeologists in the strategic selection of where to conduct excavation.

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