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French experience using sub-bottom profiler combined with sonar multi-beam as a preventive archaeological diagnostic before dredging

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INTRODUCTION

Underwater archaeological diagnosis of several tens or even hundreds of hectares can be conducted nowadays using geophysical surveys. The use of acoustic tools is emerging as a fundamental step in the diagnosis before sending divers to do visual surveillance or excavation.

METHODS AND INSTRUMENTS

There are three types of systems: those that visualise the seabed (side-scan or multi-beam sonar), those that measure the intensity of the magnetic field (magnetometer) and those which enter the sediment at depth (sediment echo-sounder or sub-bottom profiling). We will look at a combination of two of these systems. Faced with a lack of authoritative guidance using industrial protocols for on the use of these tools, Inrap decided in July 2014 to develop preventive archaeology protocols using geophysical data acquisition (Mesuris) and protocols from SHOM (Service Hydrographique et Océanographique de la Marine). A committee of acoustic tool experts considered how these systems and software could be used to explore the data, using “filter measurement” and other mathematical treatments to analyze the signal.

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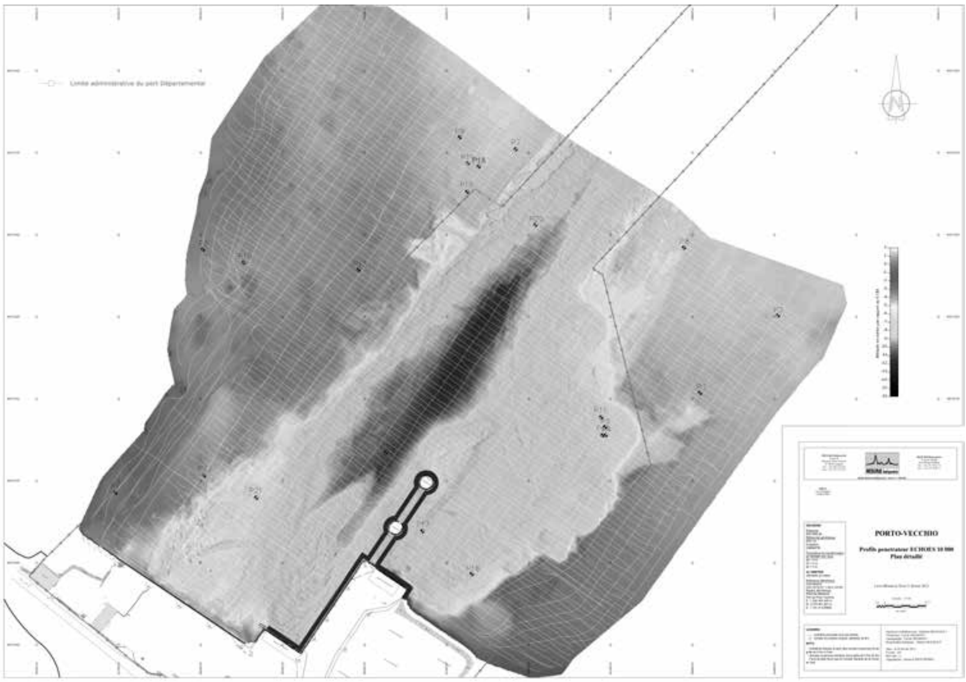

Fig. 1. Bathymetry DTM made with multi-beam sonars and sub-bottom profiles in Porto Vecchio (Mesuris)

Expert recommendations led to coupling the sub-bottom sediment echo-sounder with a multi-beam sounder (Fig. 1). Thus, Inrap collaborated with Mesuris to implement an underwater survey using multi-beam sonar (type Reson 8101) and a sub-bottom profiler (Echoes 10,000; XBLUE Company).

The use of a multi-beam echo sounder has the advantage of reliable positioning between one and ten centimetres or less. Another advantage is that even should the anomaly be covered with sediment after the survey, the reliability of the positioning will increase the likelihood of relocating the anomaly. In recent years, in Europe, multi-beam has been used in various locations for performing high-precision readings (Caiti 2009). According to Fuertes (2009: 126), from a methodological point of view, prospecting or diagnosis must be based on sea-bed mapping. As for the sub-bottom profiler surveys, they are recommended for non-intrusive diagnosis to understand sediment over the first few meters or tens of meters.

SURVEY OF PORTO VECCHIO

The Inrap Bureau of Subaquatic Activities was commissioned in February 2013 to do an underwater archaeological survey of the commercial port in Porto Vecchio in Corsica

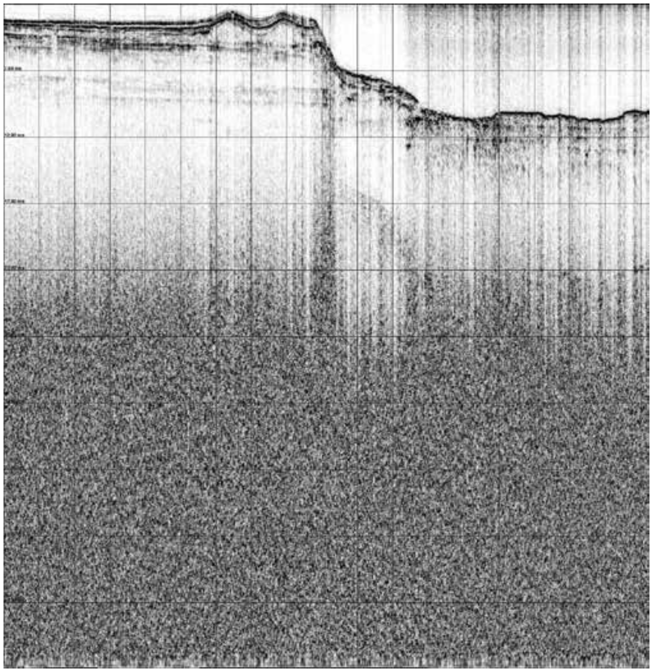

Fig. 2. Sub-bottom profile (SHOM)

(France) prior to conducting dredging work. The objective was to find shipwrecks, as well as port structures and any other manmade features.

Mesuris constructed a bathymetric Digital Terrain Model of the area (Fig. 1). A sub-bottom profile was carried out every 5 m, giving a total of 189 profiles (Fig. 2). The frequency range of the sub-bottom profiler (Echoes 10,000) is between 5 and 15 kHz for a vertical resolution of less than 10 cm and a maximum directivity of 20°. The transducers are electronically controlled by DELPH Seismic Acquisition software and read using DELPH Seismic Interpretation software. The native data to XTF were exported to SEG-Y (unformatted). They are readable with other seismic scoring software (Kogeo, Kingdom Suite, etc.).

Following the survey, SHOM made the following recommendations:

– slowest possible acquisition speed (2 knots),

– positioning paramount to superpose survey on the bathymetric DTM,

– system attached to vessel preferred over towed system,

– redundancy profiles established along different acquisition axes,

– density profiles depending on target size,

– export data processed with proprietary software in accessible and known format; proprietary software should allow export to other software (Hypack).

In addition, while conditioning the use and combination of a particular system and before starting diagnosis, it is essential to understand the geological context, sediment dynamics,

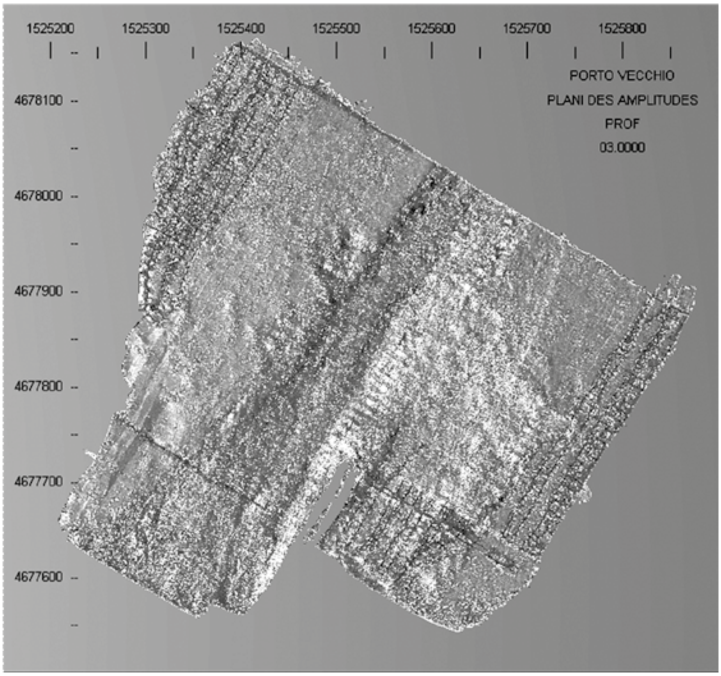

Fig. 3. Synthetic planimetry of acoustic reflectance

nature of the expected relics and their potential size. Not all the recommendations could be used in all contexts.

Seismic data (SEG-Y) were collated and analyzed by the processing chain "SID shom O-V1.11" developed by SHOM. Metadata files incorporate: position of individual seismic emission pings; speed of the ship; name of each acquired profile; ping number. These parameters are used to check the acquired profiles. Geo-referencing of each profile permits a cross-check whether the scores achieved on a profile are consistent with adjacent profiles. All the georeferenced scores are exported and integrated into QGIS (Quantum GIS V2.8).

RESULTS

The features discovered counted 51 in all. The superposition of different data in QGIS permitted an easier classification of the elements found (geological, false hyperbolic echo, anthropogenic, etc.). However, in order to differentiate between abnormalities of a geological or anthropogenic origin, additional geological research on the local area was essential.

At the same time, a mathematical analysis was conducted by B. Wirtz, using Delaunay triangulation and other calculations, including complex function, differential calculus, geometrical and analytical concepts (curvature, gauss curvature, Fourier series). For the bathymetric data, a polynomial orthogonal projection of the initial data was developed using inverse Gram

Matrix, the object being to detect slight changes in acoustic properties of the sediment, which were invisible in the initial formatting of data, but could be highlighted by a complex combination of computations.

The results identified foremost a possible fossil beach. Secondly, 3D cartography of bedrock was produced and, thirdly, several abnormalities were located. These indices are oval shaped, between 10 m and 30 m long, and from 5 m to 10 m wide, resembling potential shipwrecks.

Developments in underwater preventive archaeology and the use of different geophysical techniques will lead to improvements of acoustic tools where essential, such as the use of multi-beam sonars, sub-bottom profilers, magnetometers and side-scan sonars. Further applications will define the extent to which these methods are best suited to finding buried artefacts, depending on the hydro-sedimentary context.

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