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ΙΔΡΥΜΑ ΤΕΧΝΟΛΟΓΙΑΣ ΚΑΙ ΕΡΕΥΝΑΣ

Έργο ΠΕΦΥΚΑ: Περιβάλλον και Φυσικές Καταστροφές: Νέες μέθοδοι για τη μέτρηση και βελτίωση της ποιότητας του περιβάλλοντος και για την αντιμετώπιση φυσικών καταστροφών

# ΠΑΡΑΔΟΤΕΟ Π.2.2.1.1

## Τίτλος: Βιβλιογραφική μελέτη αναφορικά με την εφαρμογή της μεθόδου της ηλεκτρικής τομογραφίας για την διασκόπηση θαλάσσιων/παράκτιων περιοχών με έμφαση στον εντοπισμό υποθαλάσσιων αρχαιοτήτων.

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# Geophysical methods in shallow water environment: application to archaeological surveys

This report collects in the literature the methods of applied geophysics for archaeology in submarine environment and it focuses on very shallow water costal environment.

## 1 Marine electric resistivity for detection of archaeological targets

Electric resistivity survey is nowadays a standard method used for offshore archaeological prospection. Furthermore the collection of direct current resistivity data from marine environment exhibits increasing interest for geological mapping [1], plume expansion or ground-water studying [2]. However the use of electrical resistivity method in submarine archaeology is not so common [3]. Data acquisition can be carried out by using submerged or floating electrodes in conjunction with continuous resistivity profiling (CRP). Loke and Lane [4] report that the choice of either option depends on the actual investigation depth: Floating electrodes have to be used if water column is not greater than 25% of the total depth of investigation. Floating electrodes can be more easily implemented and it is faster (3-5 km/hr) to carry out the survey thus avoiding the snagging of the cable [3]. However, it causes issues when there is a large current-flow and in very shallow environments. Loke [5] recommends the use of fixed submerged arrays instead of CRP in order to avoid damaging of the cables. Orlando [6] used synthetic modeling to estimate the resolution of underwater resistivity surveys employing floating or submerged probes and her results showed that floating cables give poor images when the contrast between resistivity of water and layer is too small.

Submarine electrical resistivity data can be collected utilizing different electrode arrays like dipole-dipole which is the most widely used as its geometry is simple [7]. In addition Orlando [6] discusses the use of Schlumberger array and Rucker [1] recommends a pole-pole array for collection of marine data. Baumgartner and Christensen [8] describe a particular array where probes are vertically-aligned. The choice of submerged or floating cable and the choice of the array have an impact on the resolution and the investigation depth.

An important aspect for the marine resistivity data is the effective method for data processing. Resistivity data have to be appropriately merged with geographic data and to this direction Snyder [7] gathers the resistivity data assuming that the cable follow exactly the vessel's track. Hence, the navigation data can be used for the geopositioning of geophysical data.

## 2. Other geophysical methods for investigation in underwater archaeology

Electric resistivity is not the only geophysical data which can be used for archaeological prospection in underwater environment. Moreover, resistivity data need bathymetric measurements to be interpreted.

### *2.1 Bathymetric data for resistivity processing*

Orlando [6] discusses the importance of specific parameters like estimated value of the water resistivity and water-bottom topography (i.e. water thickness) in the accuracy of the processed data. Even the smallest errors can induce important mistakes in the final model. Water resistivity is generally assumed to be constant (measured on a sample), and the topographic information is acquired as the same time as resistivity data. Rucker [1] measures water resistivity and acquires bathymetric data during the electric resistivity survey, in order to describe the properties of the water column since this information is essential for data inversion. Topography is basically measured with an echo-sounder and water resistivity using a hand-held probe.

### *2.2 Acoustic survey*

Even if Passaro [3] defines acoustic methods as unsuitable in very shallow water, surveyors often use sonar for underwater archaeological prospection. Lawrence [9] presents an equipment built for deep water which can be used in shallow water environment as well. Multibeam sonar, side scan sonar and acoustic ground discrimination sonar are the acoustic-tools of geophysicist for mapping the water that covers submerged archaeological sites. With transducer frequencies between 100 and 700 kHz, side-scan sonar discriminates objects of 20cm or less; with a 450 kHz frequency and multibeam resolves objects of 10 cm [9].

Plets [10] presents an important case study, with a shipwreck imaging in very shallow water (2-5m depth). His method, using a Chirp sub-bottom profiler, theoretically produces images with a range of 22 to 32 cm. Moreover, he succeeded great accuracy in his geopositioning data (2 cm). Obviously, sonar images are corrupted by noise and their quality must be improved using filters like Wiener filter [11]..

### *2.3 Magnetic survey*

Boyce [12] conducted a magnetic survey on the submerged roman harbor, Caesarea Maritima. Marine magnetometers are towed behind a boat, a few meters under water level (see also [14]). Boyce set the magnetometer to acquire about one measure per meter, according to the vessel speed. In magnetic survey, a diurnal correction has to be applied on data because of variations of magnetic field. A second magnetometer (e.g proton magnetometer), is used for measuring these variations. In the case of a marine survey, the proton magnetometer is placed on the shoreline. Drape corrections are also applied on collected data, in order to offset a "'terrain effect'" which is very important in marine survey. After correction, the data of Boyce survey are gridded in 3m-cells.

Quinn [13] uses the same method in his magnetic survey of the French frigate La Surveillante. He usedan Overhauser magnetometer for the data collection, corrected them for diurnal variation and terrain effect.

### *2.4 Seismic survey*

Seismic survey can provide high resolution images. Lee [15] carried out a survey using an air gun and a channel streamer cable towed behind a boat. His method also gives high resolution data and is easier to implement in costal environment. Müller [16] applies high resolution seismic survey in an archaeological site. His method consists in the use of a boomer seismic source which emits acoustic frequencies and a hydrophone array behind the boat as a sensor array. This is undoubtedly the better way of surveying in shallow water.

Missiaen and Feller [14] use three sources at distinct frequency range. Two of these are intended to map the geological sea-bottom and the third is used for seeing more precisely the top level. This third one is a nonlinear transducer source which transmits at the same time two different frequencies. It allows a vertical resolution of about 10 cm. However, they survey in deep water, and this method is not the most suitable for shallow water.

### *2.5 GPR survey*

Waterborne Ground Penetrating Radar in general does not give satisfactory results in conductive water. However, improvements in GPR technology nowadays allowed geophysicists to use it even in salt water with a penetration of a few meters [36].

## 3 Conclusions

In conclusion, many different geophysical prospecting methods exist for underwater archaeology such as electric resistivity, acoustic survey, magnetic survey, seismic survey or GPR survey. Each method is specific to the size of the target object and its depth, the resolution of the data, the array of acquisition. Each collection of data requires treatment and correction in laboratory to be interpretable.


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