# Geophysical Investigations in Podstrana Municipality and in Maritime Sport Society "Spinut" - Croatia

Report of the 2019 Electrical Resistivity exploration campaign

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1. INTRODUCTION

The present report describes the operations performed during the spring 2019 geophysical exploration campaign in the Split County (Croatia). The object of the survey was to investigate the subsoil to characterize the seaside/coastal environment and the area around a marine port, in order to understand the circulation of the fresh water in the costal environment

During the spring 2019 exploration campaign, electrical data with two different Systems were collected. Then, the data were analyzed using the Electrical Resistivity Tomography (ERT) technique. The surveys have been carried out in two different areas: one along a beach in the Podstrana Municipality and the other in the area of the marine port of Spinut Society (Figure 1).


**Fig. 1.** Map of the investigated areas: Podstrana site and Spinut site (Export from G.E. Pro)

2. GENERAL SETTINGS

The areas where the geophysical surveys were undertaken exhibit a smooth topography, with small elevation differences between electrodes.

The near surface stratigraphy is mainly consisting of gravel, sand – silty layers over a limestone bedrock in both sites. The bedrock outcrops along subvertical planes in some areas. The outcropping bedrock is more common in the Spinut site, while it consists of marly limestone in Podstrana (Figure 2).

Under the electrical point of view, the subsurface background could be considered a low resistivity medium.

**Fig. 2.** Example of outcropping marly limestone in Podstrana.

## 3. INSTRUMENTS AND OPERATING PRINCIPLES

### 3.1. The Electrical Resistivity Tomography (ERT) method

The purpose of electrical surveys is to determine the subsurface resistivity distribution by making measurements on the ground surface. From these measurements, the true resistivity of the subsurface can be estimated by using the ERT method. The ground resistivity is related to various geological parameters such as the mineral and fluid content, porosity and degree of water saturation in the rock. Electrical resistivity surveys have been used for many decades in hydrogeological, mining and geotechnical investigations. More recently, it has been used for environmental surveys. The fundamental physical law used in resistivity surveys is Ohm's Law that governs the flow of current in the ground. The equation for Ohm's Law in vector form for current flow in a continuous medium is given by

$$J = \sigma E;$$

where $\sigma$ is the conductivity of the medium, J is the current density and E is the electric field intensity. In practice, what is measured is the electric field potential. In geophysical surveys the medium resistivity $\rho$, which is equals to the reciprocal of the conductivity ($\rho$=1/$\sigma$), is more commonly used.

Geoelectrical surveys are based on the classic electrical quadripole configuration (Figure 3). The calculated resistivity value, from the measured potential V and current intensity I, is not the true resistivity of the subsurface, but an "apparent" value that is the resistivity of a homogeneous ground that will give the same V and I values, for the same electrode arrangement. To determine the true subsurface resistivity distribution from the apparent resistivity values is an "inversion" problem, which can be solved using the ERT method.

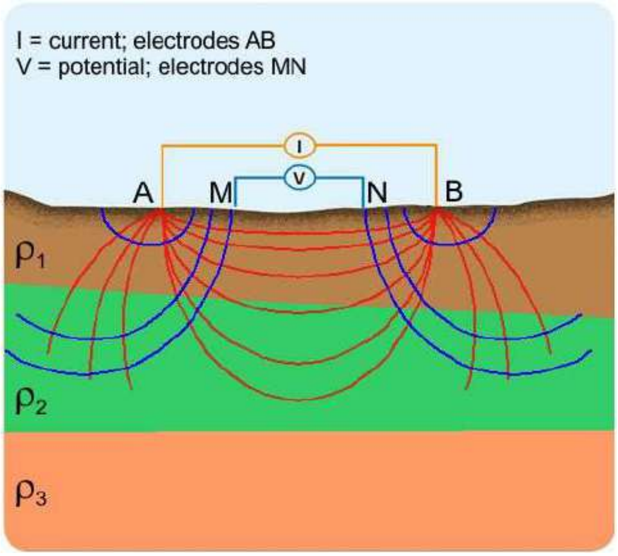


**Fig. 3.** Electrical quadripole A and B:current electrodes; M and N: potential electrodes.

Two-dimensional geoelectrical surveys are usually carried out using a large number of electrodes, 25 or more, connected to a multi-core cable. An electronic switching unit connectes the cable to a laptop computer, which is used to automatically select the relevant four electrodes for each measurement. Figure 4 shows a typical setup for a 2-D survey, with a number of electrodes along a straight line attached to a multi-core cable.

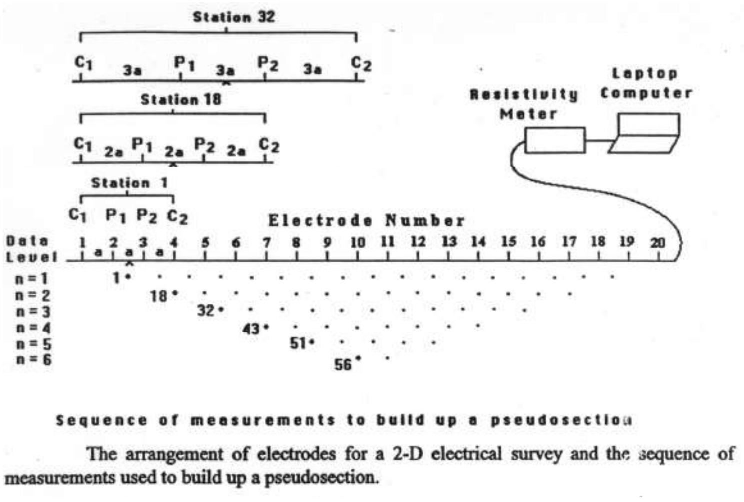


**Fig. 4.** Electrical quadripoles along a 2-D survey. Cx:current electrodes; Px: potential electrodes.

Normally a constant spacing between adjacent electrodes is used. In a typical survey, most of the fieldwork consists in laying out the cable and electrodes. The measurements are taken automatically, and stored in the computer. To obtain a good 2-D picture of the subsurface, the coverage of the measurements must be 2-D as well.

The object of geophysical inversion consists in seeking for a model that gives a response that is similar to the actual measured values. The model is an idealized mathematical representation of a section of the earth, and consists of a set of parameters that are the physical quantities we want to estimate from the observed data. The model response consists in synthetic data calculated from mathematical relationships (e.g., Poisson's equation), which are compared to the measured data. All inversion methods essentially try to determine a model for the subsurface whose response agrees with the measured data subject to certain restrictions. In the cell-based method used by the RES2DINV and other programs, the model parameters are the resistivity values of the model cells, while the data are the measured apparent resistivity values. The mathematical link between the model parameters and the model response for the 2-D and 3-D resistivity models is provided by the finite-difference or finite-element methods.

The initial model (Figure 5) is changed using an iterative approach based on the reduction of the difference between calculated and measured apparent resistivity.

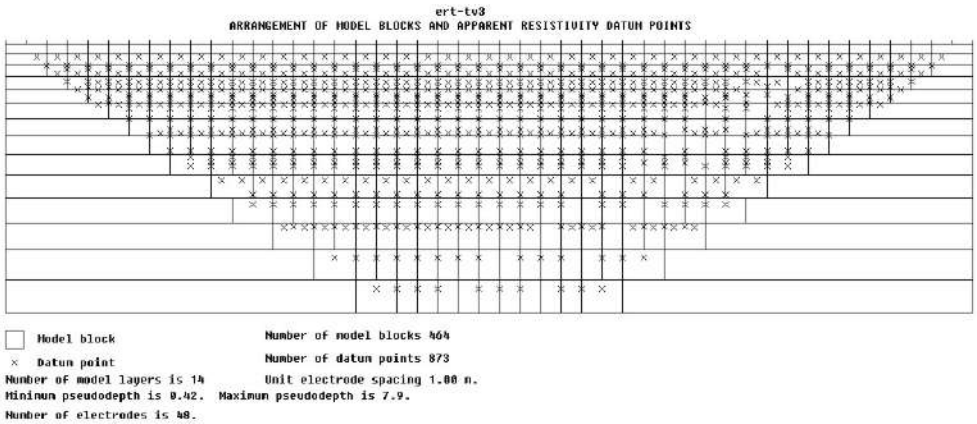


**Fig. 5.** Initial model in the resistivity inversion program RES2DINV.

## 4. DATA ACQUISITION AND FIELD OPERATIONS

### 4.1. Resistivity acquisition data

Resistivity data in Podstrana and Maritime Society Spinut have been collected both using an IRIS Syscal R1 geo-resistivimeter (Figure 6, 7, 8) and the MultiSource Wireless Data Acquistion System (Figure 9). The former was attached to stainless steel electrodes via multicore cables, capable of handling simultaneously 48 electrodes, while the latter consists of 8 transceiver units communicating with each other according to wireless protocol. The quadripolar Wenner and the dipole – dipole geometry configurations were adopted for the two systems, respectively. The survey were designed to image the shallow structure of the subsoil, providing a maximum theoretical depth of investigation of about 15 meters.

Particular attention was devoted to the electrode ground coupling. To reduce contact resistances and improve data quality, each electrode was watered using salt water.

Before every acquisition, a contact resistance check was done; after electrode watering, the measured values of the resistance was in the range of 200 - 800 ohm for all adjacent electrode couples, reflecting good operational conditions.


**Fig. 6.** Particular of the electrode coupling in the Podstrana beach

4.2. Podstrana area

In the Podstrana area the geophysical surveys were acquired along three lines: ERT 1, 2 and 3, oriented parallel to the coast. Two lines (ERT1 and 2) were acquired on the beach while the third at sea along the shoreline. The profile 2 (ERT 2) was acquired using both the Syscal and the MultiSource System, in order to integrate the resistivity data and to improve the resolution of the electrical resistivity imaging.

For each Syscal – ERT profile, the electrode spacing was 2 m, for total survey length of 94 m. The electrode spacing for the Multisource System survey was 5 m, for a total line length of 115 m.


**Fig. 7 – 8.** Field operations with the IRIS Syscal R1 geo-resistivimeter in the Podstrana beach

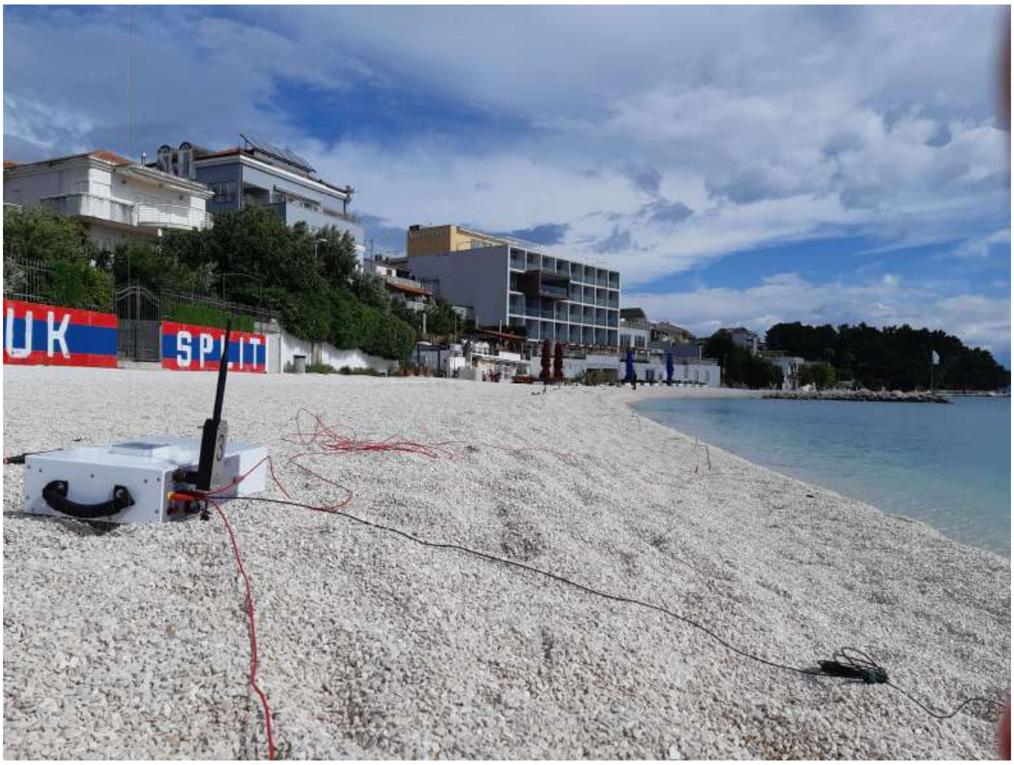

**Fig. 9.** Field operations with the MultiSource Wireless Acquisition System in the Podstrana beach

4.3. Maritime Sport Society “SPINUT” area

In this area the resistivity data were collected along 2 adjacent Syscal profiles and one MultiSource profile, overlying the Syscal surveys. Each Syscal line is 94 m long, while the Multisource line is 115 m long. As in Podstrana, the electrode spacing was 2 m for Syscal surveys and 5 m for MultiSource survey.

**Fig. 10.** Field operations in the Maritime Sport Society “Spinut”