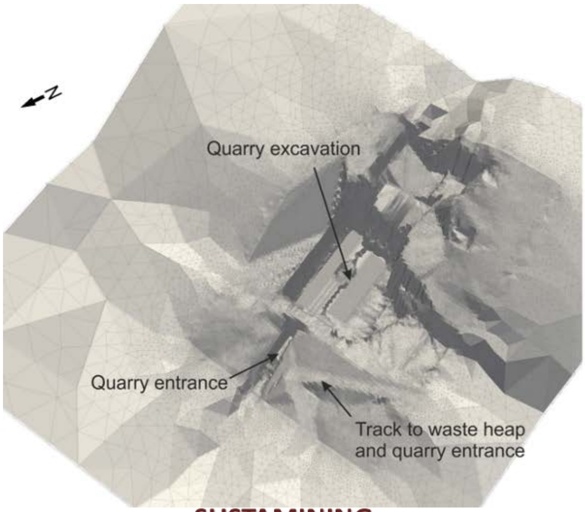
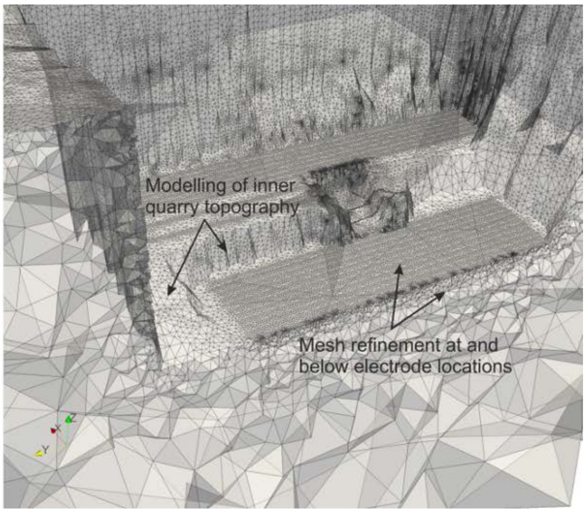
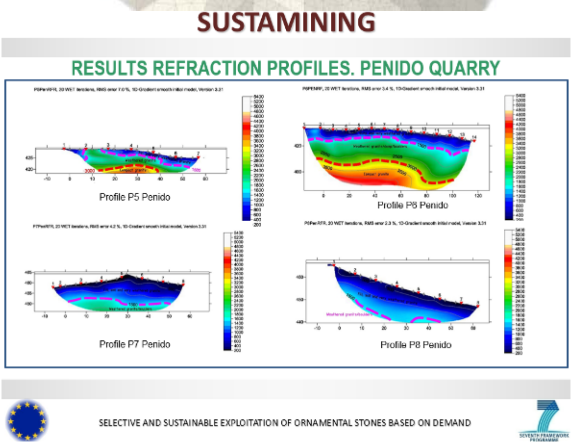
NOTIO ASSOCIATION

ELECTRICAL RESISTIVITY TOMOGRAPHY







NOTIO Association

Clay Technological Centre

C/ Río Cabriel s/n – 45007 Toledo

Tel.: 925 24 11 62
info@notio.es
www.notio.es

SUMMARY

1. PHYSICAL FUNDAMENTALS OF THE ELECTRICAL RESISTIVITY TOMOGRAPHY

The electrical tomography is a method of electrical prospecting in direct current that allows to model the structure of the subsoil by measuring the resistivities of the materials that constitute it.

1.1. ELECTRICAL BEHAVIOR OF THE ROCKS

The electrical behavior of the rocks depends on the nature of the minerals that constitute them, the porosity and degree of alteration (cracks, fractures, etc.) and the content of fluids in their pores and / or fractures, as well as the nature of the same.

If the conductivity of rocks depends only on the minerals that form them, practically all rocks should be considered insulating, since the minerals that make up the great majority of rocks present in nature are so (quartz, silicates, calcite, salts, etc.). Only metallic ores, with an appreciable amount of semiconducting minerals in their composition, could be considered semiconductor. However, practically all the stone masses have pores / fractures / fissures in greater or lesser proportion, which are usually occupied totally or partially by fluids, more or less conductors, from which it turns out that the rocks behave as ionic conductors, of resistivity very variable. Therefore, the resistivity of the rock depends, generally, on five factors.

- The porosity is the ratio between the volumes of the pores and that of the rock. When dealing with saturated layers (under the water level, that is to say under the vadose zone where the pores are filled with air and with water), the water content is equal to the porosity.

  Porosity = (volume of pores) / (volume of the rock)

  Being a ratio, the porosity is expressed in %. The total porosity also includes the water located in clay, even if clay is impermeable. For the exploitation of water, it is important to determine the porosity of free water (water which can move), and hydrogeologists speak of the effective porosity which is the ratio of the volume of the pores which are interconnected to the volume of the rock. As an order of magnitude, the effective porosity can be for instance 80% of the free water porosity. The porosity of a fissured rock can be a few percents, that of a gravel or a sand of the order of 30 percents.

	Margas	Clay	Gravels	Sand and Gravel	Sand uniform	Fine and medium Sand	Recent Alluvium	Limestones	Slates or shale
Porosity (%)	47-50	44-50	25-40	20-35	35-40	30-40	5-15	0,5-17	1-10

Porosity of some rocks (the values depend on the degree of compaction).

- Of the geometrical arrangement of the pores (called the formation factor). The resistivity decreases when the pores are more elongated and are oriented so that there is a greater connection between them, since it facilitates the mobility of the fluids between them.
- Of the proportion of holes filled with water versus dry holes. A greater proportion of water filled voids implies a decrease in resistivity since water allows a greater circulation of electric current than air.
- Of the nature of the water; pure water is very poorly conductive due to its reduced dissociation. The resistivity of the distilled water is about 10^5 Ω m. so it can be considered as an insulator. The waters found in nature have, however, appreciable conductivity, as they always have some salt dissolved. Groundwater has resistivities of 1 to 20 Ω m. and the marine waters of about 0.2 Ω m. Therefore, the higher the water conductivity, the lower the resistivity of the formation that contains it.
- Of the temperature; this parameter significantly influences the resistivity of the fluids in the pores. In particular, a drop in temperature causes an increase in resistivity and at the freezing point water changes from a dielectric to a bad conductor.

Igneous and metamorphic rocks generally have high resistivity values (between 10^3 - 10^5 Ω m.). The resistivity of these rocks depends very much on the degree of fracture they present and on the percentage of water that fills the fractures.

Sedimentary rocks are commonly more porous and have a high water content which usually decreases resistivity values.

Soils are a mixture of rocks, water and other organic and inorganic materials. This composition causes the resistivity of the soil, apart from depending on its intrinsic composition, depends on other factors such as temperature, humidity, pressure, etc. which can cause the same soil to have different resistivities over time. Humidity is the most important factor. Different degrees of humidity for the same soil can give rise to different resistivities that could lead to erroneous interpretations regarding the composition of the constituent materials of the same. Clay soils usually have lower resistivity values than sandy soils. Wet floors have resistivity values between 1 and 10^3 Ω m.

The soil water resistivity varies between 10 and 100 Ω.m depending on the concentration of dissolved salts. The low resistivity of sea water (0.2 Ω.m) is due to the high salt content, which makes the electrical tomography method an ideal technique for delimiting the depth filtration of old land dams.

As for industrial pollutants, metals, such as iron, have extremely low resistivity values (10^{-8}-10^{-7} Ω.m). Chemicals, such as sodium and potassium chloride, can greatly reduce the resistivity value of soil water to less than 1 Ω.m at moderate concentrations. The effect of electrolytes, such as acetic acid, is comparatively minor. Hydrocarbon compounds, such as xylene, typically have very high resistivity values (> 10^{14} Ω.m).

Resistivity values vary over a wide range compared to other physical quantities obtained by other geophysical methods. The resistivity of rocks and soil in a study area can vary by several orders of magnitude. In comparison, in gravimetric investigations in which differences of densities are measured, changes usually occur below a factor of 2. Seismic velocities normally do not change by more than a factor of 10. This makes the electrical tomography method a very versatile geophysical technique.

1.2. APPLICATIONS

- Identification of altered rocks. One of the most common applications is the location and definition of the extension of the alteration band in granitic terrains to know the possibility of ripping or the need to blast certain sections of a linear work. With regard to the granite alteration band, it is quite normal for it to appear in the upper part and, consequently, its presence can be controlled. But it is not uncommon for this more disintegrating material to be located at a greater depth, below a more compact surface section, whose impossibility of observation requires detection by geophysical prospecting.
- Determination of alteration coating on metamorphic rocks such as schists
- Location of fractures in calcareous soils covered by a layer of clay material. In compact rocks, high resistivity isolines are present. When a discontinuity occurs in these lines, the inflection zone indicates the presence of fractures. It has been proven that the electrical tomography successfully solves the geological structures formed by a fractured base in blocks of different size (detects fractures) and covered by a detrital sedimentary layer.
- Location of galleries and karstifications. The mine and karstifications galleries present high values of resistivity if the fluid that occupies them is air, with which they are perfectly identifiable with the electrical tomography method.
- Channeling location; the conductive character that causes a basically metallic channeling through which the water circulates causes the presence of anomalies very little resistive that can be identified as channeling, which allows to identify its position and depth.
- Identification and mapping of archaeological ruins; the isolated ruins, as in the case of tombs and, above all, the buildings, present geometric characteristics

that, after being detected, can be mapped and thus show their distribution and extension.

Disposal of electrodes in the field.

1.3. OPERATIONAL METHODOLOGY

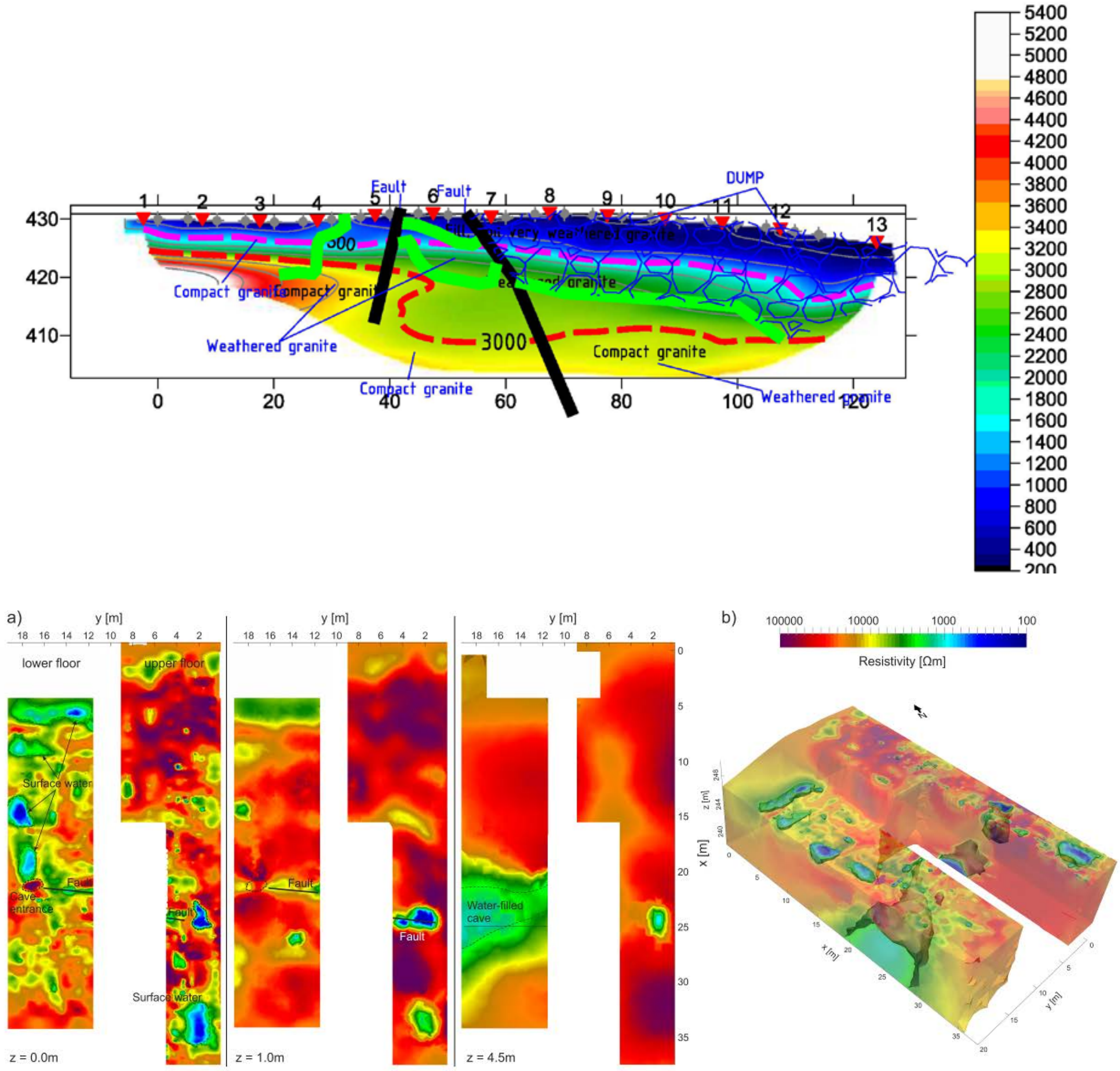
The electrical tomography method is based on the implantation of numerous electrodes, with a determined separation, in a longitudinal profile on the ground. All the electrodes are connected to a cable that in turn is attached to the measuring equipment, determining, before making the measurements, which will be the quadripoles of the entire profile that will perform the measurements and with what arrangement.

Each of these quadrupoles makes a measurement of the resistivity that is attributed to a certain geometric point of the subsoil whose position and depth in the profile depend on the position of said quadrupole and the separation between the electrodes that comprise it.

The device consists of two pairs of electrodes, two emitters and two receivers. The direct current is injected through the emitting electrodes and the potential difference is measured in the second pair of electrodes.

The profiles obtained in the electrical tomography studies are sections of the terrain that reflect the distribution of apparent resistivity values at different depths, corresponding to the different research layers. This information is later treated by mathematical inversion algorithms to obtain the images of real resistivities of the subsoil.

The research depth depends on the spacing between electrodes and the device used (pole-pole, pole-dipole, dipole-dipole and Wenner-Schlumberger), although the lower the penetration of the research, the higher the resolution, since the depth is lower. It has a higher density of measurements since it is possible to use a more closed mesh (less distance between electrodes). In principle, the resolution of the investigation decreases logarithmically with depth.



Profiles of electrical tomography and 3D recreation for interpretation.