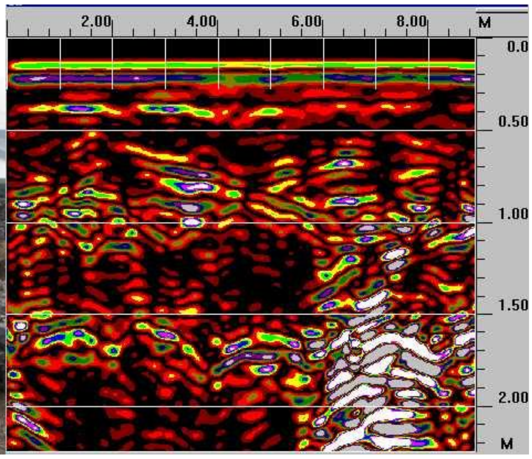
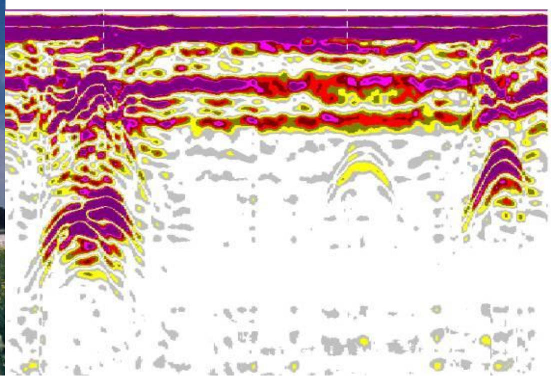
NOTIO ASSOCIATION

GEOPHYSICAL TECHNIQUE OF GPR





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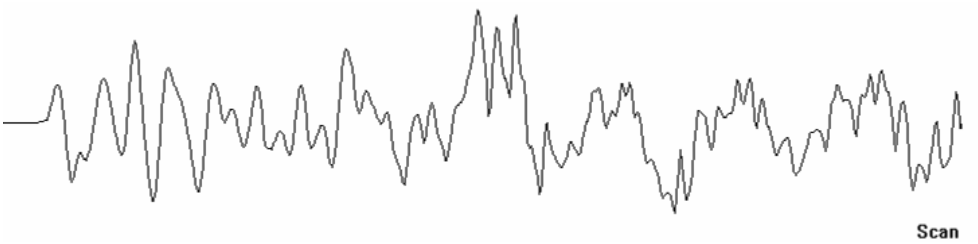
SUMMARY

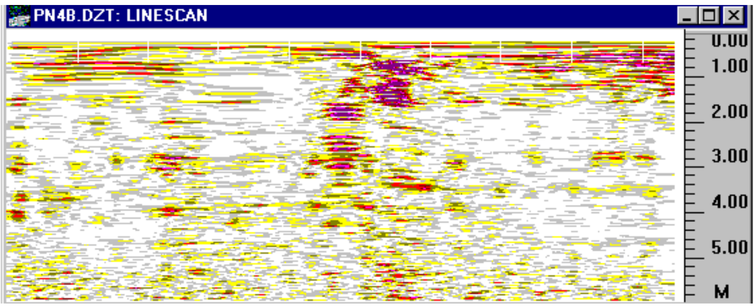
1. GEOPHYSICAL TECHNIQUE OF GPR (GROUND PENETRATING RADAR).

The use of GPR permits the emission, through antenna, of an electromagnetic wave that penetrates in the material to be analyzed, its reflection is collected by the receiving antenna in direct contact with this material. In this way a signal is recorded, which once analyzed, can detect changes of material, gaps or existing singularities inside the soil.

From a practical standpoint, the GPR can get a profile of the terrain in depth, moving the antenna in parallel with the surface along determined alignment.

The following figure shows typical signals emitted and received by the GPR. The pulse emitted by the ground penetrating radar is reflected firstly on the surface of the material and subsequently on any dielectric conductivity contrast discontinuity found in the soil.





Due to the high frequency signals from the GPR, ranging from 16-900 MHz, the attenuation is very rapid and therefore, the exploration depth is limited.

In favorable media with a low frequency antenna it can reach operating depths of up to about 30 m, but, in most cases, the effective depth of inspection is between several cm and 20 m.

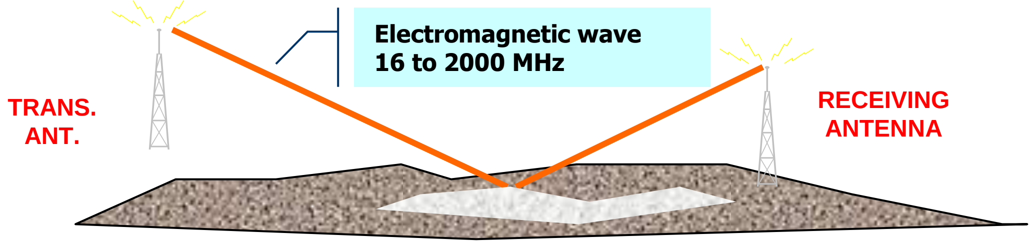
Therefore, the GPR geophysical technique is based on the analysis of the reflections of electromagnetic waves, which occur when they pass from one medium to another with different dielectric constants.

Each material, gaps, uniqueness, etc, will cause a distinct reflection of the electromagnetic wave, the analysis of reflected waves permits the differentiation anomalies in the same.

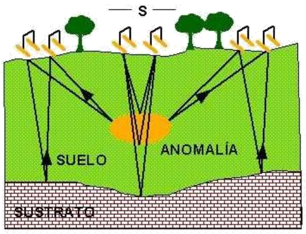
The behavior of the electromagnetic wave when it penetrate the ground, depends on the following parameters:

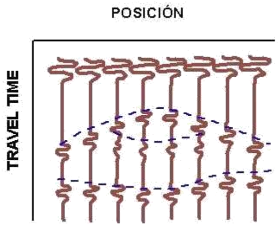
> **Electrical conductivity** is a measurement of the ease of passage of an electromagnetic pulse as is passes through a material, and it is expressed numerically as the inverse of resistivity. It's unit is the Siemens/m.
>
> The **dielectric constant** is the physical quantity on which Georadar is based and represents the permittivity an electromagnetic pulse passes with respect to the vacuum permittivity. It's therefore a dimensionless factor. In practice this constant depends on the electrical conductivity and thickness of traversed material, among which there is a comparison of their dielectric constants.
>
> The **propagation velocity** of an electromagnetic wave depends on the material traversed and the frequency of the emitted signal. In general, this speed is higher in the air or in dry materials than in water or wet materials.
>
> The **attenuation coefficient** of the material expresses the energy loss experienced by the transmitted signal as it passes through the transmission medium. The unit in which it is measured is dB/m. This ratio increases with the water content, electrical conductivity, heterogeneous composition, and the content of metal particles.

A brief description of the surveys with GPR is the following: the equipment consists of two antennas, transmitting and receiving. As its name suggests, the transmitting antenna "broadcasts" an electromagnetic wave which penetrates in the medium to be analyzed. This wave is reflected first on the surface of the material and subsequently on any dielectric conductivity contrast, discontinuity on found in the analyzed material. The reflections produced are collected by the receiving antenna, and this signal analysis permits the detection of changes in the material, gaps or other singularities which exit in the material.



Therefore, a continuous terrain profile will be obtain in depth.





1.1. Equipment calibration.

Prior to data collection in the field it is necessary to calibrate the equipment specifically for the type of material to be analyzed.

When the dielectric constant of the material value is unknown, some surveys are performed beforehand with the equipment on a zone where there is knowledge of the depth to which a certain abnormality is found and by applying the following expression,

$$\varepsilon_r = \left(t_s * c \big/ 2d \right)^2$$

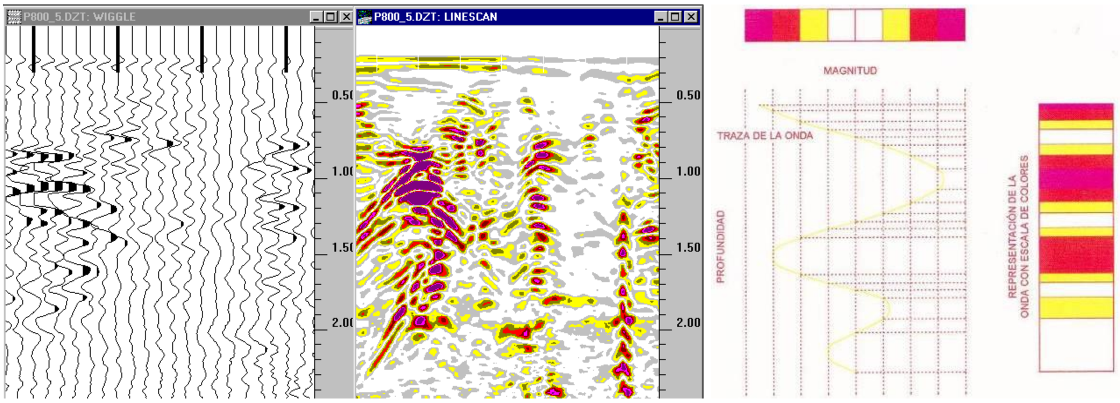
c = light speed (3.10^8 m/s).
t = time (in seconds).
d = material thickness by the wave travel (in meters).

The purpose of this calculation is to know the range of depth in meters that reach the antennas used on the material scanned. This makes it possible to locate and measure the anomalies observed in the radargrams. The following table show a list of the approximate values of the relative dielectric permittivity for certain materials:

Material	Conductivity (mhos/m)	Relative dielectric permittivity
Air	0	1
Fresh water	10^{-4} a $3x10^{-2}$	81
Saltwater	4	81
Fresh water ice	10^{-3}	4
Sand (dry)	10^{-7} a 10^{-3}	4 a 6
Sand (wet)	10^{-4} a 10^{-2}	30
Alluviun (wet)	10^{-3} a 10^{-2}	10
Clay (wet)	10^{-1} a 1	8 a 12
Sandstone (wet)	$4x10^{-2}$	6
Slate (wet)	10^{-1}	7
Limestone (dry)	10^{-9}	7
Limestone (wet)	$2.5x10^{-2}$	8
Basalt (wet)	10^{-2}	8
Granite (wet)	10^{-8}	5
Granite (dry)	10^{-3}	7

1.2. Interpretation fundaments.

The measures can be represented in two ways: as waves, or by using color scales. The following figures shows the two modes of representation of the measurement, and the relationship between them.



1.3. GPR Applications.

The GPR can be applied in a wide range of waves. Among the most common uses, include;

- **Environmental applications:**
  - Detection hazardous materials.
  - Determination extent of a contaminated area.
  - Detection of oil pollution on the water table level.
  - Research geological soil conditions.
  - Detection of waste deposits.
- **Geotechnical investigation before the planning and construction:**
  - Construction of the geological map of the surface.
  - Detection of natural and artificial cavities.
  - Research of buried objects.
- **Testing of artificial structures:**
  - Study of fractures and holes in tunnels, etc.

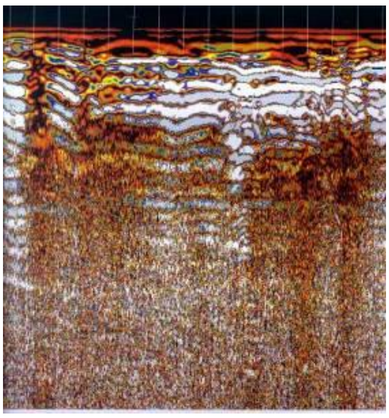
- Location of pipes, cables and other subsurface services.
- Inspection of asphalt pavement and concrete structures.

- **Exploration of minerals and raw material.**
- **Special control in mines.**
- **Archaeological and heritage studies.**

1.4. Advantages of GPR over other geophysical methods

Below there are some of the most notable advantages offered by this method over other traditional geophysical methods such as seismic surveys, electric logs, etc.:

- Non-destructive method.
- Making continuous measurements in space.
- Speed of taking measurements and data interpretation.
- Wide versatility of the equipment for a large number of applications.
- Absence of environmental impacts (no noise, no dust, no traffic disruptions, etc.)
- Low interference and even simultaneity, with usual tasks and work developed in the exploration area



2. GPR SIR 3000 SHEET.

NOTIO currently has one of the most modern and sophisticated georadar equipment on the market, as well as a complete variety of exploratory antennas, which allows working in a range of depths between 0 and 20 m. In the following sections a brief description of the equipment is made:

2.1. Equipment:

- SIR System 3000 (Geophysical Survey System, Inc. - USA), for subsurface data collection in the field.

2.2. Antenna:

- Antenna Model 3 101D, 900 MHz frequency (that achieves a maximum depth of exploration of 1.5 m).

- Antenna Model 5103, 400 MHz frequency (that achieves a maximum depth of exploration of 4-5 m).

- Antenna Model 5106, 200 MHz frequency (that achieves a maximum depth of exploration of 9 m).

- Antenna Monostatic Model 3207AP 100 MHz frecuency (that achieves a maximum depth of exploration of 15 m).

- Set antennas MLF Model 3200, which reach from the frequency 80 MHz, to 16 MHz frequency (with a depth scan in the range between 10 m and 30 m).

2.3. Computer support:

Software FGWINRAD6-MAIN, computer application base, for cabinet interpretation and field data taken FGWINRAD6-3D software to model generation of the anomalies in the subsurface, in three dimensions.

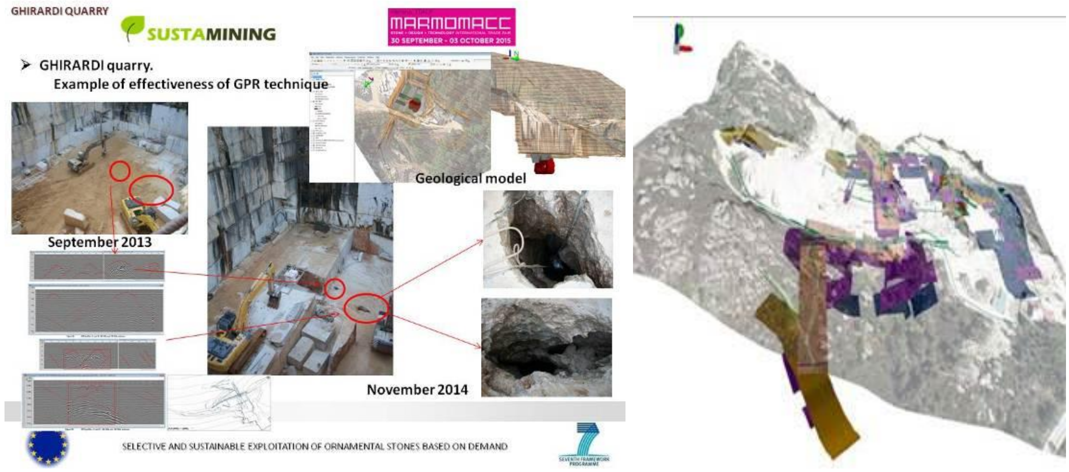
3. SOME WORKS DONE BY NOTIO.

NOTIO has extensive experience and qualified personnel to make studies applying GPR. NOTIO is a precursor of its application in numerous fields with optimal results, having even provided technical support to other companies; consultants and engineering and public and private organizations.

Below is a list of some of the most significant developments in which this technique was used geophysics:

3.1. R & D PROJECTS

- SUSMAMINING. *"Selective and sustainable exploitation of ornamental stones based on demand" (7º PM).*



- BIOXISOIL. *"New approach on soil remediation by combination of biological and chemical oxidation processes" (LIFE+).*

- Application viability of GPR in the study of different types of anomalies in the subsurface (Junta de Comunidades de Castilla-La Mancha):

  - *Oriented developing risk mapping in the subsurface;* Location of former mined and holes in the ground in order to develop a risk mapping.

  - *Oriented detecting buried objects;* Studies archaeological sites.

  - *Oriented demarcation of contaminated soils and location of potential contaminant sources.*

- Application viability of geophysical techniques GPR combined with electrical tomography analysis infiltration processes.

3.2. MINING (SAFETY)

- Old mine detection and galleries in the current exploitation of Open Pit Mine Emma (ENCASUR. Puertollano, Ciudad Real).

- Locating gaps in landfills. Stability of tailings in the region of Villablino (Minero Siderúrgica de Ponferrada, León).

- Locating holes in tailings on combustion. Stability of slopes, berms and platforms (Coto Minero del Sil. León).

- Inspection sustaining state galleries and mine closures (Villanueva del Río, Sevilla).

- Location of fissure in granite quarry (Cadalso de los Vidrios, Madrid).

3.3. Metallurgy (RESEARCH)

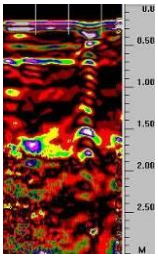
- Detection formation processes and development of cavities inside the combustion furnace coke (CENIM-ACERALIA. Mieres, Asturias).

- Application of GPR in detecting holes in cameras coke combustion process to CENIM, made on site CENIM in Madrid and in the Technical University of Aachen (Germany).

3.4. PUBLIC WORKS

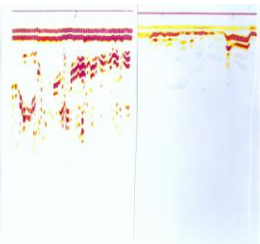
- Georadar on site campaign in Bengazhi (GLOBAL STREAM PROJECTS, Libya).

- Exploration using ground penetrating radar site underground container solid waste in the city of Toledo (URBASER).

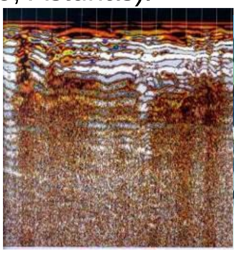



- Detection and inspection of the state of the service galleries Barajas Airport (GEOCONTROL & IN SITU TESTING. Madrid).

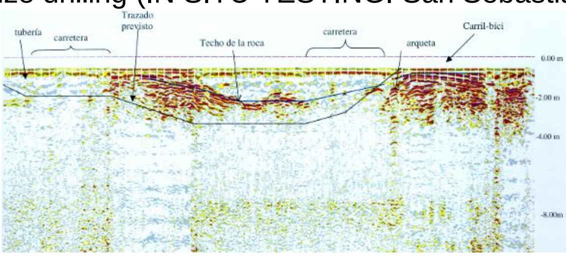

- Detection and recording the position of service pipes and their condition (GEOCONTROL. Argueda, Navarra).

- Detection of hollowness areas (adit, etc.) (IN SITU TESTING. Barrio de Ventanielles, Oviedo, Asturias).

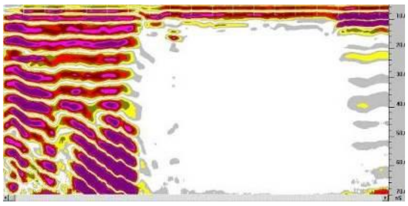
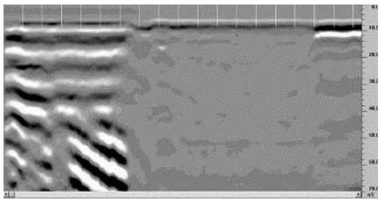



- Identify potential unknown services and determining the depth of bedrock to optimize drilling (IN SITU TESTING. San Sebastián, País Vasco).

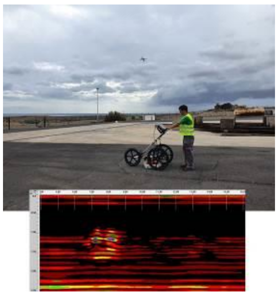


- Detection of voids in the basement in Barrio de Prado (Caravia, Asturias).

- Location of underground pipes and old warehouses on an industrial site of Portland cement factory in Morata de Tajuña (International IDOM. Madrid).

3.5. Other works





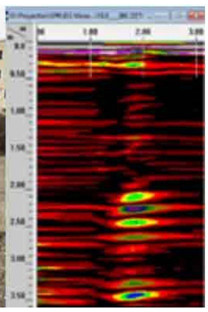
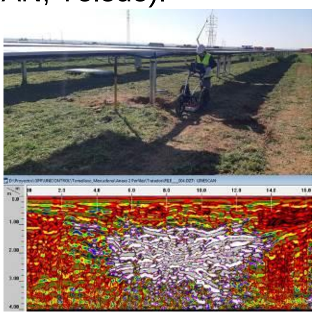
- Work at height for the detection of metallic structures in the Apolo theater in Madrid, (UNICONTROL).
- Detection of cavities in three areas of two photovoltaic parks in Manzanares, Ciudad Real (UNICONTROL).
- Georadar campaign to detect pipes and tanks in an industrial warehouse in Barcelona (RAMBOLL IBERIA).
- Detection of pipelines in an industrial site in Alcobendas, Madrid (IEG Técnicos Consultores).
- Detection in 2 phases of cavities and canalizations in the Mercadona site in Tomelloso, Ciudad Real (UNICONTROL).

- Detection of pipelines in an industrial site in Madrid (IEG Técnicos Consultores).
- Detection of pipelines and services and determination of their depth in Puertollano, Ciudad Real (EIFFAGE ENERGÍA).
- Georadar campaign to detect pipes and holes in the parish church of the Immaculate Conception in Horcajo de Santiago, Cuenca (PARROQUIA INMACULADA CONCEPCIÓN DE HORCAJO DE SANTIAGO and JAVIER ARQUERO).
- Detection of services at Manises Airport in Valencia (ALBEN 4000).



- Detection of services in the port of Musel in Gijón (AIRIA INGENIERÍA Y SERVICIOS).
- Detection of a fuel tank and services at the Fuensanta Hospital in Madrid (GENERAL ELECTRIC HEALTHCARE ESPAÑA and TIBA SPAIN).
- Detection of services at Barcelona's El Prat Airport (ALBEN 4000).
- Georadar campaigns to detect services at Tenerife South Airport. Area of the SSEI practice field and area for future ships to house disabled aircraft transfer equipment (AIRIA INGENIERÍA Y SERVICIOS).
- Georadar campaign at Seville Airport (AIRIA INGENIERÍA Y SERVICIOS).
- Georadar campaigns for OCSA Prospections and Studies.
- Detection of galleries in the area of Paseo de Malacate and Ermita de la Virgen de la Soledad (CITY COUNCIL OF LA PUEBLA DE MONTALBÁN, Toledo).



- Georadar campaign to detect old heating pipes in the Niño Jesús hospital in Madrid (GESOL).
- Geradar exploration to detect anomalies in a plot in Pedro Muñoz (Ciudad Real) for UNICONTROL.
- Georadar campaigns for CORELOGS INGENIERÍA.
- Georadar campaign to detect services in Fuenlabrada, Madrid (GESOL).
- Georadar campaign for the detection of cavities / voids in Albacete (GESOL).

- Georadar on site campaign for the detection of anomalies in the subsoil of a plot Manzanares (Ciudad Real, UNICONTROL).
- Exploration with Georradar for the location of a subsoil deposit in San Fernando de Henares of CTC Servicios Ambientales (Madrid, INNGENIO).
- Detection of leaks in underground water pipes (IN SITU TESTING. Barcelona).
- Check the state of the ground prior to the construction of a water tank (IN SITU TESTING. Antequera, Málaga).
- Detection of karst areas in the stretch of Grado Highway North (Asturias).
- Check the state of coating and detection of karst areas in the rail tunnel Vandellós (IN SITU TESTING. Tarragona).
- Measurement of thickness of breakwaters and walls in the pipeline Valencia (AGROMAN).
- Recognition of the stretch with GPR-Solera de Gabaldón-Motilla del Palancar for the high-speed train Madrid-Castilla-La Mancha-Valencia-Murcia (IN SITU TESTING. Cuenca).
- Recognition with GPR and analysis of the foundation for the construction of nursing homes and day center in Noblejas (IN SITU TESTING. Toledo).
- Check the condition of the concrete in the underground (Barcelona GEOCONTROL).
- Mapping of a fault in Marbella (CEMOSA. Marbella, Málaga).

- Location of underground pipes and old fuel tanks at industrial sites Sondika (IN SITU TESTING. Vizcaya).
- Recognition of the route of the AVE near Seseña (Toledo).
- Characterization of subsurface pilings for conducting future wind farm Espinosa de los Monteros (Burgos).
- Location of cavities on a stretch of pipeline future Cabanes-Oropesa del Mar (IN SITU TESTING. Castellón).
- Detection of anomalies in the shoe of a building under construction in Lekeitio (IN SITU TESTING. Vizcaya).
- Exploration of subsurface shoes high voltage line (IBERDROLA. Murcia).
- Location of underground pipes of Canal de Isabel II in the section of Navalagamilla-Robledo de Chavela (IN SITU TESTING. Madrid).
- Location of underground pipes (gas, water and electrical) in the neighborhood of the University (IN SITU TESTING. Santander).
- Location of water pipes in Quismondo (TRES MUEVEN. Toledo).
- Location of hollows in a reach of future processing center wind farm (IN SITU TESTING. Castellón).

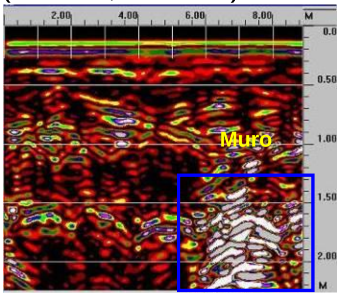
- Campaign subsurface characterization for conducting pilot tests in the future wind farm Jarafuel (Valencia).
- Location of Natural Gas underground pipes at school King's College (Tres Cantos, Madrid).
- Location of underground pipes and old deposits Treatment Station "Las Rejas" (San Fernando de Henares, Madrid).
- Detection of underground cavities and pipes (Sant Adriá del Besós, Barcelona).

3.6. ARCHAEOLOGY AND HERITAGE

- Detection forts, tombs and Roman fortifications around Grado (Asturias).
- Detection of Rincon well in Plaza Fortuna (Mieres).

- Archaeological Exploration section of the Northern Highway (Murias de Doriga, Asturias).

- Archaeological Exploration in San Chuis Castro (Allande, Asturias).

- Characterization of the alteration degree of natural stone used in singular buildings in Castilla y León (PINACAL).


- Location of limestone blocks at an archaeological site in the province of Lleida for Patrimoni Studies Centre of Archaeological Prehistory of the Autonoma University of Barcelona.

3.7. TRAINING

- Practical campaign training of GPR (IKERLUR. País Vasco).

- Collaboration with the King Juan Carlos I University in Madrid for the location of underground galleries in Ocaña (Toledo).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