15th June 2013

Geophysical Survey for preventive archaeology
3D Electrical Tomography

The case study of Villa Rivaldi, Rome
“Togetherness Esteem Attitude Mental Toughness”
Rick Pitino TEAM acronym

Who we are
About us

Our story
Geores was established through the passion, the values and the objectives shared by five professional geologists

Our mission
Offer innovative services and experience in the field of geophysical surveys applied to archaeology

Our vision
Invest 40% of funds in research and experimentation

Our values
Innovation, dynamism, professionalism, reliability, team spirit
“Success is a choice”
Rick Pitino

Geophysical Surveys
Multi-frequency Electromagnetic Surveys

Objectives

• Find buried structures and underground cavities and tunnels
• Very quick data acquisition
• Investigate extensive areas (2-3 hectares per day)
• Carry out preliminary screening of wide investigation area

Data Acquisition: Profiler EMP-400

Result: a conductivity map showing catacombs (Piazzale del Verano, Rome)
Magnetometric survey

Objectives

• Identify and georeference archaeological structures
• Investigate suburban areas or urban green areas
• Investigate confined areas down to a depth of 2 meters

Result: mapping of San Basilio site in Rome
Ground Penetrating Radar GPR or Georadar

Objectives

• The reflected electromagnetic waves determine the presence and localization of buried objects and structures near the surface.

Data Acquisition

Result: the map of the anomalous areas (Odescalchi Palace, Rome)
3D Electrical Tomography

Objectives

• Determine a detailed 3D reconstruction of the subsoil
• Identify and georeference archaeological remains
• High detail and resolution in deep subsoil

Data Acquisition: electrodes, multi core cables and acquisition unit

Result: 3D resistivity model of subsoil showing anomalous areas (Via dei Sabelli, Rome)
Cross-Hole Electrical Tomography

Objectives

- Determine a detailed 3D reconstruction of the subsoil
- Identify and georeference archaeological remains
- Investigate areas in which surface multi-electrodes cannot be laid

Data Acquisition: electrodes cable for borehole

Result: 3D resistivity model of subsoil (L.go Consalvi, Rome)
## Comparing geophysical surveys: parameters

<table>
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<tr>
<th>Survey</th>
<th>Context</th>
<th>Area size</th>
<th>Georeferentiation</th>
<th>Processing</th>
<th>Depth</th>
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<tr>
<td>3D Electrical Tomography</td>
<td>Urban</td>
<td>Regular</td>
<td>Glide</td>
<td>Primary</td>
<td>1/6 area</td>
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<tr>
<td></td>
<td>Extra Urban</td>
<td>Small</td>
<td>Volumetric</td>
<td>Secondary</td>
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<td>Cross-Hole Electrical Tomography</td>
<td>Regular</td>
<td>Medium</td>
<td>Primary</td>
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<tr>
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<td>Extra Urban</td>
<td>Medium</td>
<td>Secondary</td>
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<td></td>
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</table>
Terminology of geophysical surveys

Glossary

Mean-resistive
Standard reference model with respect to which anomalous volumes can be identified

Geophysical anomaly
Modified volume compared to the standard conditions

Geophysical anomaly with high archaeological sensitivity
Modified volume compared to the standard conditions compatible with the geo-archaeological model
# Application context

## Urban and extra-urban features

<table>
<thead>
<tr>
<th>Context</th>
<th>Standard Reference Conditions</th>
<th>Ability to define the mean resistive</th>
<th>Percentage error</th>
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<tbody>
<tr>
<td>Extra Urban</td>
<td>Natural</td>
<td>High precision</td>
<td>Low</td>
</tr>
<tr>
<td>Urban</td>
<td>Best approximation to anthropization level</td>
<td>Medium precision</td>
<td>Medium</td>
</tr>
</tbody>
</table>
Geophysics in **urban context**, considering the large number of **variables**, requires prior **knowledge of the site** and a step of **processing more complex**
“The change is not important for life. It's life!”

Rick Pitino

The evolution of archaeological geophysics
The traditional methodological approach

Features

• Default standard geometries independent from the local context

• Mono and bi-dimensional acquisition with a few measurement points

• Interpretation phase out of the local context and overly dependent on the interpreter’s capabilities

• Results are often not grounded in reality excavation
**Geores protocol**

**Features**

- Fast and high precision equipment
- New acquisition geometries and custom techniques for each site
- Transition to complete three-dimensional acquisition. We investigate volumes, not surfaces
- Processing software with high performance and adaptable to the target
- Using one or more methods by overlapping
- High contextualization
Geores protocol

Reference parameters

Design
• Identification of the target
• Individuation of the working target
• Choice of the best methodology

Acquisition
• Choice of techniques and geometries more suited to reach the aim using the target chosen specifically for each area of investigation

Processing
• Individuation of the reference standard conditions (mean-resistive) for the local subsoil
• Analysis of the data quality for the correction of instrumental errors
• Geophysical model for the team of interpretation
Geores protocol

Reference parameters

Analysis and interpretation
• Multidisciplinary team with geophysicist - gearchaeologist - archaeologist
• Definition of the geoarchaeological model
• Reconstruction of the geomorphological dynamics of the site and the palaeogeographical environment
• Focus on the target and elimination of non usable anomalies
• Direct verification and refining of the result

Direct verification - post
• Coring focused on anomalous volume
• Excavations within small depths
The "Reverse" methodology

The approach of Geores to the observation of results

- Reference to the non-anomalous areas with very low error (2-5%)

- Anomalous areas must be "sieved" to be used

- The evolutionary path is from “instrumental” anomalies to "man-made" and to "archeological“ anomalies

- The elettroresistivity map must be read in a first phase in “negative”, by individuating those areas with no structures and only after a complex analysis of the interpretation team the anomalies can then be classified
Only a correct choice of the standard terms of reference ensures the success of the survey.
Metro C Case study – Rome
Geophysical surveys in the area of Villa Rivaldi, with the aim of locating the possible presence of buried archaeological finds and infrastructure
The context

THE CASE. The construction of Line C of the Rome Metro has required the realization of geological surveys, excavations and archaeological surveys. Geores has carried out geophysical surveys in the areas interested by the project: Rome - Campo Romulea, Quartiere Celio, Giardini Via Sannio, Via Fori Imperiali, Villa Rivaldi, Tratta T3 of the “Colosseo – San Giovanni” line.

LOCALIZATION. The area of investigation is located in Rome, in the gardens of Villa Rivaldi, between Via dei Fori Imperiali and the viewpoint Cederna, north-west of the Colosseum.

GEOMORPHOLOGICAL CHARACTERIZATION. The study of local existing bibliographic data has allowed to examine the general conditions of the site and to reconstruct the geological-environmental conditions and evolution.
Villa Rivaldi localization
Choice of the geophysical survey

- 3D surface Electrical Tomography
  - Medium-high Interference
  - Archaeological level reference within a depth of 6 meters
  - Local anthropic deposit has been highly altered
  - The study requires a high level of detail and the georeferencing of anomalous volumes
  - High knowledge of the site
  - Urban Context

High knowledge of the site
Medium-high Interference
Archaeological level reference within a depth of 6 meters
Local anthropic deposit has been highly altered
The study requires a high level of detail and the georeferencing of anomalous volumes
Urban Context
Data acquisition

Map of the spread of electrical tomography

- Multielectrode spread for resistivity data acquisition
- Square mesh electrode with 1.5 m side
- Sampling points in depth is 0.5 meters
- Area interested by the electrical tomography survey
Data processing

Features

• Quality of the raw data
  Good with noise within 2%

• Filtering and optimization
  Limited

• Definition of the standard reference range
  Mean amplitude in ohm.m

• Expected error
  Low on resistive peaks, medium-low on the limit with the mean- resistive
The results
Overlap of resistivity maps from 34.5 to 32.5 m height above sea level
The results

Identification of a circular fountain

“... the resistivity investigation shows in this point the image of a large circular structure, with high visibility and high resolution, ... part of the ancient archaeological fabric ... However, it can not be exempt from evidencing the great similarity between the trace shown by the resistivity and the map of a circular fountain testified on this area between 1667 and 1810”.

Gianluca Schingo Archaeologist
The results

Identification of an ancient structure excavated in 2002

"... you can notice other interference images with mostly straight shapes, visible especially among 34.5 m and 35.5 m above sea level. In this height range there is a visible anomaly that can be related to an ancient circular structure discovered and excavated in 2002"
The results
Identification of ancient masonry structures

“On the eastern edge of the survey area there is a **wide homogeneous anomaly** ... on which there are some lines of higher resistivity, aligned on the final stretch of Via del Colosseo. **These lines clearly indicate ancient masonry structures** ... based on piroclastic tuff ... **with the same orientation of some ancient walls found in 1932** about 35 meters further east”

Gianluca Schingo Archaeologist
The results

Identification of medieval spoliation areas

"... the walls creat two reservoirs in which there are inconsistent filling areas (outlined in light blue) that can be interpreted as if medieval spoliation areas or modern re-buried later on."

Gianluca Schingo Archaeologist
The results
Identification of anomalies due to structures to be verified

"... resistive areas in high contrast with the local mean-resistive and/or with long rectilinear shapes. It can not be excluded that they are related to buried anthropogenic elements in the subsoil, unknown today. It is advisable here to perform targeted direct surveys”

Gianluca Schingo Archaeologist
The results
Anomalies due to instrumental causes

“... areas showing a light contrast with local mean-resistive and/or with amorphous shapes. These areas are likely due to instrumental causes and/or fluctuations in the electric field, or the presence of small geological variations that do not constitute particular item of interest to the investigation”

Gianluca Schingo Archaeologist
The results

The survey has identified several anomalies

• Anomalies overlapping the model known in the literature

• Anomalies different from the model, to verify with further investigation
"Often the fear of change is a strong lever not to improve because change is an unknown that scares!"

Rick Pitino

Conclusions and future scenarios
Benefits of geophysical surveys

Applications in urban context

In urban context geophysical surveys are essential when:

• The depth of archaeological interest is very high
• The technological network is very dense
• The interference with building is very high
• The available surface area is reduced
• Under existing buildings
Benefits of geophysical surveys

Time and cost saving

The use of geophysics as a support service for archaeological investigations allows to:

- Decrease up to 30% of excavation volume
- Reduce up to 50% the time needed for archaeological surveys
- Reduce the costs of archaeological survey
The future of geophysical surveys

Technological innovation and experimentation

Research and development activity carried out by Geores has the following aims:

• New precise and quick acquisition equipment, able to control noise

• Better performance of software able to use more complex algorithm of subsoil variable management

• Higher ability to determine morphometry of anomalies even at greater depths

• Ensure a higher depth of investigation maintaining a high detail
To ensure that geophysical methods successfully support preventive archaeology it is necessary to train professionals that use them, to promote the technical evolution, reduce costs and direct resources to archaeological research.
Questions and answers
Geophysics applied to archaeology is a reliable scientific process?

Yes, if it is scientifically used.
Geophysics can really help archaeology?

Yes, if some absolute parameters are respected.
A geophysical survey which is independent of the context, has it any sense?

No, a multidisciplinary team work is very important, in a known context.
More the context is known, higher is success.
Is geophysics an absolute precise investigation?

No, as in all investigation techniques, the precision depends on the process used.
Geophysical surveys have a high error? 

The error **depends** on the precision required, that is the dimension and position of the target.
What can a geophysical survey identify in the subsoil?

Buried structures with a dimension which is higher than the designed detail of the survey.
Geophysics is a photograph of the subsoil?

No, it is an electromagnetic image of the subsoil.
Can archaeology be regardless of preliminary geophysical investigation?

Yes, if the investigation is carried out in a traditional way.

No, in order to have the possibility to design further excavations from a preliminary map.

No, in order to reduce the costs and direct resources from preventive digs to excavation and value development activities....and of course No, if it is true that progress is irreversible!
Thank you