

## CASE STORY

Archaeology, Bedrock, Geophysical  
| GPR & Resistivity |

### ► GPR plays an important role in the unsealing of the Legendary Tomb of Christ

Thousands of people are visiting the Church of the Holy Sepulchre in Jerusalem every year. The church is one of the most important sanctuaries of Christianity and pilgrims visit the place where Christ shall have been buried and resurrected from the dead.

The Tomb of Christ (Holy Sepulchre) is enclosed within a freestanding domed ciborium-like structure termed the Holy Aedicule. The legendary site has now been mapped by geophysicists, engineers and archaeologists to examine the church's subsurface environment revealing cavities and underground canals, partly to elucidate the structural evolution of the Church from a historical perspective and partly to assess how the subsurface environment affects the state of preservation of the building.

*"Our distributor in Greece, Terra-Marine, was assigned for this comprehensive and challenging project by the National Technical University of Athens",* says Dinora Marquez Flores, Regional Sales Manager South and East Europe, Guideline Geo.

*Mapping of the supposed Tomb of Christ with MALÅ GPR solution. Photo: Gali Tibbon©*



### Covered with marble for more than 500 years

The supposed Tomb of Christ has been covered in marble cladding for centuries. The probable reason of this protective measure has been the risk of visitors causing damage to the tomb by removing parts of the burial rock to keep as a souvenir.

### CLIENT PROFILE

The National Technical University of Athens (NTUA) was founded in 1837 and is the leading academic institution in Greece. After a historic agreement was reached between the three Christian communities the historic Guardians of the Holy Sepulchre, a rehabilitation project of the Holy Aedicule of the Holy Sepulchre was implemented, including the mapping of the subsurface environment in its vicinity.

The scientific supervision was assigned to an interdisciplinary team from NTUA headed by Chief Scientific Supervisor Professor Antonia Moropoulou and including Professor Emmanuel Korres, Professor Andreas Georgopoulos, Professor Constantinos Spyarakos and Assistant Professor Charalambos Mouzakis, Deputy Construction Site Manager. Terra-Marine - Guideline Geo's distributor of geophysical equipment in Greece - has performed the mapping and geophysical analysis.

### PROJECT

- Site: The Church of the Holy Sepulchre in Jerusalem where Christ is supposed to have been buried
- Purpose: As part of the framework of the church restoration - Map underground structures to find fractures, canals, voids and detect humidity zones
- Methods: GPR (Ground Penetrating Radar) & Resistivity
- Instruments: MALÅ GX (GroundExplorer) & ABEM Terrameter LS

## CHALLENGE

The historical venue needed to be thoroughly investigated to reveal what is hidden under the floor and behind the walls. Partly from a historical perspective – to map potential underground canals and voids, features and man-made structures from different historical periods and partly from a preservation perspective – to identify humidity sources and subsurface areas that could influence the “state of preservation of the church”. A penetration depth of 2 meters, with high-resolution data output, was needed. On-going restorations of the church created additional challenges.

## SOLUTION

### Penetration depth and resolution focus – determined the choice of solution

The MALÅ GPR solution GX (GroundExplorer) and the ABEM Resistivity solution Terrameter LS were used to optimize the surveys in the church with the invaluable cultural value. The rock background was in addition mapped with GPR up to 4 meters depth.

Alternative Guideline Geo GPR and Resistivity solutions were evaluated and the MALÅ GX (GroundExplorer) with 160/450/750 MHz antennas together with the ABEM Terrameter LS were selected for their penetration depth. The resistivity survey was conducted with an electrode spacing of 0.8 m, using Schlumberger & Dipole-Dipole arrays. Contact electrodes (produced by Terra-Marine) and bentonite was used to ensure the electrode contacts. Imaging and data processing software have been used to create the 2D/3D subsurface images and the post process analysis.

Resistivity measurement with ABEM Terrameter LS. Photo: Gali Tibbon©

## Comprehensive survey of the Church of the Holy Sepulchre

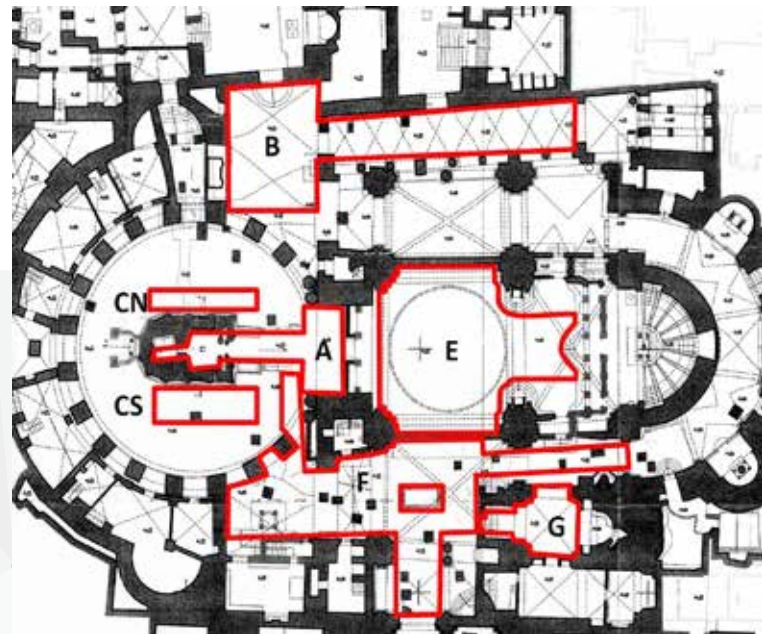
The general ground plan below of the Holy Sepulchre (Courtesy of D.-D.Balodimos, A.Georgopoulos and G.Lavvas, 2003) is marked with the survey method used per area:

**Area [A,B,E,F,G]:** Ground penetrating radar (GPR)

**Area [CN,CS]:** Resistivity Survey

Used for the detection of underground channels and voids

Method per area



## RESULT OF GEOPHYSICAL SURVEY

The different areas were successfully and efficiently mapped, even though the current situation with on-going rehabilitation works caused additional challenges.

Many archaeologically interesting discoveries related to man-made infrastructures - drainage canals, voids/cavities as well as remains of previous building phases of the Church - were mapped.

The mapped targets were analyzed by archaeologists, engineers and geophysicists and correlated with historical events, evidence and other findings from the rehabilitation project, to study the structural evolution of the Holy Aedicule and the Church of the Holy Sepulchre. In addition to historical discoveries – the resistivity surveys indicated other problems that need future actions.

*“Our performed survey is an important part of the preservation of this irreplaceable cultural treasure”, says Pavlos Sotiropoulos, Technical Director Terra-Marine. “The high resolution data from the ABEM and MALÁ equipment has provided the archaeologists with comprehensive research material to investigate the church and its subsurface in detail”.*

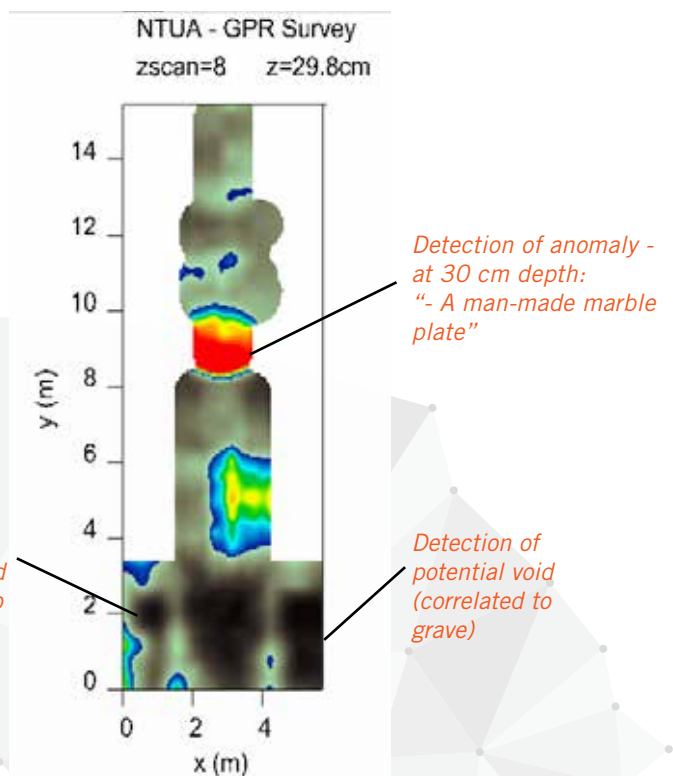
## GPR SURVEY FACTS

- ▷ Detect of underground structures (tunnels, voids, pipes)
- ▷ Map humidity zones
- ▷ Map fractures extension at the wall of the Hole Sepulchre
- ▷ Investigate the Holy grave in terms of the mapping voids and the bedrock depth

## RESISTIVITY SURVEY FACTS

- ▷ Complementary to GPR
- ▷ Map humidity zones/presence of water
- ▷ Map underground structures

## The supposed Tomb of Christ



The supposed Tomb of Christ mapped with GPR. Photo: Terra-Marine



## Acknowledgement & Sources

- We thank the National Technical University of Athens, Terra-Marine, His Beatitude Patriarch of Jerusalem Theophilos III and the three Christian Communities for sharing the technical information, data and images related to the Holy Sepulchre project
- Kristin Romey, National Geographic – for inspiring reading - Article in National Geographic (see below)
- Gali Tibbon - Photographer (www.galitibbon.com, gali.tibbon@gmail.com)

## Don't miss out this video & reading about the revelation of the Tomb of Christ

- **Materials and Conservation, Reinforcement and Rehabilitation Interventions in the Holy Edicule of the Holy Sepulchre.** Scientific Coordinator: A. Moropoulou; Interdisciplinary Research Group NTUA: E. Korres, A. Georgopoulos, A. Moropoulou, C. Spyrakos. National Technical University of Athens (2016) ISBN 978-618-82612-0-4

- **Presentation upon completion of the Holy Sepulcher's Holy Aedicule Rehabilitation.** Scientific Coordinator: A. Moropoulou; Interdisciplinary Research Group NTUA: E. Korres, A. Georgopoulos, A. Moropoulou, C. Spyrakos, Ch. Mouzakis. National Technical University of Athens (2017) ISBN 978-618-82196-4-9

- **National Geographic's film** (Oct. 28, 2016): *A closer look inside Christ's unsealed tomb*

- **Article by Kristin Romey, National Geographic** (Oct 31. 2016): *Unsealing of Christ's Reputed Tomb Turns Up New Revelations*