

Using geomatics and geophysics to study underground anthropogenic water systems: the UAW project

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Abstract – This paper presents some preliminary results of the scientific investigations carried out at underground water channels located on Mounts Nebrodi in Sicily (Southern Italy). We performed several geophysical surveys as well as geomatics approaches were used in order to reconstruct 2D and 3D digital models of this underground monuments. n here, we also present the potential of valorizing these cultural heritage sites and its underground structures by the means of advanced technologies and digital reconstructions.

I. INTRODUCTION

The qanats were channels used for drainage and water transport to provide a stable source for water supply in human settlements as well as for the irrigation of fields. We know that this technology first developed in ancient Persia around the seventh-sixth century BC, to later spread to other geographical areas, from the Mediterranean to China. The Romans built them in Libya and Tunisia, while centuries after the fall of the Roman Empire it was the Arabs who built many in the territories they conquered, developing the construction technique to make the most of water resources.

II. THE UAW PROJECT

The aim of the UAW project is to characterize and digitize selected underground anthropogenic water systems in Malta and Sicily. In this paper, we present some preliminary results of some qanat located on the Mounts Nebrodi (Sicily, Figure 1). Many civilizations in the past have used the underground domain to carry out different activities that have consequences in the surface domain. Examples of this are the *qanat* systems which are channels (or a network of underground channels) usually excavated on the rock. A simple sketch is given in Figure 2 in order to visualize the *qanat* system structure.

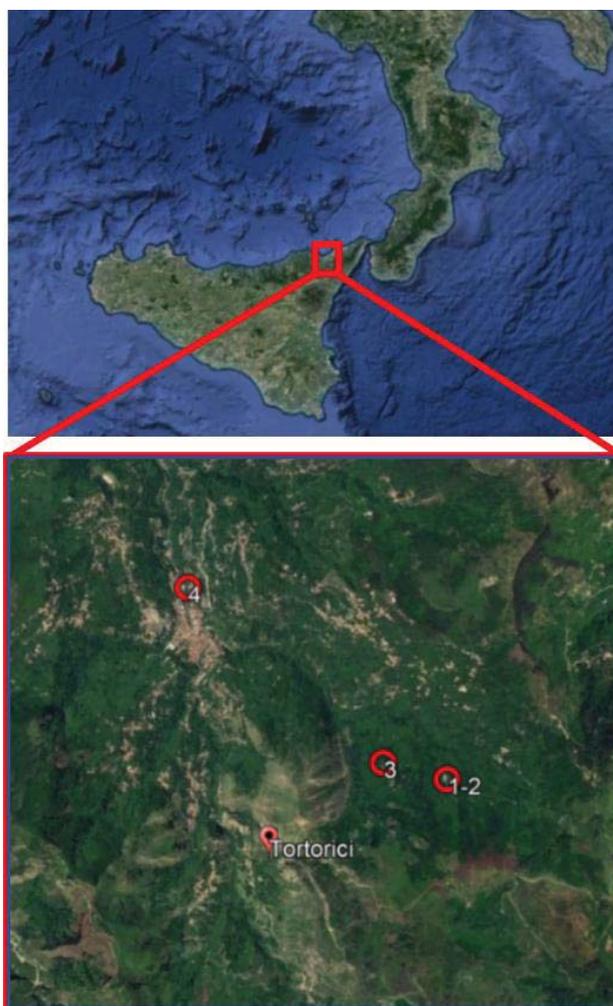


Fig. 1. Geolocation map (a) of the Nebrodi area and location of the underground water systems analyzed in this study.

They were carefully designed in order to intercept the water table and transport water from the aquifers in

highlands through a location in a lower position. Those anthropogenic structures are present in several countries around the world, typically constructed by ancient societies in arid and semi-arid climates for irrigation.

In this project, we are focusing our attention to qanat systems located both in Malta and Sicily. The ultimate goal of the project is to study and compare these underground water systems.

We applied a multiapproach technique, using geomatic and geophysical techniques. Lidar data, photogrammetric point clouds and 3D models are used to reconstruct the geometry of the channels and study the internal characteristics.

High-resolution shallow geophysical techniques (ERT, GPR and seismic) are employed to track their position in the hosting rock as well as compute the slope of the channels. At last, in selected cases, inferences about the water flow are made complementing the information with thermal images. Specifically, this project will focus, for each of the underground structure selected, on:

- analyze satellite images to characterize local context where the qanat systems are located and the principal geological features in the area;
- determine the location, geometry and size of the qanat systems;
- generate high resolution 3D models by using unmanned aerial vehicle (UAV) photogrammetry and/or Lidar;
- acquire electrical resistivity tomography (ERT) and GPR analysis in order to evaluate the extension of the system and identify the water table from which water is collected;
- acquire low frequency ground penetrating radar (GPR) profiles to better understand the shallow stratigraphic boundaries.
- research the connection between lithology and internal structure in relation to the physical underground variations along the outcrops.
- generate quantitative geological models from the joint inversion of the geophysical data.
- establish a method to research similar systems by combining and use of the above mentioned techniques.

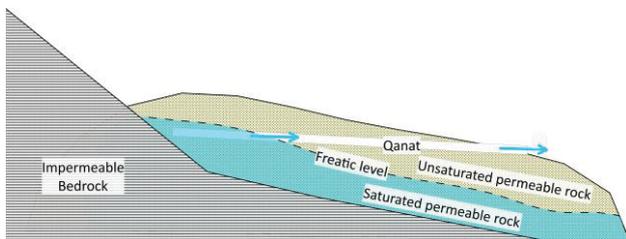


Fig. 2. Sketch of the underground water system.

The project is carried out mainly by the Department of Geosciences at University of Malta and the

“Dipartimento della Scienza e del Mare” at University of Palermo. The Department of Geosciences at University of Malta has been involved in recent years in the study of natural and anthropogenic underground structures by the mean of geophysical and geomatics techniques. On the other hand, the department of the University of Palermo has a long history in deep geophysical investigations, crustal dynamic studies and field geology. Thus, both departments find in this project a mutual beneficial collaboration. It will be fundamental for future collaborations of the highest quality in the field of geophysics and geomatics applied to cultural heritage and water management.

III. THE GEOPHYSICAL AND GEOMATICS SURVEY

In order to investigate the sites and to reconstruct the geometry and orientation of the channels a series of geophysical surveys have been carried out. In particular, we carried out analysis based on non-invasive techniques to identify and map the underground water system extension. We carried out acquisition campaign using ground penetrating radar (GPR) and electric resistivity tomography (ERT). Both techniques are the most resolute geophysical method in near surface geophysics. The digital models of the investigated underground water complexes have been produced by the means of Lidar and photogrammetric surveys (details of the technique can be found in [2], and [3]). Figure 3, 4, and 5 reports the digital models of the qanat systems studied in the present paper. At the same site a geophysical investigation was also carried out. In particular, a ground penetrating radar and electric tomography have been performed.

GPR data were acquired by the use of a pulsed GPR system equipped with a double antenna at 200 and 600 MHz [1]. The data were gathered along an orthogonal grid size 20x20 cm, and were processed with zero timing, background removal gain vs. depth, 1D filtering and Kirchhoff migration. Slices with a time step of 10 ns were then achieved. The processing was performed with the Reflexw commercial code. Data showed the presence of clear anomalies in correspondence of the water channels. Photogrammetry is a comprehensive method that enables 2D and 3D reconstruction of terrain and/or artifacts. It can be defined as the science of obtaining reliable information about the spatial properties of the surface and objects, without physical contact, by using some kind of image (aerial, terrestrial or subaquatic). To construct a 3D photogrammetric model of a church several optical images were acquired by the mean of RGB cameras that are steered by employing a gimbal in order to stabilize the images and obtain a better final digital reconstructed 3D model. Several hundred of photographs were taken



Figure 3: Digital model of the site #1 in Figure 1



Figure 4: Digital model of the site #3 in Figure 1

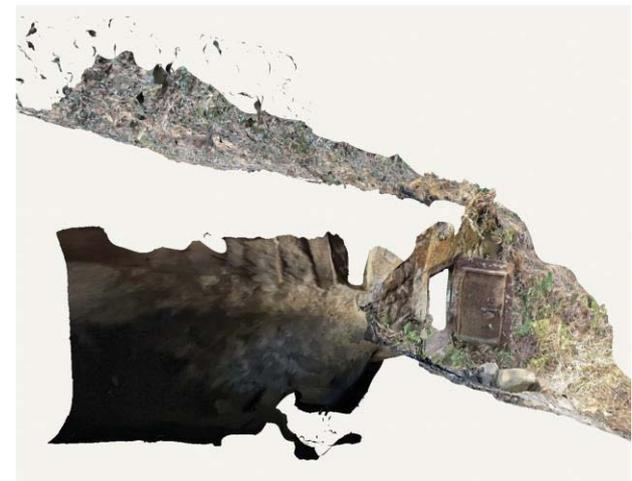


Figure 5: Digital model of the site #3 in Figure 1

at different levels and angles to obtain a high percentage of overlap (above 70%) between successive images to ensure a correct digital reconstruction and Agisoft Metashape [8], a commercial software that uses the Structure-from-Motion technique, was used to process the images. The model was scaled using markers of known dimensions in order to scale the final 3D model.

The photogrammetric process can be summarized in 5 main steps: (i) Image selection; (ii) Camera alignment; (iii) Dense point cloud construction; (iv) Mesh generation; (v) Texture making. The final product is a three-dimensional reconstruction of the studied area, on which high-precision measurements can be performed being the final 3D digital model duly scaled.



Figure 6: Digital model of the site #4 in Figure 1

Figure 3, 4, 5, and 6 show the final 3D digital model of internal and external parts of investigated water channels.

IV. RESULTS AND CONCLUDING REMARKS

In this study we present a combined geophysical and photogrammetric study of different underground water channels located in northern Sicily. The creation of the 3D digital model is used for promoting the built heritage of one of the main cultural heritage sites of the village and touristic entities in the area. The final idea, being the site not accessible to the public, is to make them accessible through the use of digital models and digital technologies. The non-invasive investigations also offer information on the history of the monuments. All this information is integrated within the digital platform and data and results can be easily made available to practitioners, site curators as well as general public (Figure 6). The same digital models can be used for integrating all the gathered scientific information as well as historical information related to the sites. The same information can be used to create virtual tools that can help in exploring the site and its hidden beauties also from remote locations through the use of Virtual Reality (VR). This can be effectively done by the means of VR

headset which is a head-worn apparatus that completely covers the eyes for an immersive 3D experience (Figure 7). VR tool can also contain specialized information related to the historical site and serve as repository for results of different scientific investigations [e.g. 5, and 6].

Finally, the results will disseminate knowledge on underground culture and assist the local community in planning the restoration and potential fruition of the site. From a scientific point of view, three-dimensional reconstruction of the site represents a great advantage over other survey methods as it enables different measurements and volumetric estimations to be carried out on the site.



Fig. 7. Head-worn apparatus that completely covers the eyes for an immersive 3D experience

In conclusion, the presented example and holistically the proposed approach can be considered as a valuable resource to celebrate and preserve cultural heritage sites. They can be made accessible to the public in a virtual form if other means are not possible. Indeed, it represents an important tool to valorize the full potential of the site as well as be a valuable support for the local communities development.

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