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GPR 3D model in the area of the San Nicola church, Misterbianco (Sicily)

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Abstract. In 1669 the most destructive eruption on Etna volcano was recorded since historical times (about 700 BCE), whose lava flow destroyed completely the ancient town of Misterbianco, located on the southern slope of Mount Etna. San Nicola church is one of the three churches that historically were covered by lava flow. In the 1980s, some works for the construction of a parking lot allowed to discover an ancient wall belonging to the church. Some georadar prospections were carried out in the investigated area finalized to reconstruct the planimetric development of the ancient church and to direct future excavation works.

1. Introduction

Misterbianco is a small town located on southern slope of the Mt. Etna at 213m a.s.l., and during its long-life history was hit by different earthquakes and eruptions. The largest historical eruption occurred in 1669 and lasted for about 4 months (Boschi et al. 1997), changing completely the morphology of the southern flank of the Mt. Etna. Between 25th March and 4th April the lava flow reached the settlement of Misterbianco submerging it completely (Branca et al., 2013). The historical settlement, dated back to the 14th century AD, had originally three different churches, two of which were identified whereas the third one is still buried by lava with an unknown position. Given the magnificence of the eruption, it is important to consider that this report represents the first geophysical study performed at Misterbianco site 350 years after the eruption, and that provides important information on the ancient San Nicola church. Moreover, a few well-documented cases of geophysical investigations on cultural heritage buried by lava flows have been reported so far by Castellaro et al. (2008), consequently this work can be considered as a pioneer investigation, opening important prospects on future geophysical investigations not only in Misterbianco but also in other Etnean areas that had experienced similar destructions in the past. Starting from these considerations, we tried to reconstruct the site history by performing a GPR survey devoted to the identification of planimetric development of the church. In addition, we performed a UAS (Unoccupied Aircraft System) survey to map adequately the investigated area and to located properly the GPR survey.

The *San Nicola* church was probably built in the second middle of 15th century AD as referred by local historians (personal communication). We do not know any other historical information on this building neither the spatial extension nor plan development, because the entire historical documentation was lost during the eruption, thus the planimetric reconstruction was deduced by comparing GPR anomalies with other churches of same period. Historical sources described the 1669 eruption and referred that lava flow submerged the church, and the only visible remain is relative to external southern wall (Figure 1). Probably the lava flow filled the internal part of church and covered it completely. In the 80s, this area was subject to strong anthropization with huge buildings constructions among which a football field with an annexed parking area. The latest was originally planned to be erected above the remains of the church, and after the removing of wide portion of lava the ancient remains came to light, left to a neglect state until now. The investigation is finalized to enhance the knowledge on the Misterbianco settlement by uncovering the ancient remains of this building though future archaeological excavations. The only survey, performed by the Soprintendenza di Catania, permitted to discover a majolica floor at 9 m of depth from surface.

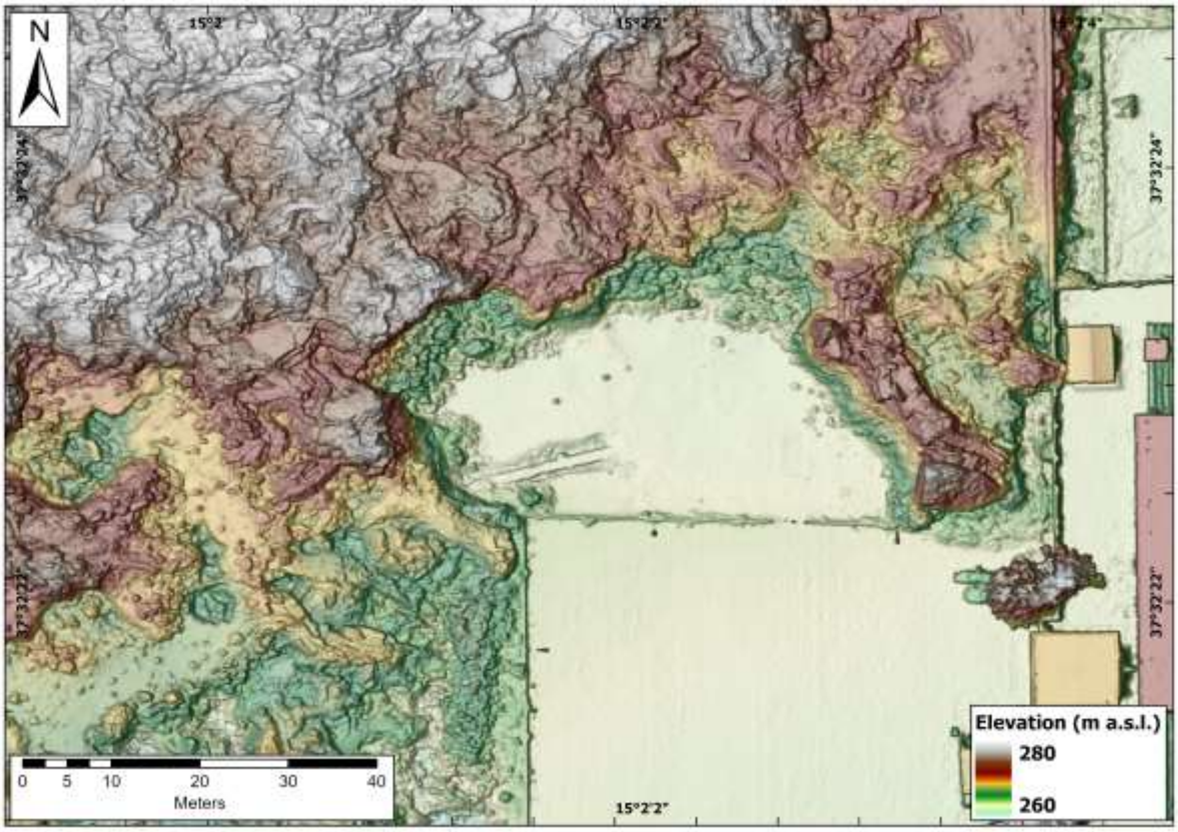

Figure 1. Digital Surface Model (10 cm/pixel) with superimposed hillshaded image of the area where the southern wall of the church was unburied.

2. Structure-from-Motion aerial photogrammetry

We performed a detail topographic survey of the study area by means of Structure from Motion (SfM) aerial photogrammetry. We collected 544 aerial images using a DJI Phantom 4 Pro UAS with a 1” CMOS 20MP sensor and a 24mm (35mm equivalent) focal length lens with a double grid flight path and nadir to off-nadir camera angles. We maintained a constant flight altitude of 50 m above ground level during the flight and we acquired partly overlapping (75% front and 75% side overlap) aerial digital photos. This low flight altitude was chosen due to flight restrictions in the area and in order to obtain a ground sampling distance (GSD) of 1.5 centimeters.

We then processed the acquired georeferenced images using the Agisoft Metashape® software package (version 1.6.3) based on the Structure-from-Motion and multi-view stereo photogrammetry algorithm (SfM-MVS; James and Robson, 2012). The workflow of our photogrammetric analysis included: 1) camera triangulation with image position and orientation and generation of sparse point cloud; 2) filtering of the sparse point cloud to remove points with bad geometry, large pixel matching errors and large pixel residual errors; 3) generation of dense points clouds and 4) generation of orthomosaic and Digital Surface Model (DSM).

The coordinates of a set of ground control points needed to scale and georeference the SfM point clouds and the derived DSM and orthomosaic were measured using a dual frequency GNSS receiver in Real-Time Kinematic (RTK) positioning.

The extracted DSM and orthomosaic have a resolution of 10 cm/pixel and 5 cm/pixel, respectively, and cover an area of about 10 hectares.

3. GPR survey

Ground penetration radar (GPR) technology is probably the most common technique in archaeogeophysics (Capizzi et al. 2012; Dojack 2012; Conyers 2013; Garrison 2016; Ranieri et al. 2016; Casas et al., 2018). The GPR technique allows to detect buried structures and to reconstruct 2D maps and 3D models.

The GPR surveys were performed at the top of the church, on the external part of the roof which is actually a walkable area. The investigated area is 800 m^2 around the area where an ancient wall remains is still visible.

The surveys were carried out using a RIS MF HI-MOD system (IDS GeoRadar s.r.l.), equipped with a dual system of 600 MHz to 200 MHz antennas. The antennas have been selected according to the resolutions and depth of investigation. In particular, 41 parallel profiles were acquired with a spacing of 0.5 m, according to hypothetical average size of the buried structures. A total of 1127 meters of GPR profiles have been analyzed and processed to reconstruct a 3D GPR model of the investigated area.

The 2D GPR profiles were firstly processed to eliminate background noise and applying a frequency filter. Finally, the data were reorganized in timeslices (Goodman et al. 1995) to obtain a three-dimensional model of the electromagnetic reflectivity of the subsoil (Figure 2), up to a depth of about 7 meters. In particular, the first 3 meters were reconstructed with the data acquired with a 600 MHz antenna, while the deeper data were obtained from the 200 MHz antenna. The main refractive hyperbolae made it possible to reconstruct an average speed of about 0.09 m/ns. Using this value depth slices have been constructed.

The model highlighted several anomalies that can be interpreted with the presence of buried wall structures. It also highlighted some anomalous areas inclined from a depth of two meters up to about 6-7 meters deep (Figure 3). These could be associated with the shape of the lava flow that is likely to be found inside the buried church.

The depth slice referred to a depth of 1.2-1.8 meters shows an alignment with the same direction as the unearthed wall, as can be seen by superimposing the depthslice on the 2013 satellite image (Figure 4).

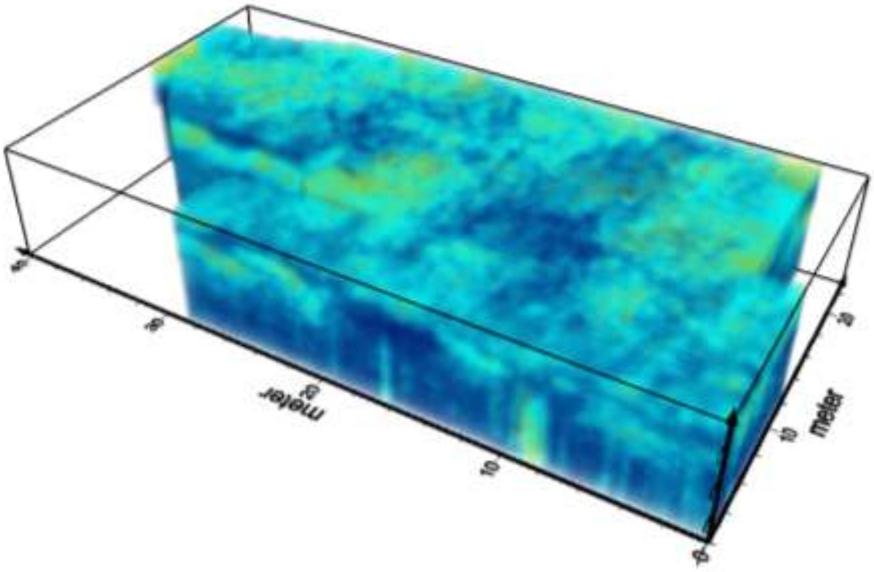

Figure 2. 3D volume rendering of GPR data.

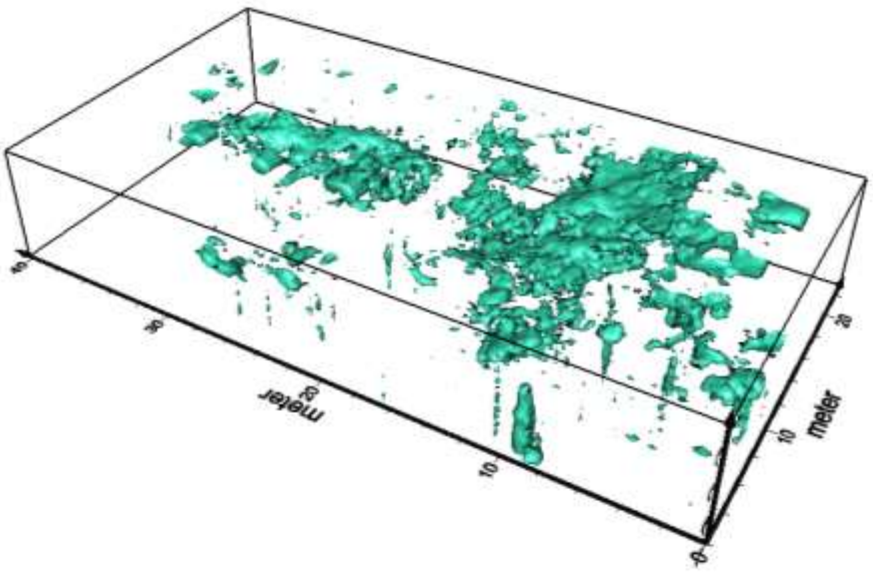

Figure 3. Isosurfaces of the 3D model that highlight the high reflectivity values.

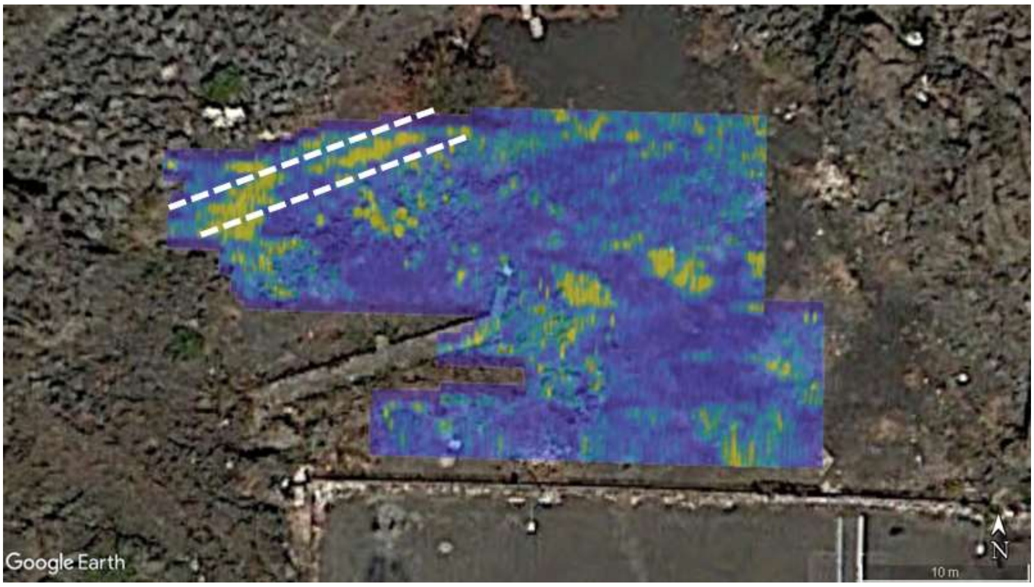

Figure 4. Depthslice referred to the depth of 1.2-1.8 meters superimposed on the satellite image of 2013. The white dotted line indicates the position of the wall identified by the investigations.

Conclusions

The georadar surveys in the area where a perimeter sight of the church of San Nicola was found allowed to highlight a non-homogeneous subsoil, as it should be in the event of a compact lava flow. Surely there are buried structures and surfaces of discontinuity that suggest the presence of a lava flow inside the buried church. Furthermore, the surveys on the surface made it possible to identify the presence of the remains of the other perimeter wall of the church, delimiting it and allowing us to hypothesize the geometric shape of the plant. The GPR survey shows indeed an anomaly consistent with a wall parallel to the outcropping remain (Figure 4), that allows us to suppose that the church was about ten meters large and W-E oriented with an apsidal area located in the eastern part.

However, only any excavation operations will be able to clarify the state of conservation of the church remains and the possibility of restoring it as well. This will enhance site history adding an important piece of historical information to the knowledge of 1669 lava flow.

Acknowledgments

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