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Toward the Virtual reconstruction of Grotta Romanelli, Apulia (Southern Italy)

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Abstract –
After 40 years of closure to researchers and public, Grotta Romanelli was reopened to scientific research in 2015. Continuing the tradition initiated by Blanc, the new excavations follow a multidisciplinary approach, involving specialists of different disciplines. A pivotal part of the project is also focused on digital technologies and experimental methods, to promote data sharing and scientific dissemination. With this aim, a 3D model of the entire cave has been produced by photogrammetry. This technique allows to create a 3D model of a real object, in a digital environment and with high resolution photos.
During the 2016 excavation campaign, the base for the 3D model has been created. During the last excavation campaign, in September 2017, the 3D model has been edited and updated with the new surveys.
Here we present the last update of the model and the relative workflow.

I. INTRODUCTION

Grotta Grotta Romanelli has been considered a key site for prehistoric studies in Italy, since the beginning of XX century. The cave, located on the East coast of southern Apulia (Italy), was discovered in 1871. In 1900 P.E. Stasi realised the remarkable importance of the site as the first evidence of the Palaeolithic in the Italian peninsula. In 1914, G.A. Blanc started the excavation campaign, producing the first systematic paleontological and stratigraphical study with scientific methods [1][2]. The cave and its deposits were object of extensive studies until the end of the seventies, when the site fell in a sort of oblivion. Despite decades of researches many open issues on archaeology and geo-palaeontology need to be investigated and clarified. In 2015, the reopening of the excavation campaign broke the spell of inactivity in the field.

The importance of the site, requires a multidisciplinary approach, ranging from palaeontology to geology from archaeology to geochemistry, among many others.
Since the first field work, in 2015, it has been apparent that the sediments inside the cave had been exploited and that the legal (and illegal) excavations performed in the past have left visible scars and a consequent lack of documentation. Thus, in addition to the strictly scientific part, the field-work has been planned to include an extensive and progressive documentation of all the features of the cave such as stratigraphic layers, geomorphological structures, and rock art.
At the end of the excavations of 2016, a virtual model of the entire cave (including the vault) was realized using photogrammetry. It constitutes a starting point for a continuous virtual documentation, that can be achieved adding to the base model the virtual model of every section opened during the excavation campaign. The 3D model becomes a virtual and interactive diary of all the activities affecting the physical space of the cave and it could be linked to a database where the information about

geological and archeological/paleontological findings could be stored [3].

Here we present the first digital model of Grotta Romanelli made after the 2016 campaign and the workflow that has been applied to produce the updated model of the cave, after the 2017 surveys.

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II. MATERIAL AND METHODS

Photogrammetry is a method often used in many scientific fields and has been largely exploited in paleontology and archeology during the last ten years [4][5]. With this technique, a 3D model can be created processing high resolution photos in a digital environment. To create all the 3D models of the cave and the newly excavated sections, Agisoft Photoscan (Agisoftphotoscan.com) has been used. This software, through a series of distinct steps, allows to derive three-dimensional models and other products such as point clouds, DEMs and orthophotos, which can be integrated with GIS platform.

To build the 3D model of Grotta Romanelli, all the data analysis and derivation process were carried out as follows: 1) censing and uploading photos; 2) aligning photos; 3) creating point clouds; 4) markers positioning; 5) mesh and texture creation; 6) DEM and orthophoto generation and building; 7) export of DEM.

The camera used for every shooting session is a Canon EOS 500D. The camera mounts an 18.0 Megapixel CMOS (APS-C) image sensor and is equipped with a Canon EF lens and a Canon's DIGIC 4 image processor. The camera has been set with variable parameters of f-stop and exposure time depending on both light conditions and subject. The number of photos taken depends on the size and the shape complexity of the subject (Table1).

Table 1. Number of photos for every 3D model.

Cave	Section 1	Section 2	Section 3	Section 4
N°	N°	N°	N°	N°
386	30	67	69	30

The workspace is based on a unique .psx file made by five chunks, one for the entire cave, and the others for each 3D section model.

The model of the entire cave (first chunk) Fig. 1 acts as a relative spatial reference. Thus, to upload the dimensions and the spatial positions of each model in relationship with the first chunk, shared points have been selected on both of them. Those points act as control points to produce spatial adjustments which allow the positioning of the model in the 3D cave, Fig. 2.

The initial 3D model of the cave is not deleted or modified, but updated progressively with the new chunks relative to the new sections.

The DEM and the contour lines of the isolated sections have been produced through the exportation of the dense point clouds of each model in .txt file and processed with Surfer software.

The texture has been extracted and automatically applied on the final model using Agisoft Photoscan.

III. RESULTS

The final .psx file has a dimension of 2,7 Gigabyte.

The 2016 model of the cave have a size of 71 Megabyte and counts 1,046,285 faces, based on a dense cloud of 30,733,439 points.

Every single section, elaborated in high quality, has more than 24 billion points as dense cloud and an average of 3 billion of faces for the 3D model, the exported models are about 200 Megabyte size.

The final 2017 model of Grotta Romanelli has more than 36 billion points of dense cloud, and 6 billion of faces for the 3D model. The exported .OBJ file is 497 Megabyte size Fig 3.

IV. DISCUSSION

The cave model and the section models are extremely detailed (more than 30 billion of points) allowing the possibility to analyse the cave and to investigate the activity done during each year.

The exported model in .OBJ file is quite manageable, with a dimension of 144 Megabyte. Thus, the 3D model is easy-to-use with standard on line connections and with PC with medium hardware performances.

This method is extreme cost-effective; the only costs are for a high-performance camera, a PC with medium performance and program licenses.

The model is in constant evolution, can be modified and updated, keeping at the same time the information relative to each survey. Those characteristics are crucial to implement the excavation diary for scientific purposes but could be also used in many circumstances. In fact, the model is editable and adaptable to museum installations, scientific dissemination and research and can be further integrated with several new technologies (Captcha, virtual tour and VR).

V. CONCLUSIONS

Italy has played and plays a role of great importance in the study of prehistory and geology and Quaternary palaeontology. The Italian sites have enabled the international community to define chronological schemes, palaeobiogeographical models and to develop new methods of investigation. Yet, there is a real risk that this heritage, still able to provide new important research topics, could be forgotten, especially as regards the central and southern regions of our country. Grotta

Romanelli was among the first sites in Europe where scientific methods were applied in the field and for decades has been a strong reference for the stratigraphy and the prehistory of Italy. The excavations started in 1914 by C.A. Blanc were managed with an innovative multidisciplinary methodological approach bounded to become a standard for future excavations.

In the Third Millennium, the new excavations and the study of Grotta Romanelli, constitute not only an extraordinary site for multidisciplinary research, but also a major opportunity to be used as a true open-air museum, an element of great cultural and tourist attraction for the development of the area. In this regard, in addition to the progress of the researches, the project aims to provide tools for the conservation and use of geo-paleontological and archaeological features of such a special area. As a matter of fact, both the sediments and the walls of Grotta Romanelli are subject to erosion caused by increasingly frequent storm surges and water percolation. The presence of an active microflora causes a continuous attack to archaeological and paleontological materials in the hypogean environment. Therefore, the use of virtual modelling techniques applied to both the site and elements such as fossils, artefacts, engravings is a modern possible answer to these needs, a flexible and interactive tool available for those (Soprintendenza and other institutions) that have to protect and manage the precious and "delicate" cultural heritage of our country.

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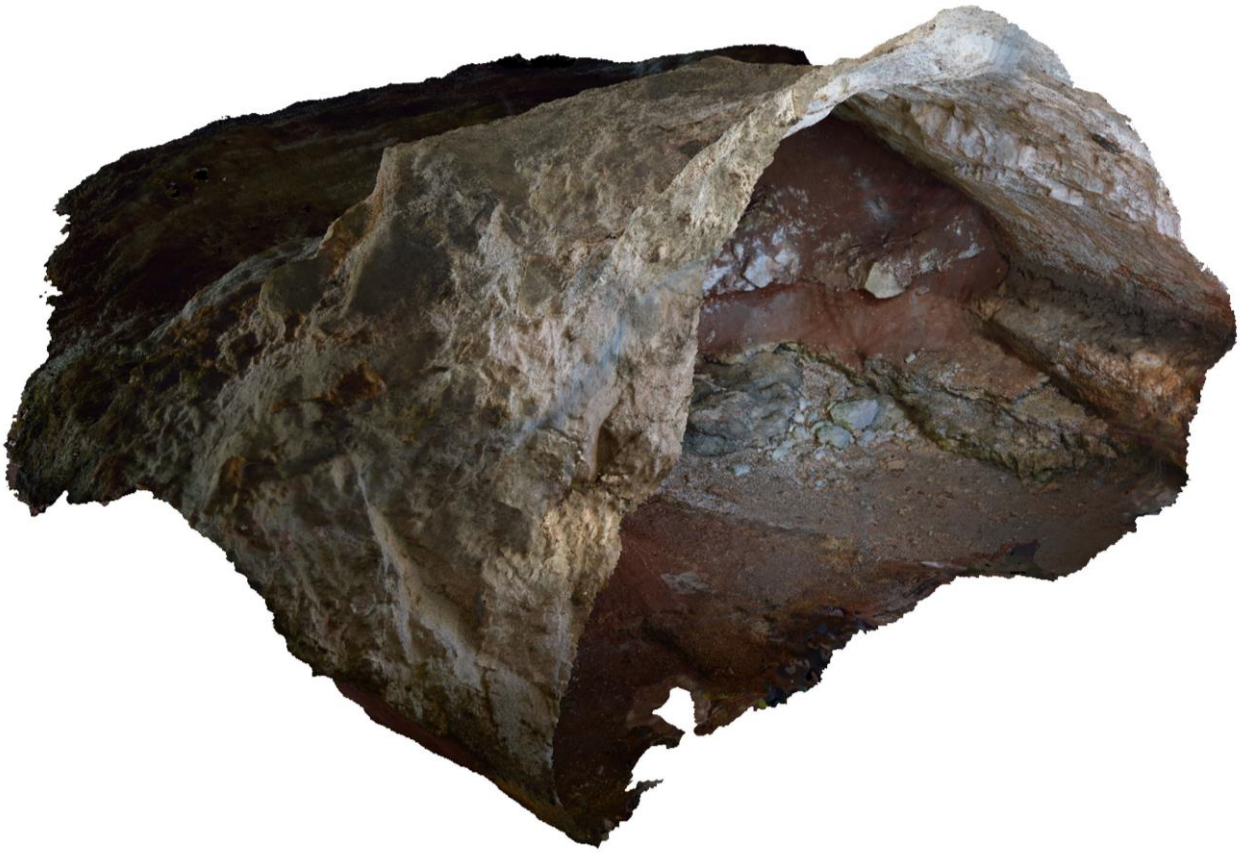

Fig. 1. Model of Grotta Romanelli after the campaign of 2016

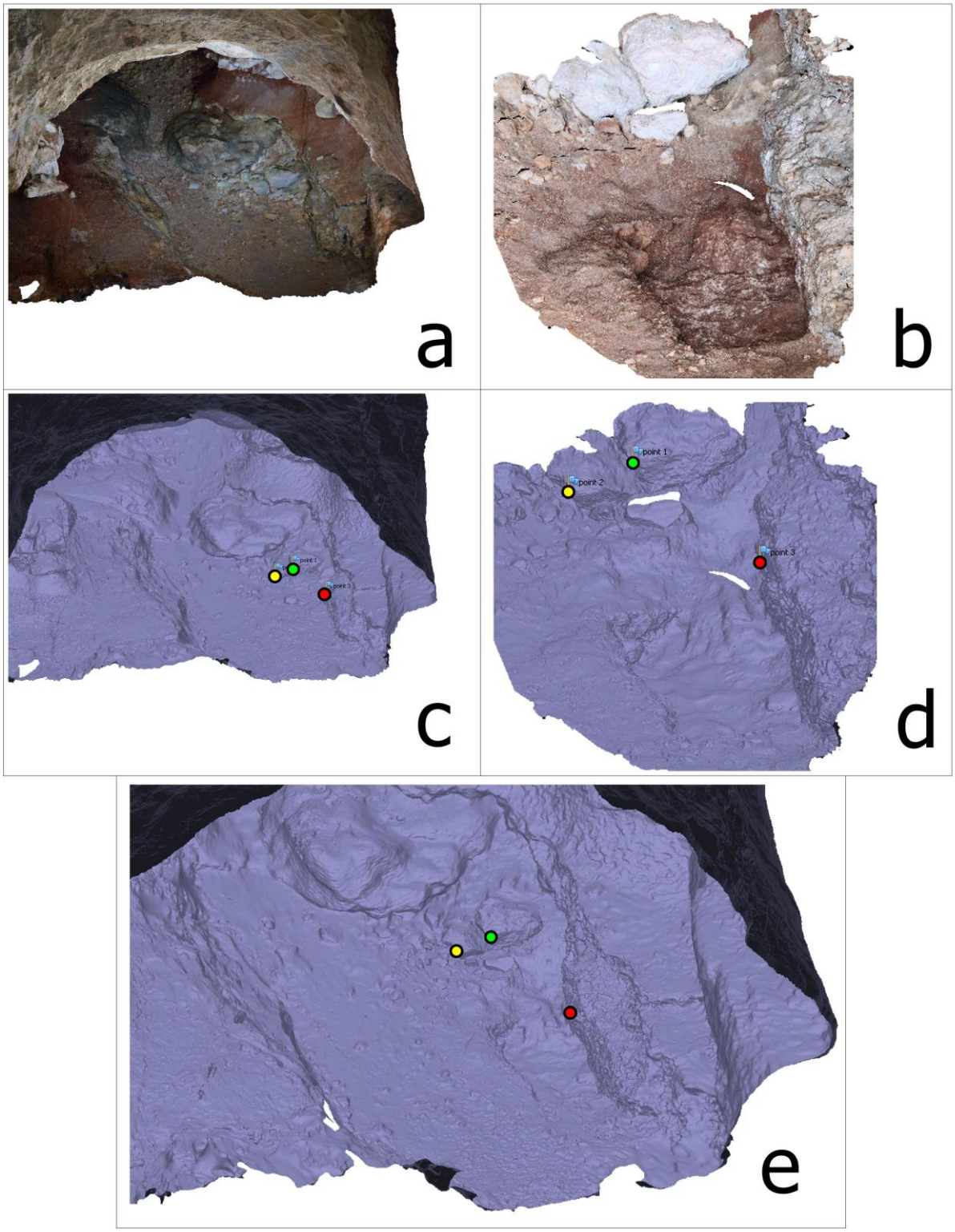

Fig. 2. a) Area of the 2016 cave model; b) excavation area called "Section 1"; c-d) positioning of the landmarks on the models; e) Merging of the updated model of the entire cave.

Fig. 3 Final model of Grotta Romanelli after merging and texturing.