The roman quarries of Lapis Specularis in the Vena del Gesso Romagnola: the Lucerna Cave and the Cà Toresina Quarry

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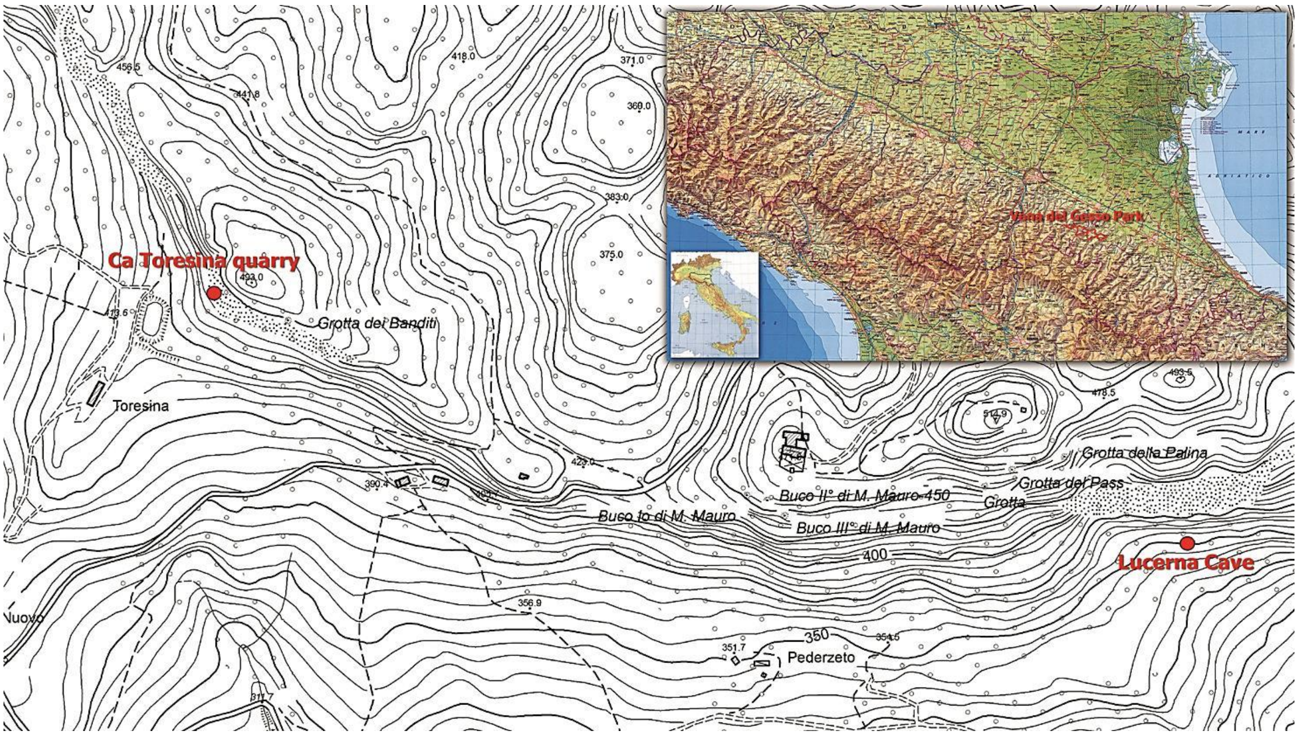
Introduction

Right: Fig. 1 - Geographical sketch.

Left: Fig. 2 - The Primary Gypsum in the Vena del Gesso Park (Photo: P. Lucci).

The Emilia-Romagna Regional Speleological Federation launched research project about the roman quarries of *Lapis Specularis*. This project is determined to survey and study the roman artificial cavities in the Vena del Gesso Romagnola (Northern Italy). The project is developed with the organizations: the Archeological Superintendence of Emilia-Romagna, the Romagna Parks and Biodiversity Organization, the Bologna and Modena and Reggio-Emilia Universities, the Emilia-Romagna Region.

Geographical sketch



The Vena del Gesso Romagnola is in the Northern Italy, in the Romagna Apennines Mountains, in Emilia-Romagna region. Today this area is protected with a park, because it's very important. The Regional Park of Vena del Gesso Romagnola was established by LR n. 10/05 over an area of 6,063 hectares, to protect the Gypsum outcrop that extends for about 25 Km from the valley of the Lamone river to the one of Sillaro stream (Fig. 1). Gypsum is a sedimentary evaporite easily soluble and the area is rich in karst; more than 200 caves have been explored, for a total length of over 40 Km. The flora and fauna are rich because of the two micro-climates of the southern sides (hot and dry) and north (fresh wet) of the outcrop, with rare and interesting species.

The Vena del Gesso is also a site of great interest by the historical point of view, having been continuous inhabited since the Bronze Age, with moments particularly interesting as the quarries of *Lapis Specularis* during the Roman Empire.

Currently all *Lapis Specularis* quarries are in the Monte Mauro area. The Park was a good tourist system, which can be enriched thanks to the ongoing researches about *Lapis Specularis*, setting up a specific section in the planned museum on the history of man in the Vena del Gesso.[1]

Geological Framework

The Vena del Gesso (Ravenna, Northern Italy) is an excellent natural laboratory for understanding the first phase of the salinity crisis, the dramatic geological event that has turned the Mediterranean Sea into a giant saline inhospitable to most life forms during the Messinian (Upper Miocene), between 5.97 million and 5.6 million years ago. The Messinian salinity crisis has produced 16 layers of selenite Vena del Gesso (Primary Lower Gypsum) with crystals up to two meters tall containing fossilized filaments of cyanobacteria (Fig. 2).

As soon as the deposition of gypsum finished, the area has been affected by tectonic events that have triggered massive submarine landslides causing the dismantlement of the gypsum formation and the deposition of the Resedimented Lower Gypsum unit.[2]

The tectonic events produced also many fractures in the primary Gypsum layers. The waters flow dissolved gypsum and enlarged these fractures, producing lenticular voids. After the water settled transparent crystals of secondary gypsum. The environment was very peculiar: oversaturated of $CaSO_4$ and fixed water. This condition allowed the development of big and transparent crystals: the *Lapis Specularis*.[3]

Historical framework

The ancient sources provide a lot of information about *Lapis Specularis* quarries, trade and use, thus integrating the picture outlined by the archaeological evidence. The available documentation mostly dates from the 1st and the beginning of 2nd century A.D., when *Lapis Specularis* started to be employed to a great extent in the production of window panels.

Plinius the Elder and Isidorus of Seville are undoubtedly the main sources about this kind of stone. Another important set of information comes from the inscriptions, spanning from the 1st to the 5th or 6th century A.D. Among them, the most noteworthy are some Roman funerary inscriptions dating from early imperial times and concerning liberti of the Julio-Claudian dynasty, called “specularii” or “speculariarii”, i.e. craftsmen involved in the production and/or manteinance of the window panels.[4]

This secondary Gypsum replaced mainly the glass for windows from roman age to very latest ages. The *Lapis Specularis* was used also to create greenhouses and apiaries. The Circo Massimo in Rome was covered from *Lapis Specularis* powder, to shine during the exhibitions. The roman medicine used the powder as therapeutic purposes.

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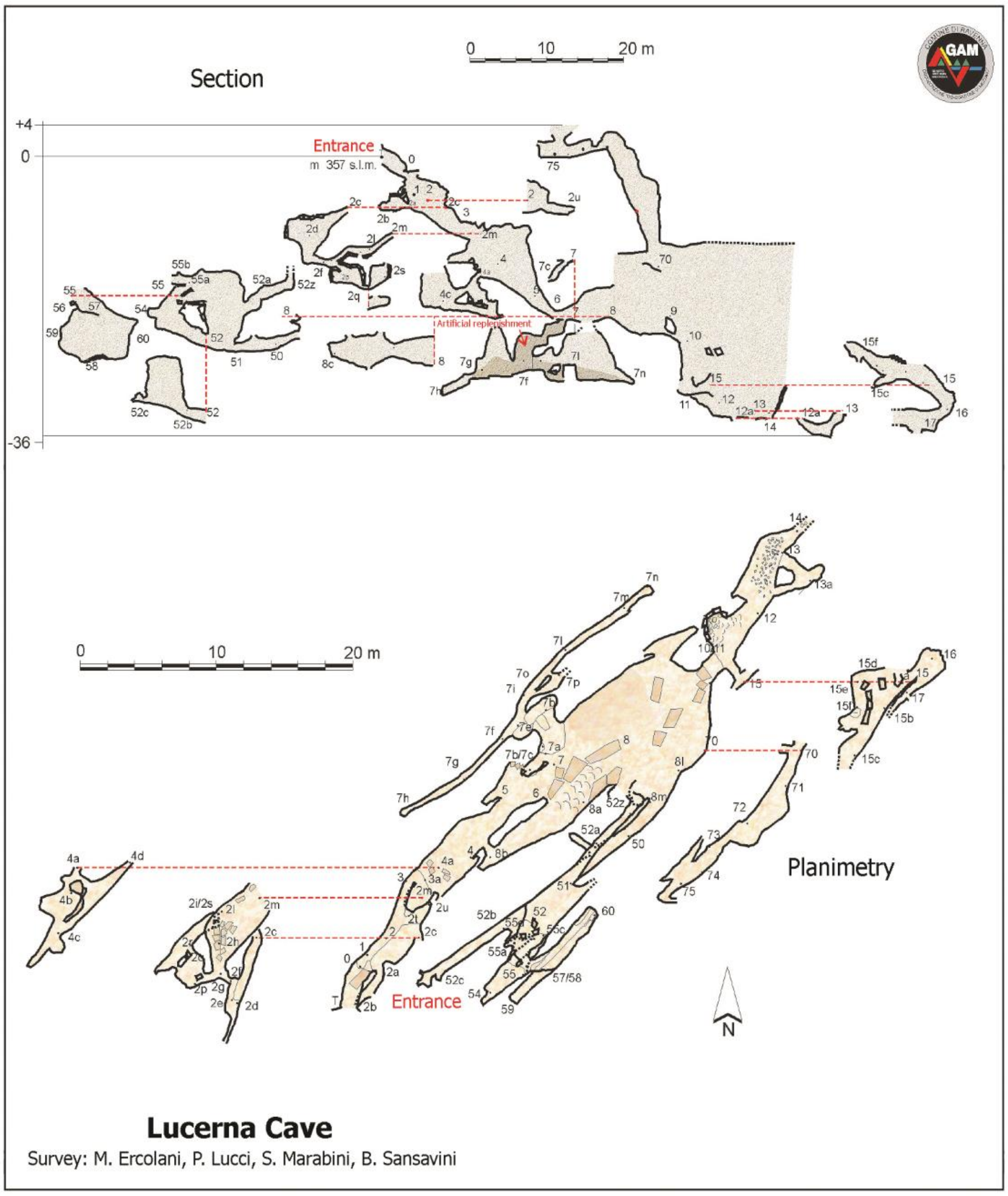
[1] Costa 2015, 193.
[2] Lugli 2015, 17.
[3] Demaria 2013, 91.
[4] Tempesta 2013, 45.

Right: Fig. 3 - The survey of Lucerna Cave.



The *Lapis Specularis* is present in a lot of countries in the Mediterranean Basin. Plinio in his book *Naturalis Historia (XXXVI, 45-46)* cited the more important quarries in Spain, Tunisia, Italy, Cappadocia (Turkey) and Cyprus Island. Plinio wrote: ..*et in Bononiensi Italiae parte breves*..., indicating the area in the Apennines around Bologna. It's possible, that the discovery in the Vena del Gesso Romagnola corresponds at this area.[5] Currently, in Italy are known quarries of Lapis Specularis only in Sicily and Emilia-Romagna. At this time the Vena del Gesso is the alone area in the mainland Italy with Lapis Specularis quarries. In this last two years the speleologists discovered fifteen extraction places; it is possible that the activity was very widespread in the roman age in this territories.

The Lucerna Cave

Nowadays, the Lucerna Cave (literally, in Italian, 'Lamp Cave', because of the findings of Roman and Late Roman oil lamps inside it) is the largest underground quarry of Lapis specularis discovered in the Messinian Gypsum outcrop of the Vena del Gesso romagnola (Northern Italy).

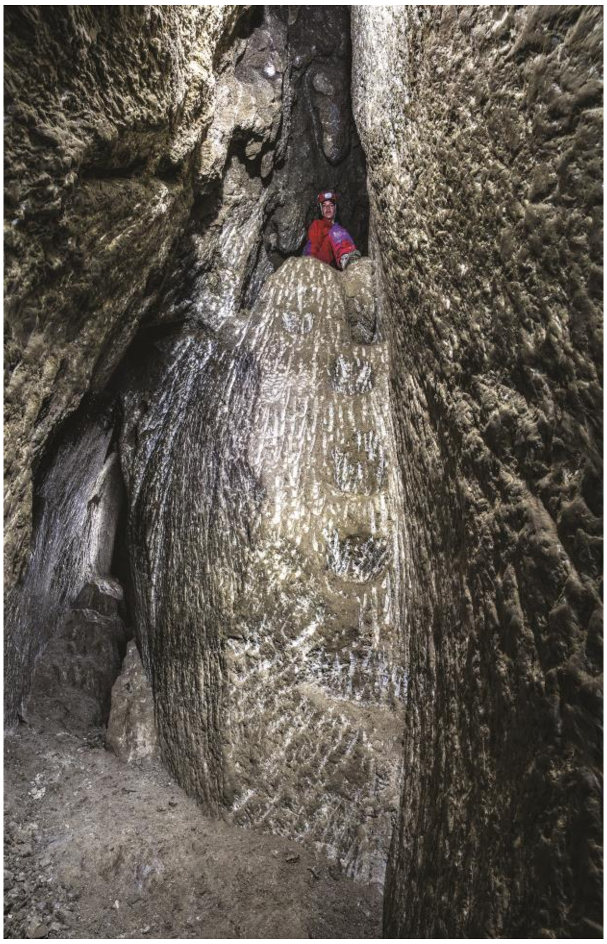
[5] Guarnieri 2013, 11-13.

Left: Fig. 4 - The central room of Lucerna Cave (Photo: P. Lucci).

Right: Fig. 5 - The steps carved in the Gypsum, Lucerna Cave (Photo: P. Lucci).

Starting from November 2000, this cave was explored, mapped and emptied from processing residues by GAM Mezzano Cave Club (Fig. 3). From a speleological point of view, the cave do not present any explorative problems, while the emptying works of the anthropogenic deposits (not finished yet) required almost a decade, in cooperation with archaeologists.

The materials filling the cave have to be identified as fragments produced during the works, moved from a place to another, inside the cave, on the basis of the progress of excavations. After the emptying process carried on by speleologists, several spaces, previously filled with a thick, anthropogenic stratigraphically unit, were now accessible: they were characterized by man-made traces of digging tools, in particular chisel-made traces on the walls; some archaeological materials, dating back to Roman and Late Roman Ages, were discovered, e.g. fragments of oil lamps, pottery, a coin dating back to Marcus Aurelius Age.



The Lucerna cave was born how natural cave and later was used how quarry of Lapis Specularis (Fig. 4). The mouth of the cave is in the Monte Mauro wall, a precarious area. A lot of Gypsum boulder covered an old staircase carved in the rock. Inside are present a lot of manmade works, recesses to oil lamps, to wood beam, to wood small steps, to worker's foots (Fig. 5). These recesses were of service to help the laborers to take away the Lapis Specularis (Fig. 6). A lot of cave parts was enlarged to find or to take the secondary Gypsum. In an ambient there is a little hole in the wall, to put a rope to descend in the underlying crevice.[6]

The chisel-made traces are very close and regular. The kinds are:

1) chisel-made fishbone, regular, same angle and very close; the utensil was a pickaxe with flat point;
2) chisel-made very deep and wide, from top to bottom in the complete wall; the utensil was a pickaxe with flat point; this work was of service to enlarge the cave;
3) chisel-made very surface, almost polishing; the utensil was a pickaxe with flat and wide point; this work was of service to improve the passages in the cave.

The used tools to dig the cave were chisels, pickaxes, picks, axes, hammers (Fig. 7). The used tools to extract the Lapis were awl, wood wedge and small mallets.[7] The Lucerna Cave was reconstructed with laser scan method.[8]

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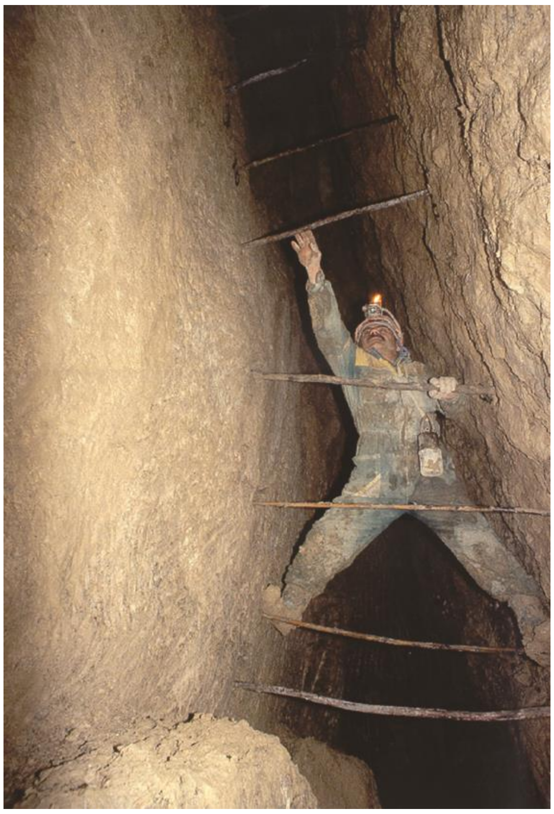
[6] Ercolani M. et al. 2013, 99-107.
[7] Guarnieri 2013, 119-120.
[8] Santagata et al 2015, 411- 418.

The Ca’ Toresina quarry



Left: Fig. 6 - The recesses for rungs, Lucerna Cave (Photo: P. Lucci).

Right: Fig. 7 - The chisel-made traces in the gypsum (Photo: P. Lucci).

The Ca’ Toresina quarry is in the Gypsum wall between Ca’ Faggia Pass (West) and the Monte Mauro Peak (East). The quarry is 50 meters long; therefore it is actually the second most important place of extraction (Fig. 8). At the discovery the quarry was almost completely closed from detritus. It’s necessary to remove the debris, now after hard and long work the quarry is a tunnel with 1-3 meters width and 7-8 meters high. The tunnel is largely artificial, but some-times there are traces of water karst erosion. The tunnel walls have many chisel scratches and a lot of recesses to oil lamps and wood beam. Sometime these traces are covered from concretions of gypsum (Fig. 9 and 10). In the top of the quarry it is an ascending branch, where there are clear chisel-made traces. In the detritus were hundreds of *Lapis* scraps that have traces of saw. It’s possible, that a first work of transformation was made in the quarry. At present this place is the bigger finding of *Lapis Specularis* sheets with saw traces (Fig. 11). In the detritus were also a lot of evidences, which the Archeological Superintendence of Emilia-Romagna is studying.[9]

The methodology

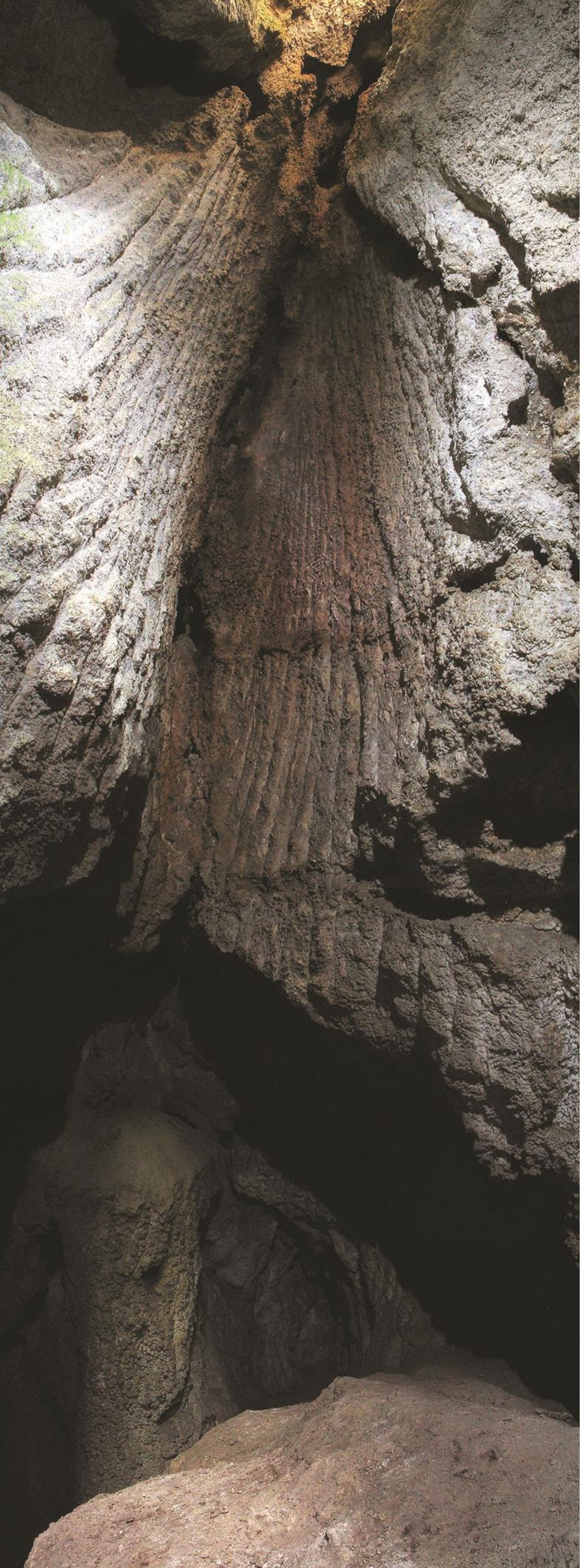
Agisoft PhotoScan is the used software to obtain the 3D model of *Lapis Specularis* quarry by Ca’ Toresina. Agisoft PhotoScan is an advanced image-based 3D modeling solution aimed at creating professional quality 3D content from still images.[10] Based on the latest multi-view 3D reconstruction technology, it operates with arbitrary images and is efficient in both controlled and uncontrolled conditions.

You must take the cavity from a lot of viewpoints with a series of high definition photography. Photos can be taken from any position, providing that the object to be reconstructed is visible on at least two photos. Both image alignment and 3D model reconstruction are fully automated.

The first stage is camera alignment. At this stage the software searches for common points on photographs and matches them, as well as it finds the position of the camera for each picture and refines camera calibration parameters. As a result a “sparse” point cloud and a set of camera positions are formed (Fig. 12).

The “sparse” point cloud represents the results of photo alignment and will not be directly used in the further 3D model construction procedure. On the contrary, the set of camera positions is required for 3D model construction.

[9] Ercolani M. et al 2015, in preparation.
[10] Agisoft LLC 2015, P.v.



The second stage is building “dense” point cloud that is based on the estimated camera positions and pictures themselves. Dense point cloud may be edited and classified prior to export or proceeding to 3D mesh model generation.

The third stage is building the “mesh”. The software reconstructs a 3D polygonal mesh representing the object surface based on the dense point cloud. Having built the mesh, it may be necessary to edit it.

After the geometry is reconstructed, it can be textured with the original photos. Using markers, it’s possible to specify locations within the scene (Fig. 13). These markers are the ground control points and are used for measuring distances and volumes within the scene. The more photos are used to specify marker position the higher is accuracy of marker placement. To define marker location within a scene it should be placed on at least 2 photos

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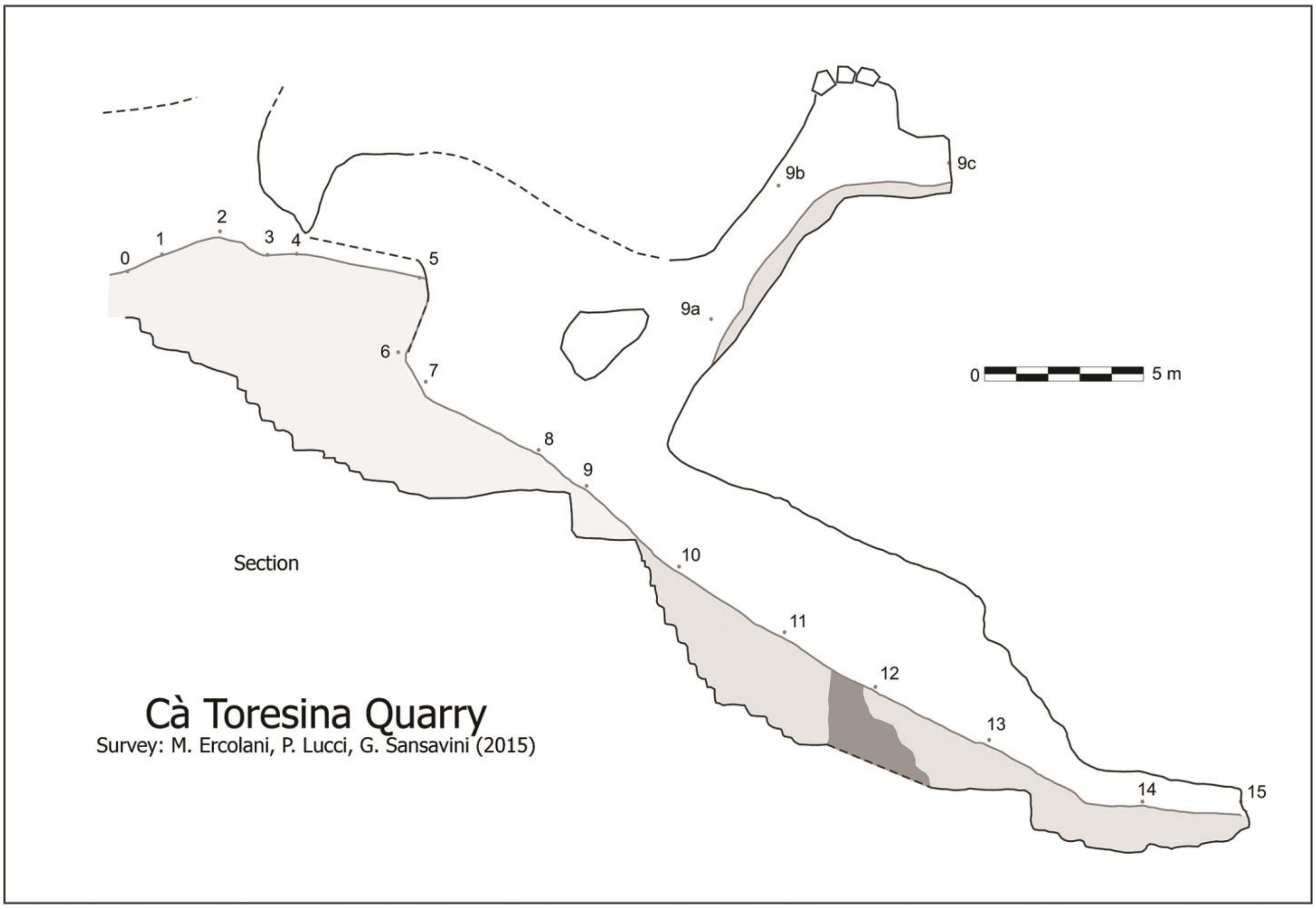
The methodology offers the advantage to obtain a 3D reliable model with limited task. It’s very important the photos’ definition: the software isn’t able to align blurry or not defined photos. The object’s surface must not be reflecting. In the quarry the tunnel has a lot of recognizable points, the software uses these points how homologous points to align the photos.

Every photo must cover the previous image with 60% both horizontally and vertically. It’s necessary to plan the logic sequence, without holes. You must take hundreds of photos every section of tunnel.

The procedure is very heavy for the hardware, because the processing information are propor-tional to the photos’ definition. It’s necessary to section the tunnel in segment 10 meters long, named “chunk”. The dense cloud contains more or less 60 - 90 millions of points. It’s need an hardware very powerful.

The photos are the main point of work: it’s necessary clearness and sharpness. The lens must not distort the images, only middle wide-angle lens are suitable to these shots. Every photo must cover vertically and horizontally the previous photo at least 60-70 %. It’s necessary to take hundred photos also for little reconstructions. The logical sequence of the photos is very important: it needs don’t skip never sections of the cave.



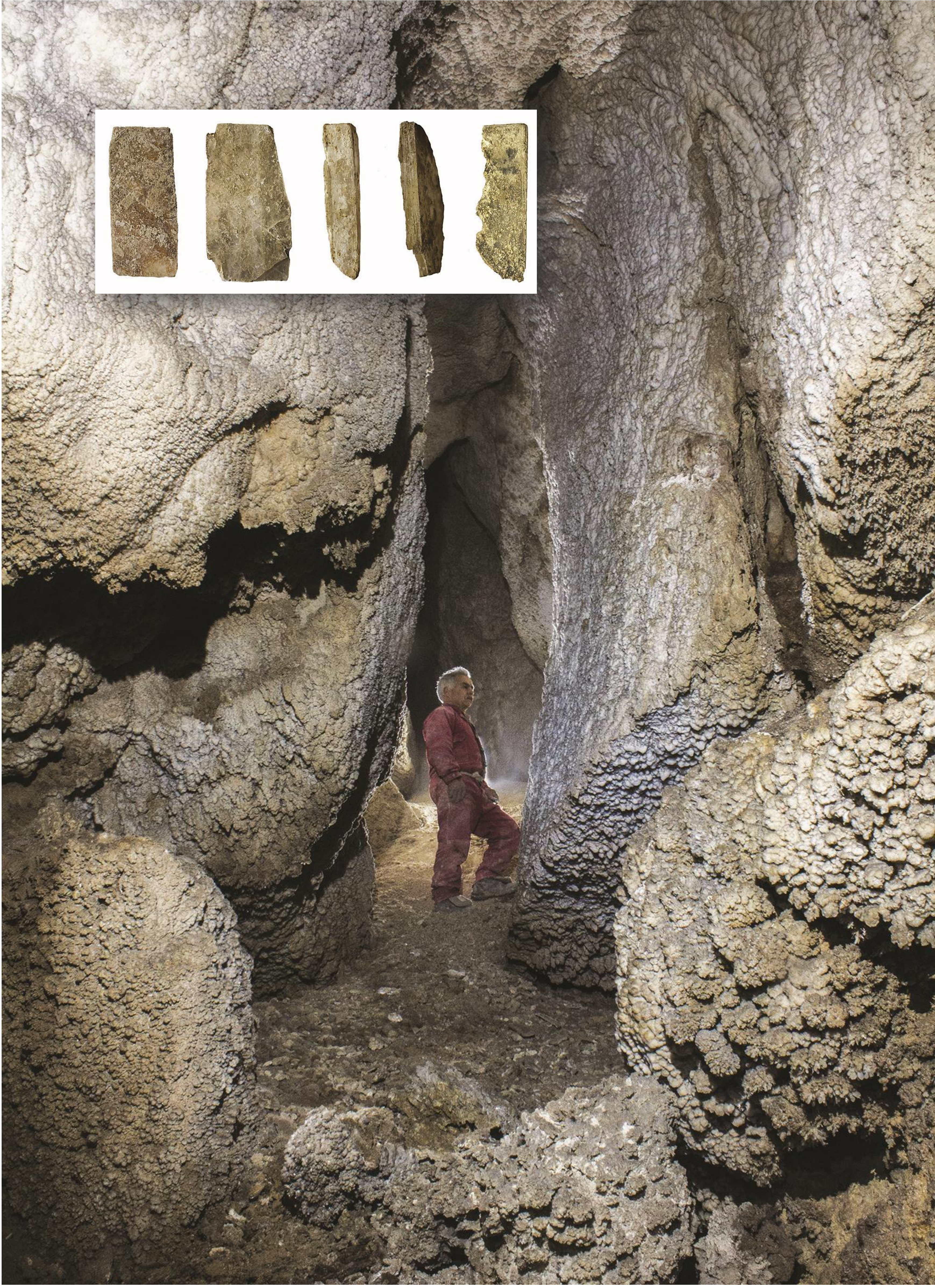
3D model of Cà Toresina quarry

Top: Fig. 8 - The section of the Cà Toresina quarry. The grey part is the removed replenishment.

Right: Fig. 9 - The first part of Cà Toresina, the walls have many chisel scratches (Photo: P. Lucci).

The photos for the 3D model of Cà Toresina quarry are more or less 2500. The used camera is a Nikon D810, the sensor has 36 Megapixels and size 35.9 mm x 24 mm; the lens is an AF-S 17-35mm f/2.8 D ED, used always with 17 mm focal. The used sensitivity is 100 ISO every tunnel section and the used stop is 5.6. The files' format is the "Tagged Image File Format" (TIFF). Every file is 300 dpi and has the dimension 7,360 x 4,912 pixels (100Mb).

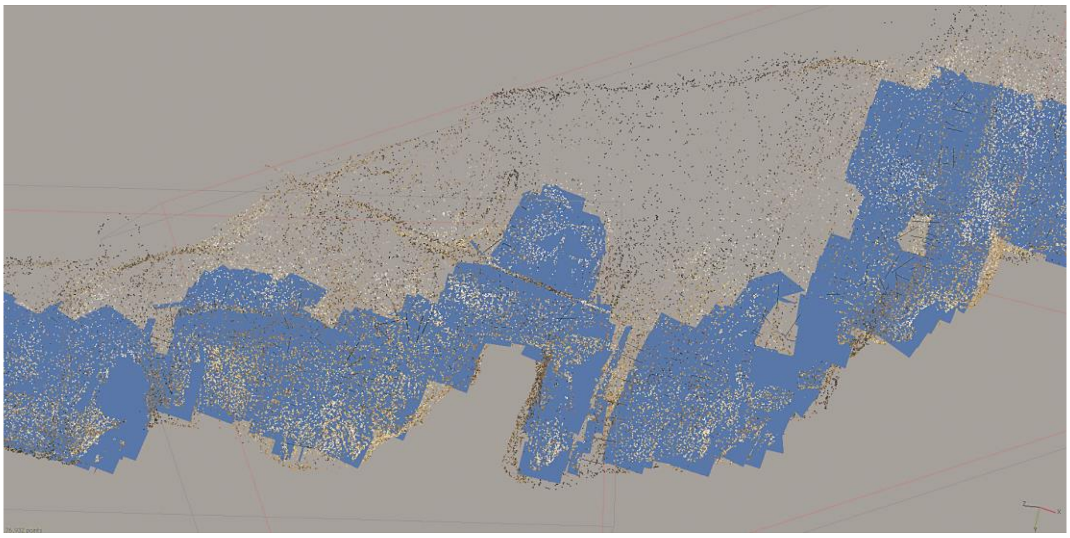
The cave was divided in four sections named "chunk": around 490 photos every chunk more a lot of repeated photos to improve the overlay between two contiguous chunks. The reconstruction with underground photos is very complicated. The lighting isn't in the cave and it needs to use artificial lighting how the flash. The Agisoft PhotoScan user manual doesn't suggest the flash use, because the shadow in the walls changes in every photogram and the software struggles in the alignment. I take more photos with 80-90% overlay, to resolve this problem. Obviously the number of photos increases perilously. The cave dimensions are very narrow, I have to use wide-angle to take photos, but the software prefers the middle lens. I put in every chunk a lot of markers: recognizable ground control points with little objects. I put in the area of overlay between two contiguous chunks the software markers. These software markers are in the single photo and help the software to link the contiguous photograms. Every marker must be in three photos, to have the related 3D coordinates. The markers use simplifies the chunks alignment and set up homogeneously the orientation and the dimension of the sections. If the operations are correct, the reconstruction is fluid and complete. The recognizable ground control points are of service to define a really dimension at the model with really measures (Fig. 14).

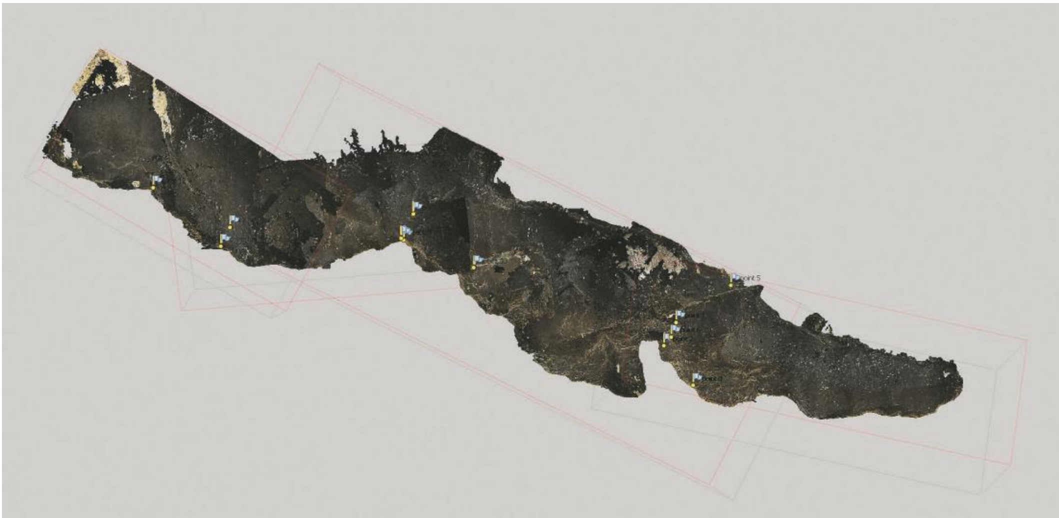


Finally the model satisfies the expectations, it's possible:

- To display the quarry's shape
- To measure the dimension
- To explore the quarry's inside
- To recognize the chisel-made in the rock.

The software exports the 3D model in a lot of format to other software.





Left: Fig. 10 - The interior of the quarry (Photo: P. Lucci).

Inlay left: Fig. 11 - The Lapis Specularis sheets with saw traces (Photo: P. Lucci).

Top right: Fig. 12 - The sparse point cloud and the cameras position.

Center right: Fig. 13 - The dense point cloud and the software markers.

Bottom right: Fig. 14 - The complete model of the Cà Toresina quarry.


Problems

The Cà Toresina quarry is a tunnel with three levels of ground. The width varies from 30 cm to 2 meters. The ceiling is quite difficult to light in the narrow points. In these points it's necessary to take many photos, because it's impossible to control the framing. Where it's impossible to photograph the ceiling, the model is open. The shots must be very careful: you must take the same area from a lot of viewpoint. The shot sequences must be planned before to decide the place of recognizable ground control points. The choice of these positions is fundamental and it must foresee the following alignment of photos and the production of model. The step of reconstruction needs an adequate hardware: Processor I7 6700K (4 Hz), RAM 32 GB DDR4, video adapter VGA with 6GB DDR5, Hard disk SSD 3.5 TB.

Conclusions

The photogrammetric method of Agisoft PhotoScan is versatile and quite cheap compare to other reconstruction methods how Laser scanner; but the photographic equipment can be relatively cheap, because the camera must have very good quality and the lens must not have distortions. The software doesn't need a long formation. The example of Cà Toresina quarry highlights that this method allows a careful and true reconstruction of underground space (fig. 15 and 16). With this method it is possible to measure inside objects to archaeological studies. The next step in the project will be the creation of a video for an inside virtual visit, with the obtained model. The visitors of the planned museum on the history of man in the Vena del Gesso will can see the interior of the Cà Toresina quarry. In the future it will be possible to extend the 3D reconstruction to all *Lapis Specularis* caves in the Monte Mauro area.

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Left: Fig. 15 & 16 - The inside of the quarry in the 3D reconstruction.