LASER SCANNER SURVEY AND TRU VIEW APPLICATIONS OF THE "GROTTA DELLA LUCERNA" (RAVENNA, ITALY), A ROMAN MINE FOR LAPIS SPECULARIS

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Abstract

The Grotta della Lucerna (Lamp's Cave) is a small cavity (about 400 m long and 36 m deep) located in the Regional Park of Vena del Gesso Romagnola, at Zattaglia (Ravenna, Italy). This cave represent one of the few documented mining sites of *Lapis Specularis* in Italy, a particular type of secondary gypsum that was mined in Roman times and worked to obtain thin transparent cleveage sheets used for windows. Crystal processing traces and artificial changes made to facilitate the exploitation and transport of the raw material are visible in all the areas currently explored. The archeological findings allow to constrain the period of exploitation between the 1st and the 4st century CE. We performed a laser scanner survey of the most accessible areas of the cave by carrying out 33 scans inside and 3 outside the cave. The data analysis allowed the construction of a tri-dimensional model, from which it was possible to draw plans and sections with very high (centimetric) accuracy. With the Leica Tru View applications it was also possible to produce an interactive model which permits the navigation inside the point data, with the possibility to move between the scans. Other operations are also possible such as distance measurements, notes and coordinates input, snap print directly by photos and points measured with the laser. This application has been used also for the drawing operations in bi-dimensional mode using the Cloudworks plug-in that allows to draw lines and polylines directly from the TruView in Auto-Cad.

Keywords: lapis specularis, secondary gypsum, laser scanner survey, Vena del Gesso.

Riassunto

La Grotta della Lucerna è una piccola cavità con uno sviluppo planimetrico di circa 400 m e 36 m di dislivello, situata nel Parco della Vena del Gesso Romagnola. Questa grotta rappresenta uno dei rari siti di estrazione di Lapis Specularis attualmente documentati in Italia, un particolare tipo di gesso secondario che veniva estratto in epoca romana per ricavare sottili lastre da utilizzare allo stesso modo delle lastre di vetro per finestre. Tracce di lavorazione ed adattamenti artificiali per facilitare i lavori di estrazione del materiale sono numerose e presenti in quasi tutte le zone della grotta attualmente esplorate. I ritrovamenti archeologici hanno aiutato a inquadrare il periodo di sfruttamento della grotta in miniera tra il I e il IV sec. d.C. Per effettuare il rilevamento con laser scanner delle zone più accessibili della grotta sono state effettuate 33 scansioni all'interno e 3 all'esterno della cavità. L'analisi dei dati ottenuti ha permesso di ricavare un modello tridimensionale da cui è stato possibile ottenere piante e sezioni con una precisione centimetrica. Attraverso l'applicazione Leica Tru View è stato successivamente realizzato un modello interattivo che permette la navigazione all'interno del rilievo, in cui è possibile muoversi tra le varie scansioni ed eseguire diverse operazioni tra le quali misure di distanze, inserimento di testi, snap print, inserimento di coordinate direttamente dalle fotografie e dai punti di misura. Questa applicazione è stata utilizzata anche per realizzare i modelli bi-dimensionali tramite il plug-in di Cloudworks, con il quale è stato possibile disegnare direttamente dal Tru View sul foglio di disegno in ambiente Cad.

Parole chiave: *lapis specularis, gesso secondario, rilievo laser scanner, Vena del Gesso.*

Introduction

Gaius Plinius Secundus, better known as Pliny the Elder, Roman naturalist and philosopher who lived between AD 23-79, described a particular and transparent stone known as *Lapis Specularis*, widely used in Roman times for the production of door and window panels.

This particular stone similar to glass was quarried in many areas of the Roman Empire in Spain, Italy, Greece and North Africa from cavities or natural gorges, trying to follow the fractures in which this rock was formed.

The stone is gypsum in its secondary macrocrystalline form that may be easily split to form thin transparent sheets.

The first exploitation site for *Lapis Specularis* discovered in Italy is located in a cave called "Grotta della Lucerna".

This name derives from the discovery of some Roman lamps used by miners to lighten the cave during the mining operations.

This paper describes the detailed laser scanner survey that we performed in this important archeological site.

Geology and description of the cave

The Grotta della Lucerna is located on the southern side of Mount Mauro, not far from the village of Zattaglia in the Regional Park of the Vena del Gesso Romagnola. This peak rises 515 m a.s.l. between the two rivers Senio and Sintria, and is the highest of the Vena del

Fig. 1: the Vena del Gesso Romagnola (photo Piero Lucci).
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Fig. 2: Monte Mauro (photo A. and G. Lanzoni, UPcamera Multimedia Flying Technologies).
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Gesso Romagnola, a gypsum ridge running WNW-ESE in Emilia Romagna between the provinces of Bologna and Ravenna for a length of about 25 km, and with an average altitude of about 370 m a.s.l. (Fig. 1).
The first phase of the Salinity crisis that affected the Mediterranean Sea during Messinian (from 5,971 to 5,33 Ma; Roveri et al., 2014) led to the deposition of primary evaporites in this area, alternated with clay material rich in organic matter (Lugli et al., 2010).
The presence of gypsum in this area has always influenced human settlement and the economies of local communities, and in this context the Grotta della Lucerna represent one of the oldest evidence of the use of this material (Ercolani et al., 2013).
This small cave, known to the register of natural caves in Emilia Romagna with the number ER-RA 831, has two entrances located close to each other. The main one is located at an altitude of 357 m a.s.l. while a few meters below there is a second entrance opened a few years ago during the first works of excavation. The cave is developed along a system of vertical fractures (Fig. 2).
The Grotta della Lucerna was discovered in November 2000 by the local group Speleo GAM Mezzano that has conducted the long work to remove the filling of the cave and to carry out archeological excavations (still in progress), as well as a first mapping survey. The cave shows the presence of traces of tool marks represented by curved grooves on the upper vault of the entrance and some steps carved in the surface of gypsum.
At the time of the first explorations the entrance of the cave consisted of a narrow hole with a diameter of about fifty centimeters which immediately led into a vertical shaft several meters deep.
There are many areas in this cave explored and surveyed in this years but in most cases there are signs of previous visits by humans, and the archeological findings allow to constrain the period of exploitation between the 1st and the 4st century CE.
After the discovery of this cave other smaller ancient excavations sites have been documented at Mount Mauro.

Laser scanner survey

The Grotta della Lucerna was first mapped between February and April 2002 by M. Ercolani, P. Lucci, S. Marabini and B. Sansavini using the classical techniques of speleological surveying (compass, clinometer, metric rope etc.) that led to the realization of a very detailed map. This early map has been essential for the planning of the laser scanner survey and especially for the planning of the scan targets.
Laser scanners are measurement instruments able to automatically acquire spatial coordinates of a spatial region or a surface of an object.
This technology is based on emission and reception of a light beam. The types of laser are divided into several classes determined in accordance with European standards depending on security policy.
Laser scanners can be classified into different categories, depending on the receiving system and signal processing: *triangulation scanner* (emitter and receiver are separated by a known distance called base line) and *ranging scanner* (emitter and receiver coincide).
Ranging scanners are divided in *time of flight* and *phase base difference* scanner. In the first the laser pulse is emitted toward the object and the distance between transmitter and reflecting surface is based on the time taken by the signal to travel the distance between the source of emission and reception by the signal (AA.VV. Rapporti Tecnici I.N.G.V., 2010). Phase

Fig. 3: survey operations inside the cave (photo Santagata T.).
Fig. 3: operazioni durante il rilievo della grotta (foto Santagata T.).

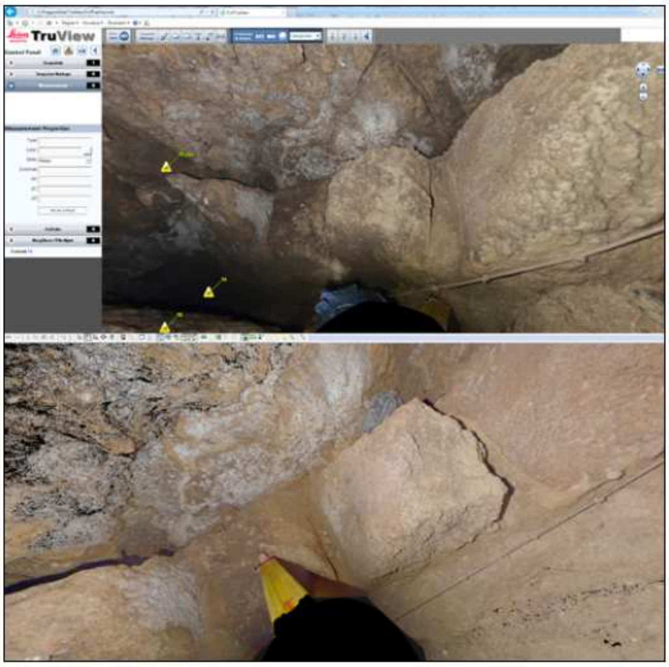

Fig. 4: traces of excavations visualized with Leica TruView aplication (screenshot Santagata T.).
Fig. 4: tracce di scavo visualizzate con l'applicazione Leica TruView (screenshot Santagata T.).

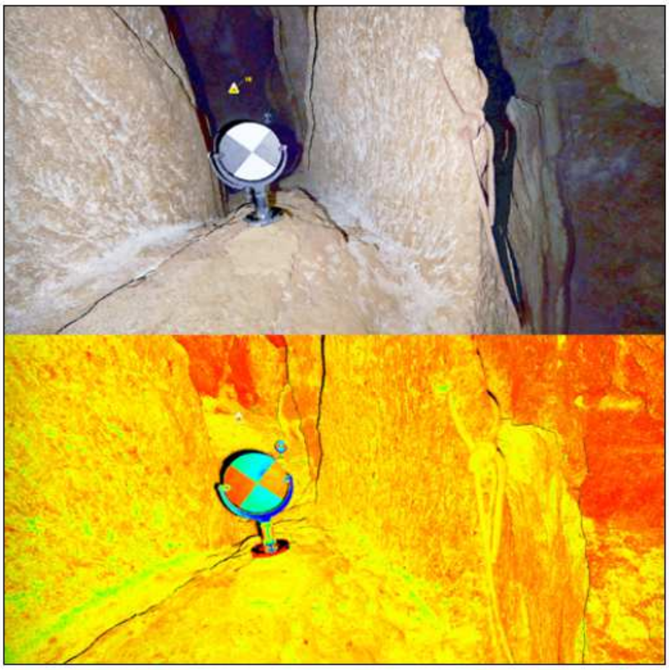

Fig. 5: target used for the survey visualized in Cyclone (screenshot Santagata T.).
Fig. 5: i target utilizzati durante il rilievo visualizzati in Cyclone (screenshot Santagata T.).

based scanning utilizes a constant beam of laser energy that is emitted from the scanner and the distance is calculated by comparing the phase difference between wave transmitted and received.
The scanner used for this work is a Leica HDS7000 (Fig. 3), a phase difference scanner equipped with a dual axis compensator, on-board control, wavelength of 1,5 microns, laser "CLASS 1" with a flow rate of 187 m and a resolution of 0,1 mm. This tool is provided with an external camera Canon D7000 with wide angle lens and a support necessary to take photographs that will be join to the scans.
During the operations in the cave, scanner and camera were mounted on a tripod (the same type used for total stations); for each scan we proceeded first with the scanner detection and then the instrument was removed to use the camera.
Some targets were used to have connection points easily identifiable even from photos. The targets are circular aiming devices with a magnetized support base rotating over 360°.
The steps for detecting the cave with terrestrial laser scanner were divided into three working days.
The first day was devoted to inspect the cave to plan the subsequent survey phases.
At first we performed three scans outside the cave to obtain the surface profile of Mount Mauro with the location of the cave entrance, while the other five scans on the day were performed inside the cavity down to the room located just beyond the security gate.
The scans and photographs were then processed with the software "Leica Cyclone" to create a 3D model by registering the control points for joining the scans.
On the second day, twelve scans were performed and particular attention was paid in some passages with traces of excavations to cover them as completely as possible (Fig. 4). In this phase the final room of the cave was also surveyed carrying out five scans.
The third day was dedicated to the survey of the secondary branches and the lower parts of the cave. The presence of numerous trace of excavations suggested to perform more scans to document them in detail. Up to a total of sixteen scans were completed after the temporary removal of obstacles such as stairs and ropes positioned to facilitate some passages.
The scans on the north-west branch of the cave resulted the most challenging because of its narrow walls .
The use of this type of instruments inside a cave involves many risks, and the instrumentation was always stored in a special box and pulled out just for the time strictly necessary.

Data analysis and "TruView" application

The survey phase was completed with the acquisition of thirty-six scans and related photographs. The data set was transferred on an external hard drive and then on a computer to begin the final processing. Because of the enormous amount of data collected and processed (about 96 GB), to perform graphic design it was necessary to use a workstation with specific characteristics (CPU Intel i7 with Enermax power pack, Ram 16gb with two internal hard disks SSD Samsung 128 GB for primary system and an external 320 GB HD Data Backup extractable, Nvidia GTX580 3D graphic card).
The data downloaded directly from the laser scanner can be opened using the Leica Cyclone software, which consist of a suite of software modules (including Publisher for creating TruView file sets) and import the scans for further processing.
The original scans show colors from yellow to red (depending on the reflectance of the surface detected

Fig. 6: the main screen of Leica TruView application (screenshot Santagata T.).
Fig. 6: la schermata principale dell'applicazione Leica TruView (screenshot Santagata T.).

by the laser) and the first step is the coloration of the different point clouds based on the photographs. The further step is the union of the thirty-six scans using as reference the targets placed during the survey.
To color the point clouds it is first necessary to merge the photographs together. During the survey, each scan was associated with eight panoramic photographs of which six along the azimuthal axis and the other two upward and downward with increments of sixth degrees.
The coloration of the point clouds was done using the Leica Cyclone software through the selection of common points on scans and photographs; in this way is possible to obtain the true color of the points (Fig. 5).
To merge the scans it is first of all necessary to identify and name on each scans all the targets placed during the survey, which are then automatically identified by the software.
In order to obtain a better precision to overlap the photos with the point clouds, for almost all the scans it was necessary to use a manual control of the points in addition to the targets used during the survey. This operation was carried out by selecting a minimum of four points in common between pairs of scans, to obtain a complete overlap with a relative error of 0,004 m.
The final result of this first stage of data processing is a 3D model which comprises all the point clouds with true colors that may be used for spatial analysis and transfer data to other formats for processing with other applications.
After the creation of the 3D model, it is possible to produce another interactive model which permits the navigation inside the point data using the free application TruView. There are a number of options available in Cyclone to control the accuracy, resolution, color and file size before the creation of the TruView model.
With this tool it is not necessary to use the Cyclone software to view the 3D model, which can be saved on any external support (DVD or USB memory systems) to visualize it on any computer.
TruView allows the navigation inside the 3D model through a screenshot. Using a simple "panoramic"

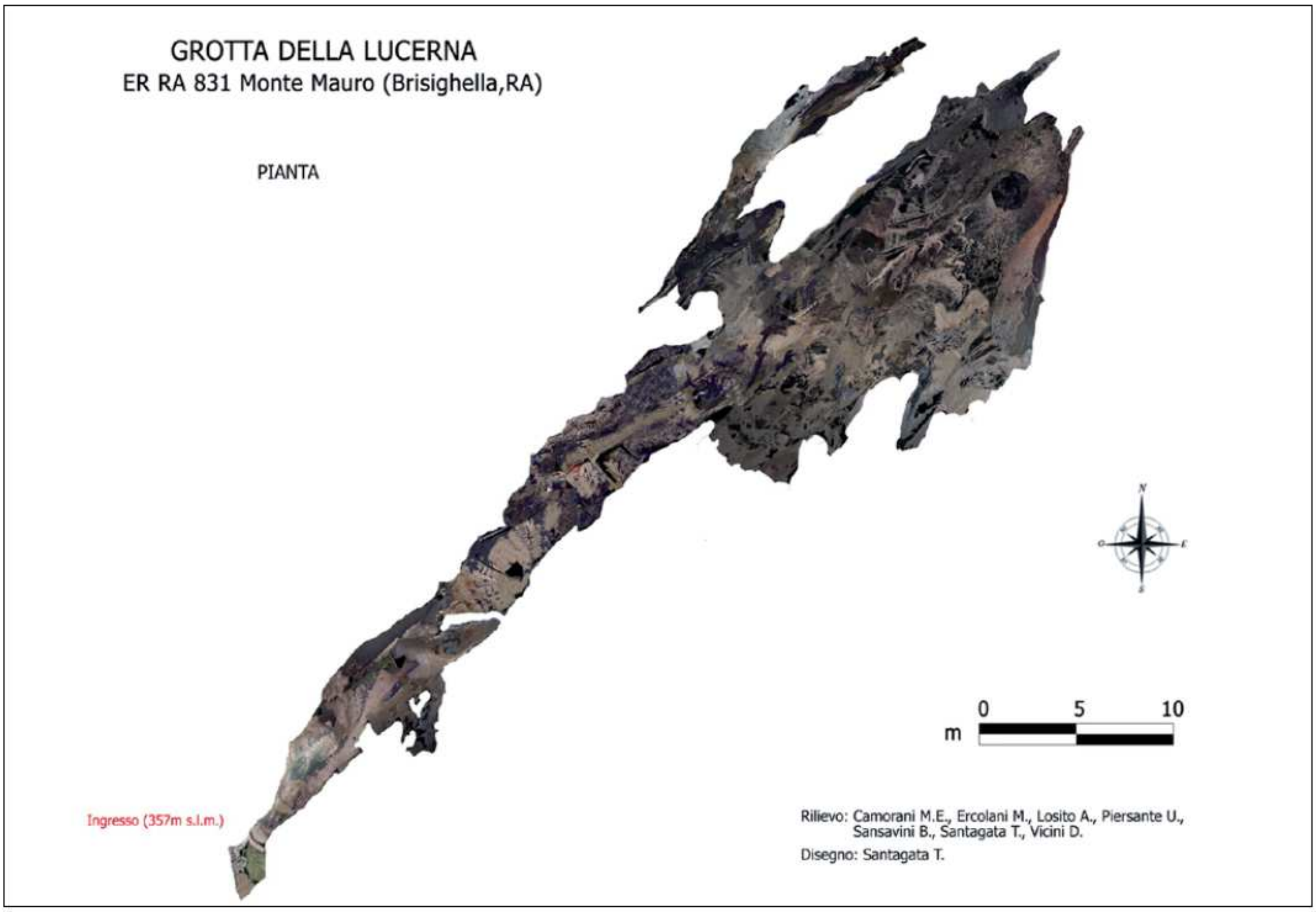

Fig. 7: plant of the areas detected with laser scanner.
Fig. 7: pianta delle aree rilevate con laser scanner.

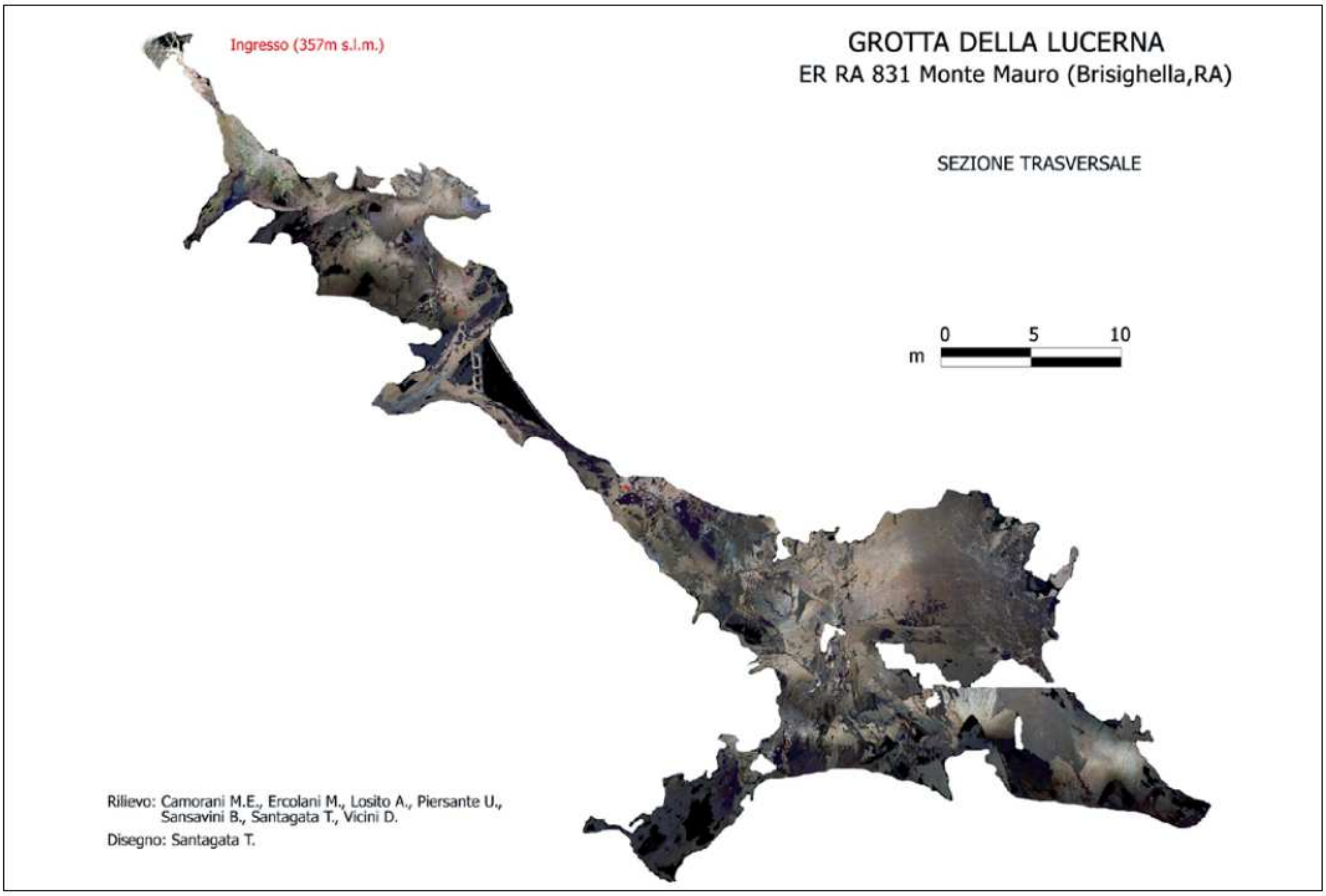

Fig. 8: section of the areas detected with laser scanner.
Fig. 8: sezione delle aree rilevate con laser scanner.

viewer approach, this application let to rotate the view, zoom in or pan over point clouds (Fig. 6).
In TruView, users can click on a pixel of the image and extract real 3D coordinates of the point selected or click on two pixels and extract distances. Other operations such as point markup, notes input, quick snap print, save of specific views and markup with an associated camera view or control units of measure are also possible.
This application has been used also for drawing

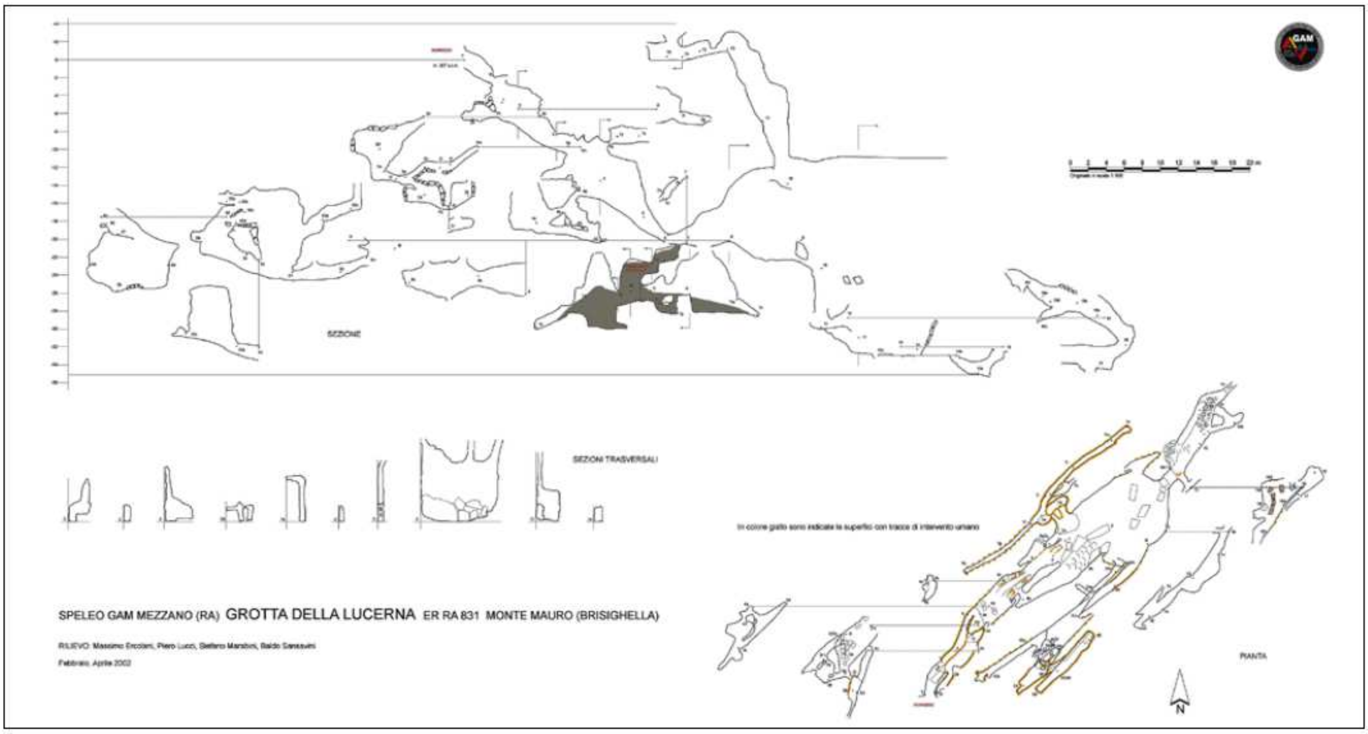

Fig. 9: reference map of the RA831.
Fig. 9: rilievo della RA831.

operations of plan and section of Grotta della Lucerna in 3D (Figs. 7 and 8) and bi-dimensional mode using the Cloudworks plug-in, with which it is possible to draw lines and polylines directly from TruView in AutoCad.

Conclusions

The laser scanner survey and digital 3D modelling of the Grotta della Lucerna have provided an accurate database that allows significant quantitative analysis for the study of archaeological traces and the morphology of the cave.
Furthermore, the data acquired were used to produce panoramic images, videos with point clouds animations and a model with the TruView application, with which it is possible to access the cave virtually and operate within it.

Acknowledgments

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