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From clandestine caverns to sepulchral chapels. Shedding light on the mysterious Holy Caves of Granada's Sacromonte Abbey.

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The principal objective of this research work is to produce a thorough cartographical representation of the Holy Caves of Sacromonte Abbey. Today, no graphical documentation remains in existence to act as successor to what Ambrosio de Vico created on copper plates in 1596. By comparing the modelling of the Holy Caves produced through new digital technologies with the top-view drawings of the ancient engravings, will be able to identify areas of both alignment and divergence from the original layout plan.

With this information, we will then be able to produce a hypothesis pertaining to the caves' evolution, backed up by the sources that we have consulted from Sacromonte Abbey's own archive and from the Historic Diocesan Archive of Granada.
The sum of this information will enable us to document this unique example of subterranean heritage via a multimedia approach leveraging the digital representation of historical monuments.

Key words:
Surveying; subterranean; heritage; Granada; Sacromonte.

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1. INTRODUCTION AND BRIEF HISTORY

In the year 1595, a group of treasure-hunters came across a lead slab in one of the caves on Valparaíso Hill, near Granada, upon which could be found the following Latin inscription: "*Corpus ustum Divi Mesitonis Martiris, pasus est sub Neronis imperatoris potentatus*" *("The burnt body of the martyr Saint Mesitón, who suffered under Emperor Nero's power")* [1]. This was the first piece of a total of four lead slabs, along with ashes, human remains and 223 lead plates inscribed in Latin and Solomonic characters, upon which were interwoven stories about famous figures such as Saint James, Saint Cecil and the Virgin Mary. This find marked the beginning of a long period of history awash with mystery and controversy regarding the authenticity of certain discoveries, which transcended culture and the local ruling class, and which ultimately involved The Vatican, King Philip II and The Spanish Inquisition.

Almost every discovery in question took place in these caves [2]. The state of the caves during the time in which the discoveries took place has been pretty well documented in various contemporaneous sources [3]. All of these allude to the fact that the caverns were stuffed with filler material, and that stretches of stone wall could be found in certain inner areas, along with the remains of structures made out of the stone used to cover the spaces.

On the engraving known as "*Descripción de las cavernas del monte sacro de Granada en las cuales se hallan las reliquias y libros Santos*" (*"Description of the caves of Granada's holy mount within which lie relics and holy books"*) these are described as being: *"todas llenas de tierra, y piedra hasta el techo y por los costados, como paredes de piedra, todo a mano*" – *"all full of earth, with stone extending to their roofs and sides, like stone walls, all built by hand"*. Their three entrances were: *"muy angostas, cerradas con artificio con piedras y se estrecha en ellas tanto la peña, que no se puede entrar sino el pecho por el suelo*" – *"very narrow, deliberately closed off using stones, and the rock is narrowed in them to such an extent that the only way to enter is by crawling on the ground"*. The caves were composed of spaces with different characteristics: cavities that enabled passage and several ovens or lime-kilns.

The mystic nature of the caves is evident in the texts found on the slabs and lead books. These document the martyrdom of the saints Cecil, Hiscius and Thesiphon, along with their disciples [4], when they were immolated alive in the caves during the second year of Nero's reign, where the apostle Saint James lived with his disciples for forty days while he wrote Historia de la Verdad del Evangelio (The History of the Gospel Truth) (Martinez Medina, 2006). After the discoveries were made, it became necessary to rebuild part of the caves due to the subsidence that had occured and to reinforce other sections, so as to avoid any additional subsidence. This was instigated by Pedro de Castro. According to text records (Antolinez, 1996) the restoration was faithful to the original plans and proportions of the excavations. These days, the caves make up part of the monumental complex, and they function as a sort of gallery that provides access to ovens and lime-kilns that had been converted into places of worship, three chapels and a small church built following the discoveries. The tambours and roofs of the chapels emerge from the surface of the hill (Fig. 2). The narrow and winding design of the cave extends to a length of 43.5 metres.

Sacromonte Abbey was built beside these caves, a monumental ensemble with origins dating back to 1600, with Pedro Vaca de Castro y Quiñones, the archbishop of Granada, its principal advocate. It was conceived as a collegiate church dedicated to Saint Cecil for the worship of martyrs, and for the span of its history it has served as a theologian and jurist college, a faculty of civil and ecclesiastical law, as well as being a high school.

2. AIMS OF THE PAPER

The main aim of this piece of research is to contribute to the graphic documentation of this architectural heritage by producing a thorough cartographical representation of the Holy Caves of Sacromonte Abbey. This objective is of key importance, because today no graphical documentation remains in existence as a successor to what Ambrosio de Vico created on copper plates in 1596.

Fig. 1 - The martyrdom of Saint Cecil and of his disciples Patricius and Septrentius on Sacromonte. Engraving by F. Heyland (Antolinez, 1996).

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Fig. 2 -View of the abbey and the caves' roofs.

On the other hand, comparing modelling of the Holy Caves made using new digital technologies with the top-view drawings of the ancient engravings will enable us to pinpoint areas where things align or vary from the original layout plan.
With this information to hand, we will be able to produce a hypothesis pertaining to their evolution, backed up by the sources that we have consulted from Sacromonte Abbey's own archive and from the Historic Diocesan Archive of Granada. The sum of this information will enable us to document this unique example of subterranean heritage via a multimedia approach leveraging the digital representation of historical monuments.

3. BACKGROUND

Ever since the first discoveries were made, and the initial doubts regarding the authenticity of the lead books found in the caves surfaced, an intellectual debate has been waged that has produced significant output both in favour of and against the findings. The finest exponents of Granadan and Spanish culture had an opinion one way or the other – as was the case with Francisco Bermúdez de Pedraza, Juan Bautista Pérez, Justino Antolínez de Burgos, Ignacio de las Casas, and Diego Nicolás Heredia Barnuevo, among others.
Once the debate surrounding the authenticity of the findings was overcome, more recent research work focused mainly on clarifying the provenance of an *œuvre* such as this, on its cultural and social significance, on the translation of the lead books and their doctrinal content, the historical reconstruction of that age, etc. As part of these studies, certain researchers have been involved, such as Mercedes García Arenal, P.S. van Koningsveld, G.A. Wiegers, Manuel Barrios Aguilera, A. Katie Harris and José Antonio González-Alcantud (Barrios Aguilera, García Arenal, Eds., 2011) or C. Alonso (1979). However, we detect a complete absence of references that address this topic from the same point of view that we are using in our own research – although there is a great number of publications dedicated to the application of new digital technologies for the generation and collection of data related to subterranean heritage, these have been applied to other locations [5].
Our starting point is the graphic documentation that we have from the era, made on copper plates. On the different plates, two systems of representation have been used: top-view and perspective-section view. Both resulted from the need for engraving the resulting motifs and the place they were found onto the copper slab. According to Gomez Moreno (cit. by Moreno, 1974: 62) [6], when the first discoveries were made, a silversmith named Alberto Fernández was hired in order to create some copper plates.
The drawings he used to engrave "*Descripción de las cavernas del monte sacro de Granada en las cuales se hallan las reliquias y libros Santos" ("Description of the caves of Granada's holy mount within which lie relics and holy books")* (Figure 3) are known to be part of a survey carried out by Ambrosio de Vico, the senior *maestro* of Granada Cathedral. He was tasked with reinforcing the caves when they were first discovered in order to avoid any subsidence (March 1595), as well as the subsequent repair and reconstruction work conducted to return them to their original state (1597) [7]. The role he played as a trusted technician for Francisco de Castro and his accumulated knowledge about the caves, serves as sufficient proof, in our opinion, to assume that this would have been a reliable survey, given the means available in that era.
In addition to the two copper plates that represent the plan-view of the cave [8], we see that there is another method of representation, which we have called perspective-section view. We are referring here to engravings made by Francisco Heyland. These involve views in which a unique graphical method is used in which perspective and the section of the terrain are combined in order to portray the two different categories of work that they were carrying out – the surface-level and the subterranean. These perspectives enable us to observe the ovens or lime-kilns in greater detail.
These were the spaces in which ashes and human remains were found, and, according to the ecclesiastical authorities, they played an important role in the wider dissemination of the Sacromonte myth. We can also observe the position of openings on the hillside, the number of entrances to the cave, and certain aspects of the local culture of the time, such as clothing, work tools or figurative ornamentation with

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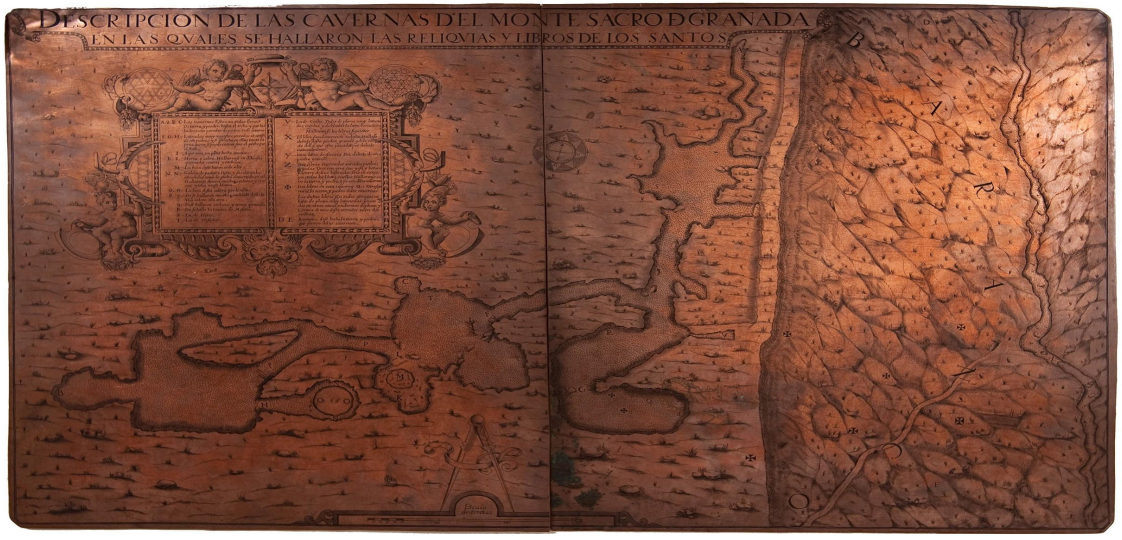

Fig. 3 - Engraving known as "*Descripción de las cavernas del monte sacro de Granada en las cuales se hallan las reliquias y libros Santos" ("Description of the caves of Granada's holy mount within which lie relics and holy books").* Engraving by Alberto Fernández. Drawing by Ambrosio de Vico. Photo: courtesy of the Abadía del Sacromonte.

Fig. 4 - Engraving that depicts the scene on 14 April 1595, when Pedro de Castro went up with his retinue to collect bones and ashes from Sacromonte. Engraving by F. Heyland (Antolinez, 1996).

Renaissance motifs, cherubs, and festoons and stamps related to the discovery of the plate itself (Fig. 4).

4. METHODOLOGY

Terrestrial laser-scanning can be leveraged successfully for cultural heritage documentation purposes where very complex geometry and irregular shapes are involved (Yastikli, 2007). We consider this appropriate for representing these caverns (as negative or underground spaces), as we find it to be consistent with the building process itself, from the inside to the outside, in an inverse order to the one established by the construction traditions of the era we are looking at.

The general phases of this work are:

4.1.- Onsite data-gathering.

4.2.- Producing the three-dimensional digital model of the spaces.

4.3.- Producing the three-dimensional digital model of the surroundings.

4.4.- Analysis and comparison against existing cartographical content.

4.1 Onsite data-gathering

Onsite data-gathering was carried out across two fieldwork visits, the first of which took place in November 2016 and the second in March 2017. A Leica Nova MS50 was used as a surveying instrument. A closed polygonal shape was traced with local coordinates on which vertices represented the positions of the stations. In these locations, various point clouds were developed using a laser scanner. The principal challenges were the poor lighting conditions and the narrowness of the gallery spaces. The latter compounded the issue of visibility at different points within the stations. In addition, the narrow spaces prevented us from reaching the minimum distance of 1.5m that was needed in order to make survey readings possible (Fig. 5).

Classical topography has played a crucial role in joining up different point clouds within the same coordinate system (Peña Velasco *et al*, 2017). Due to the lack of visibility, it was not possible to use support points in all stations, nor to use the automatic correlation of common points. So a closed polygonal shape was created in order to achieve that goal (Buill *et al*, 2013). It was made up of twenty station points, and for all of these several point captures were made at 2cm intervals, except with the last four stations, which enabled us to close up our polygonal shape, outside the abbey itself. The closing errors of this polygon were 4cm in the X coordinate, 7cm in the Y coordinate and 6cm in the Z coordinate.

Subsequently, we had to compensate for these, since the closing errors were within our tolerance levels. Once back in the office, all fieldwork data were backed up using Leica's *Infinity* software in order to develop a single point cloud with which to work, made up of the 28 point clouds from the various scanning sessions conducted. All of these were in the same coordinates system, meaning that they were already aligned and when combined, they added up to a total of one

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million points. Figure 6 shows these data and the polygonal shape we devised.
Afterwards, we triangulated the model using Leica's *3D-Reshaper* software. In order to generate a unique mesh of triangles, all of the individual meshes we had created had to be refined and merged, and any open outlines and holes had to be closed up (Remondino, 2011). The resulting mesh was formed, in this case, of 2.3 million triangles.

4.2 Producing the thre-dimensional digital model of the spaces

From this three-dimensional virtual model of the caves (Fig. 7), top-view, elevation-views and sectional-view representations were created in order to define the spaces graphically. The top-view is unpublished and features forks in passages that may well have been connected in times gone by (Fig. 8).

Analysing the spaces, we are able to identify three distinct types:
Chapels: There are a total of four chapels, namely Capilla de la Dolorosa (Virgin of the Dolorosa Chapel), Capilla de La Piedra (Stone Chapel), Capilla de Los Gitanos (Gypsies' Chapel) and Capilla de Santiago (Saint James's Chapel). Their surface areas fluctuate between 8.33m x 13.21m for the largest and 4.18m x 3.42m for the smallest (Fig. 9).

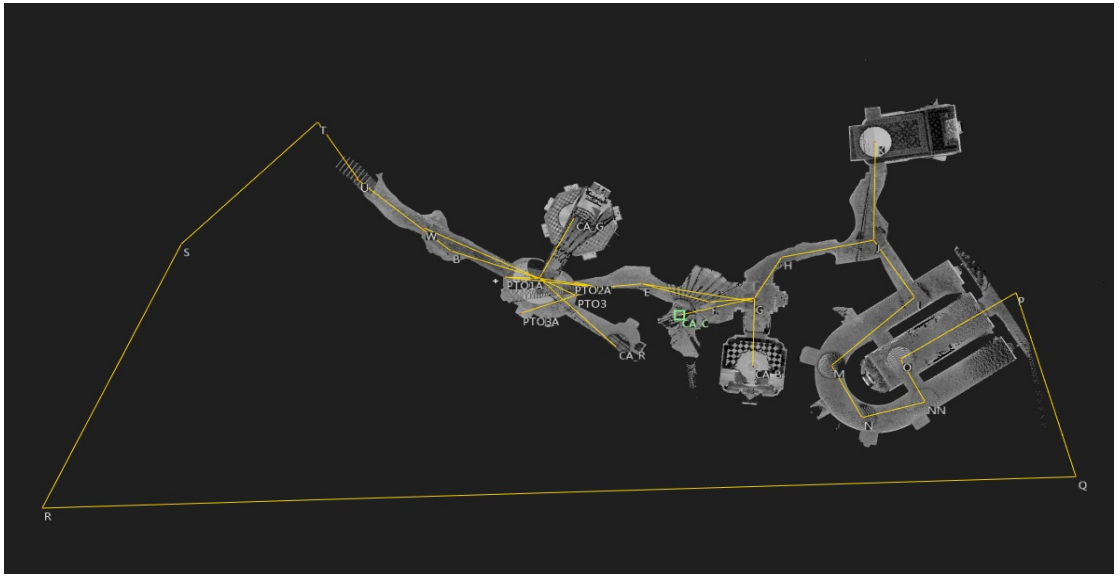

Fig. 5 - Image of gallery 1 in which the narrowness and darkness of the survey conditions may be observed. Authors' image.

Fig. 6 - Image of the closed polygon (traverse method), observed from point A to closing point U, using a yellow line, and including the point clouds of the caves as well as the control points. Image produced by the study's authors.

Fig. 7 - Three-dimensional image of the closed-up generated model, after joining up the various point clouds and defining/refining the closed mesh. Image produced by the study's authors.

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Construction work began on these spaces in 1600 on Pedro de Castro's orders, to provide places of worship for the faithful. They feature different styles and their natural overhead lighting contrasts with the darkness of the subterranean galleries from which they are accessed. Their built mass protrudes on to the hill's outside surface.

Galleries: These feature an irregular geometry, and are predominantly longitudinal, which renders them somewhat corridor-like. Their finish is rough and irregular, with widths fluctuating between 0.74m and 2.24m. We can identify four stretches with lengths between 7.25m and 18.01m, and heights ranging between 1.73 and 1.93 metres.

There are spaces with larger dimensions that join up various gallery sections. Their walls are less rough and the stone of the terrain is not visible. They are covered with domes and are placed at strategic spots, such as the entrance to the Capilla de la Dolorosa, and the lime-kilns of Saint Hiscius and Saint Cecil, respectively.

Ancient spaces reconverted into places of worship: These are ancient ovens and lime-kilns, with diameters fluctuating around 2.25 metres. The layout of Saint Cecil's lime-kiln is irregular, its outline dictated by the terrain itself. It features a hole for ventilation and to let in natural light. Saint Hiscius' lime-kiln has a clear geometry with a circular base (2.25m in diameter, with niches of 0.40m in depth and 2.53 in height) and a hemispherical vault (Fig. 10).

4.3 Producing the three-dimensional model of the surroundings

We obtained a digital model of the plot from the Spanish National Geographic Institute (IGN), which was 5m x 5m in size and in ASCII format.

Using that model, we drew level curves with a gradient offset of 5m in order to present the zonal topography using the GIS freeware *gvSIG*.

We then added an orthoimage from Spain's Plan Nacional de Ortofotografía Aérea (PNOA), which we obtained from its online digital archive. In addition, we incorporated cadastral information pertaining to the abbey acquired from the Spanish Dirección General del Catastro's website.

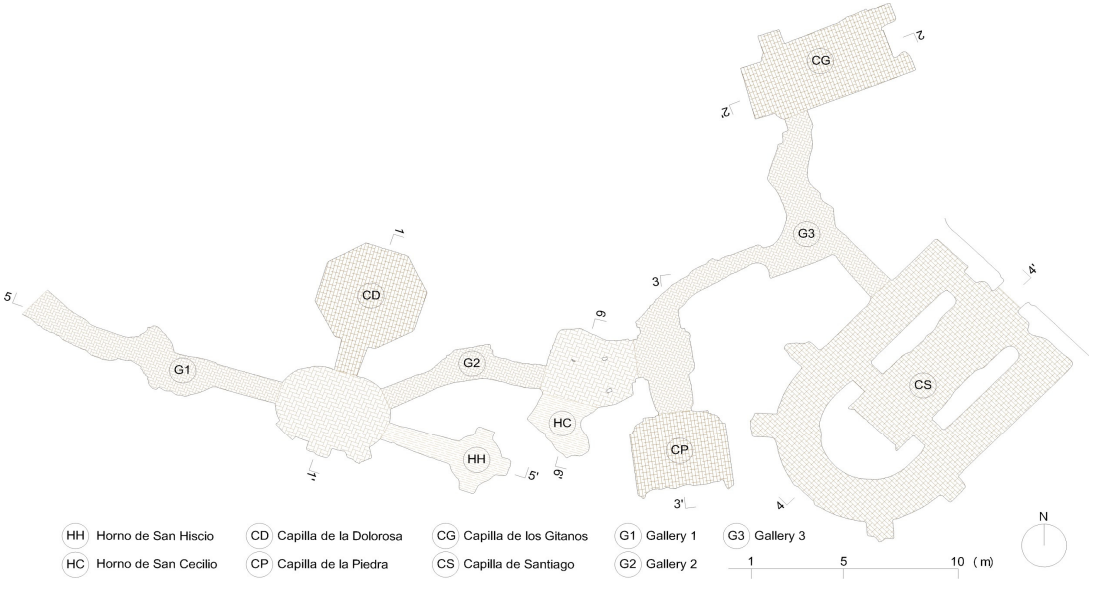

Fig. 8 - Top-view of Sacromonte's caves. Authors' image.

Fig. 9 - Capilla de La Piedra's dome (Stone Chapel). Interior view.

Fig. 10 - Saint Hiscius' lime-kiln

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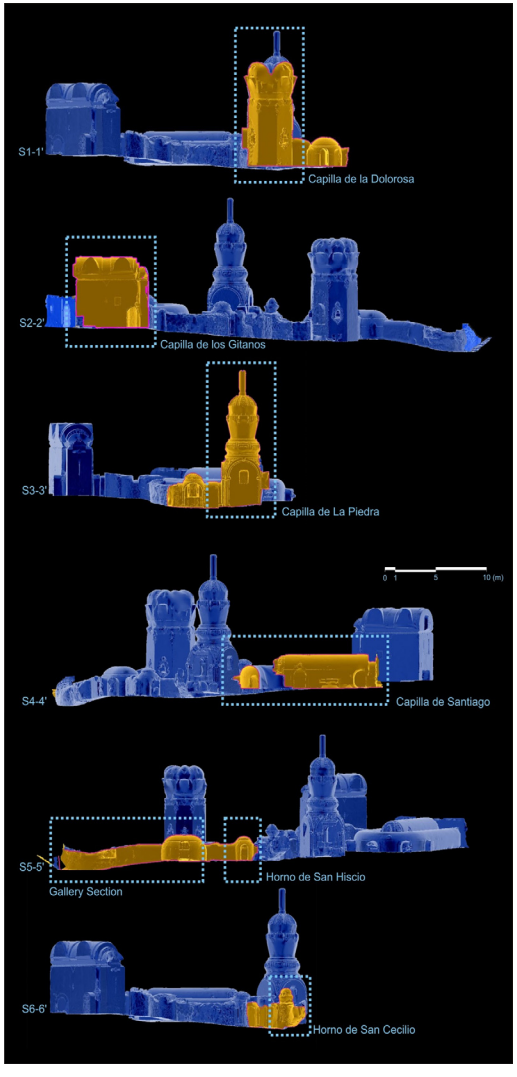
Combining all of the above information, we were able locate the layout of the caves using the ETRS89 system and to generate a map of it (Fig. 12).



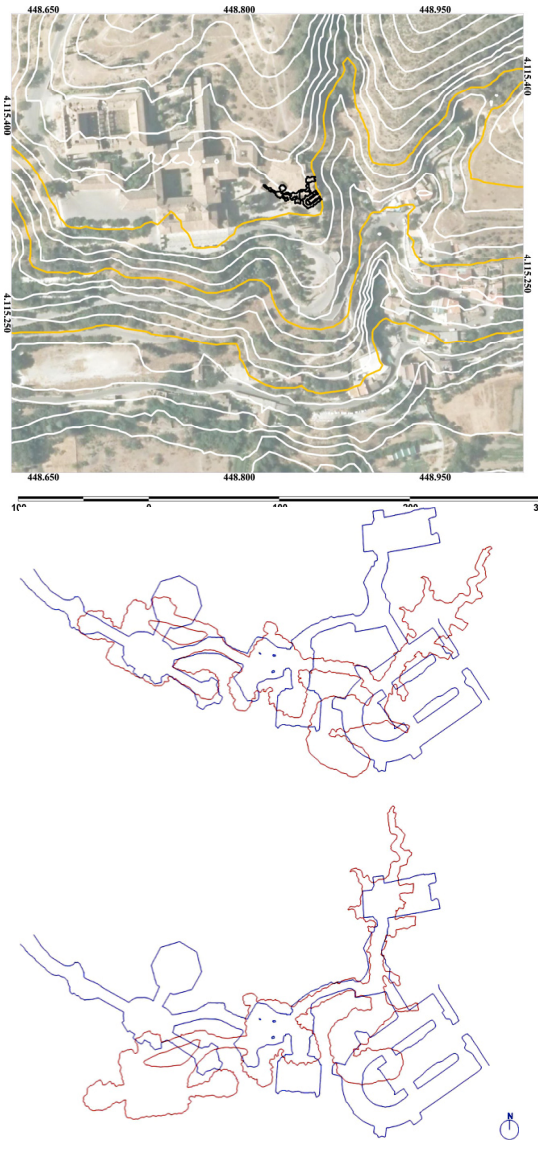


Fig. 11 - Sectional views of the different spaces identified in the

Fig. 12 - Resulting DMT of the surroundings. Source: Instituto Geográfico Nacional (IGN).

Fig. 13 Comparison of cartographical representations by means of translation-rotation. Red lines: 1596 plan. Blue lines: 2018 digital survey.

4.4 Analysis and comparison against existing cartographical content-

We came across a documented survey known as *"Description of the caves of Granada's holy mount"*, which was carried out by Ambrosio de Vico as part of an assignment on behalf of the abbey's bishop dating from 1595, in which the caves appear. In this layout there are no local or global coordinates, but it does feature a graphic scale. For the purposes of comparing this representation with the top-view obtained in our survey, we proceeded in the following way.

The representation of the caves made by Ambrosio de Vico was vectorised and scaled using the third of a yard ("tercio de vara") graphic scale predominant in that era. Leveraging translation-rotation methods applied to the aforementioned representation, both designs were superimposed. As can be seen in Figure 13, when it comes to comparing the two plans on their western sides, their eastern sides remain out of sync. Due to an orientation error in de Vico's outline, only one side can be made to align. However, we can also note that the outline of the galleries aligns well.

5. FINDINGS

-An accurate mapping- out of the caves was conducted for the first time, with a maximum margin of error of mere centimetres, and in poor visibility conditions. This was facilitated by combining classical techniques (such as total station and polygonalisation methodology) with other more modern procedures (such as laser-scanning multiple stations linked across a closed polygonal shape) in a complementary way.

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Both methodologies have been used simultaneously by means of a multistation.

- New galleries, which are closed at present, have been discovered thanks to historical research and the compilation of documents, using Ambrosio de Vico's 1596 map known as "*Descripción de las cavernas del monte sacro de Granada",* in which the caves are represented.

This primary source has been crucial in locating new galleries that might interconnect with the different spaces (Fig. 14)

- Geographical Information Systems were leveraged in order to locate and analyse the caves with current cartographical content.

- An interior three-dimensional model of the Sacromonte caves was produced that provided us with sufficient plans, elevations and sections to completely define both the subterranean and above-ground space. This has enabled us to identify the differentials in height across the whole complex, its empty spaces, its narrow sites, its different chapels, etc.

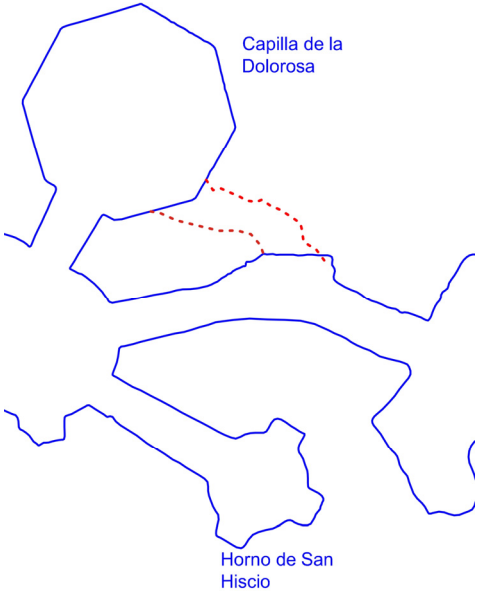

Fig. 14 - Connection hypothesis for a mortared gallery.

6. CONCLUSIONS

The challenges that subterranean architecture present, in terms of surveying it and subsequently visualising it, cause us to re-evaluate traditional measurement systems and data-gathering. The poor visibility, irregularly-shaped spaces and very cramped conditions that we faced in carrying out our research, exemplify just a handful of the issues that sites of this kind throw up.

We came up against these obstacles in certain sections of the Holy Caves of Sacromonte, while in others, the reverse was the case and it was straightforward to carry out our survey. With the methodology we used, we can conclude that it is possible to conduct an accurate survey of the spaces in question, in which the paucity of light prevented us from using other techniques. So we can conclude that the complementary aspects of the techniques that we leveraged enabled us to overcome the issues presented *a priori*.

When observing our results, and comparing them with the engraved representation from 1596 and our own onsite visit, we are able to identify three kinds of spaces, each distinguished by their use, geometry, finishes and lighting.

The location of the chapels coincides with the greater-dimensioned spaces of the original galleries according to Ambrosio de Vico's plans. The galleries have remained unaltered for all this time. We are able to observe that there is a gallery shown in the 1596 survey that is at present closed off or mortared. With reference to the lime-kilns, Saint Cecil's still has its original configuration, while in Saint Hiscius' lime-kiln we note the walls and floor have been consolidated and three niches have been added.

Finally, when comparing de Vico's engraving with our own cartographical representations, it is evident that the layout of the spaces are similar, but certain errors in the orientation of the plan drawn in 1596 do crop up, due to the challenges inherent in measuring irregular sites such as this one, as well as the limitations of the equipment available during the era in question. Nevertheless, the engraving has played a crucial role in enabling us to consolidate our research work and to determine its actual discovery date more accurately.

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NOTES

[1] According to Bermudez de Pedraza (1800:266) and Antolinez (1996: 475), the treasure-hunters followed instructions contained in an ancient recipe book. It described an ancient gold mine excavated by Don Rodrigo, the last Visigoth king. It was formed of 49 chambers and its western entrance was closed off to prevent Arab invaders exploiting the mine when his reign ended.

[2] According to texts from that era, it is referred to as a cavern with various mines (Heredia Barnuevo *et al.* [1741], Bermúdez de Pedraza [1800], Antolinez [1996]). Discoveries were made in the ravine beside the caverns while workers were extracting debris and in other nearby locations.

[3] We are making reference here to the works by Antolinez (1996), Bermúdez de Pedraza (1800), Adan Centurion (1632) or Heredia Barnuevo (1741).

[4] Sentence passed at the trial on 30 April 1600 (Heredia Barnuevo, 1741: 71).

[5] We do not refer, for instance, to the research work conducted by Blaya (2016) on the complex of subterranean wine cellars in Aranda de Duero, nor to that by Llopis Verdú (2012) on the CHRIMA project.

[6] Gómez Moreno, M. - *El arte de grabar en Granada*, 1900, p8.

[7] Ambrosio de Vico was a renowned figure culturally-speaking in the city of Granada at the close of the 16th Century. His work on Sacromonte continued when Castro tasked him with building the Iglesia Colegial (Collegiate Church) together with Alonso Sigura, acolyte of Juan de Herrera and the Jesuit father Pedro Sánchez (See Hagerty 30).

[8] The Plataforma de Vico, also known as the Plataforma de Granada, was the first representation of Granada's urban outline. It was made in the 1590s. The drawing was carried out by Ambrosio de Vico and the copper engraving was made by Francisco Heyland (1613) and Félix Prieto (1795). Upon it we are able to observe the cave within a wider context, which includes the hill where the cave itself is located and the River Darro.

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