Techniques for the Documentation, Registration and Analyses of Rock-Cut Tombs

SONIA CARBONELL PASTOR, University of Alicante, Spain

The Archeology of Death, a line emerged within the processualist theoretical position, meant great advances in issues related to the study of the funeral ancient practices, mainly through anthropological studies. However, we do not always have deposits or primary contexts, usually we find the graves looted, pillaged or modified since ancient times. In this sense, this work intends to constitute a methodological example of approach to the knowledge of the funerary sphere of a society through the application of new technologies for those cases in which we do not have any type of information referred to both the biological subjects and the grave goods that accompanied them. The study case chosen is the necropolis of Cala Morell (Ciutadella), a set of several hypogea or artificial caves with different structural characteristics that seem to be framed in the middle of the first millennium BCE but whose exact chronology we cannot determine with accuracy due to the constant plundering and reuses to which the necropolis was exposed. The goals of our research try to determine if there are socioeconomic differences within the same necropolis, if we can talk about a certain structural pattern and if the results obtained can be extrapolated to the rest of the Menorcan necropolis. The technical methodology used in this research consists in developing a quality graphic documentation using photogrammetric models, the management of a database that includes the structural characteristics of each one of the funeral units treated and, finally, the statistical analysis to infer spatial or socioeconomic issues.

1. INTRODUCTION

The study of funerary materiality is one of the most interesting ways to gain a complete understanding of past societies. The Archeology of Death is a theoretical-methodological proposal for the study of funeral practices that emerged within the so-called New Archaeology [Lull and Picazo 1989]. This proposal supposed great advances in archaeological research from the first theoretical

Author's address: Sonia Carbonell Pastor, University of Alicante, Department of Prehistory, Archaeology, Ancient History, Greek and Latin, Carretera de San Vicente del Raspeig, 03690, San Vicente del Raspeig, Alicante, Spain; email: sonia.carbonell@ua.es

approaches made by Saxe (1970), Binford (1971) and Brown (1971). The main premise of the Archeology of Death is to try to know a society through the study of its cemeteries [Chapa 1991] and, in this sense, new ways of approaching its knowledge appeared through the application of statistical techniques and quantitative and qualitative analysis. Any study that we carry out related to the funerary world requires a fundamental shift in thinking about the possible conditions and interpretive difficulties that we may encounter. We must be especially cautious with any inference we make since the burial record reflects an intentional materiality and is related to a whole host of nonmaterial aspects of social behavior, burial practices (rituals, offerings, deposition of the deceased) that are not an accumulation of materials resulting from daily activities but the result of actions determined by social guidelines [Vicent, 1995]. These are the theoretical postulates from which we started to approach the present study.

Currently, there are multiple techniques of documentation, registration and digital analysis in relation to rock-cut tombs or hypogea. The amount of various applications available seems nearly endless, especially when different techniques are combined in the same documentation process. The documentation of rock art is one of the most discussed topics, mainly in relation to the registration of volumes and the morphology of the caves [Domingo et al. 2013] but also analysis of engravings and improvements of their readability from techniques such as photogrammetry [Lesvignes et al. 2019; Rivero et al. 2019; Ruiz et al. 2019] as well as macroscopic analyses to be able to correlate tools with a certain type of marks [Plisson and Zotkina 2017]. Other examples of applicability of combined digital techniques such as LIDAR and photogrammetric models have been carried out to corroborate hypotheses about the absence or presence of certain architectural elements [Robinson et al., 2019]. Finally, there are not a few cases in which these techniques are used in matters of conservation and preservation of heritage assets, from facades [Tokovinine and Estrada, 2017; Votroubeková 2018] to the virtual reconstruction of entire buildings [Limoncelli and Scardozzi 2013] that are exposed to deterioration by biotic agents, vandalism or modern constructions.

As a starting point, it is necessary to clarify that this work comes from the specific problems of an archaeological documentation that we tried to overcome in the best possible way implementing the methodology we propose in this paper, always taking into account the economic and temporal limitations we had to face.

Our main aim was to document a type of funerary architectural structures such as hypogea or so-called rock-cut tombs. The case study presented here is limited to Menorca Island, where the idea of hypogeum acquires its own personality and is characterized, mainly, by a differential location. As far as it is known, the concept of hypogeum describes a tomb excavated in the subsoil, distancing itself from this idea of the terms "artificial cave" or the general concept "rock-cut tomb" which not necessarily imply an underground location. However, in some study areas, such as Menorca, both terms are used to refer to the same materiality that is far from what we understand by hypogeum in other Mediterranean spaces.

Although in recent decades the archaeological studies and research works developed in Menorca use a scientific methodology, which is the product of the development and constant evolution of archaeological science, it was not the same with archaeological interventions carried out throughout the 20th century. Among the problems derived from methodological and mainly documentary errors,

we highlight the scarce references to biological remains that have come to the present [Carbonell, 2017]. We cannot know for sure what population was buried in these funeral spaces and neither can we make inferences about demographic aspects. Another obstacle we had to overcome was the limited number of publications about the funerary practice we are dealing with and the scarce graphic apparatus the few ones we found had. This was undoubtedly the determining factor to propose a documentary methodology, focused on the architectural study, which would allow us to obtain quality data, accurately and in the shortest possible time.

The case study we are dealing with in this paper is the necropolis Cala Morell (Ciutadella, Menorca) (e.g. Fig. 1). This funerary space has fourteen hypogea of variable dimensions and some of them of different chronology. Two of them, hypogea 11 and 12, are funerary spaces with a megalithic entrance. It is a type of funerary space of small dimensions, oval or ellipsoidal plan and hemispherical section, whose most characteristic element is the access through a corridor that recalls the megalithic dolmens of the island [Plantalamor 1991; Plantalamor et al. 2004]. They are chronologically limited to the beginning of the third millennium B.C., but in the case of Cala Morell, we know -for certain- that these spaces were reused in the middle of the second millennium B.C. [Micó 2005].

We also find two *covetes de forn* or, according to Cristóbal Veny, Type I hypogea [Veny 1982]. We keep using the term "hypogeum" because it is a space transformed by the human being, not a natural cave. These hypogea, 8A and 8B, are two small spaces carved into the rock, with a circular and semi-spherical section, of which there is no evidence of associated material culture and, therefore, we do not have any type of radiocarbon dating. Parallels have been referenced in Sicily for this type of funerary structures that are chronologically placed around 1500 B.C.E.
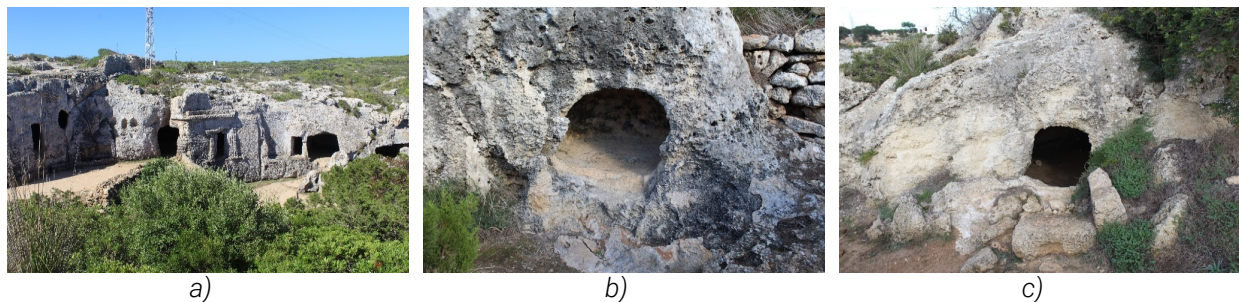

| a) | b) | c) |

Figure 1. Cala Morell necropolis (Ciutadella, Menorca: a) Overview; b) Hypogeum 8A, coveta de forn; c) Hypogeum 11, funerary space with a megalithic entrance.

Among the Menorcan parallels, there is a small cavity next to the south-west of Na Forana Cova (Son Mercer de Baix) and Cova 1 of Binigaus Nou (Es Migjorn) [Plantalamor 1991].

Ultimately, this necropolis has eleven complex-plan hypogea. These type of spaces, chronoculturally associated with the 2nd half of the 1st millennium B.C., will be the main part of this work because, due to its large dimensions, many lighting determinants are associated to its documentation. The traditional characterization of these spaces is based on the appearance of a whole set of elements and structural innovations that clearly differentiated them from the traditional natural caves, coves murades or simple-plan hypogea, which had been documented in previous chronological periods

and some of them had survived as a reuse at later times. This new architectural solution presents a greater internal compartmentalization by the provision of pilasters, flat roofs, and shelves in the walls. In general terms we could say that during the Postalaiotic period there was an increase in hypogeal complexity and dimensions [Gornés 1996].

2. BRIEF NOTES ON FUNERARY TRADITIONS AT THE MENORCAN PREHISTORY

In this necropolis, as already mentioned, there are funerary structures that correspond to different historical phases. Thus, we believe it is necessary to make a brief introduction about the different funeral traditions in relation to their socioeconomic contexts.

The island of Menorca was colonized by human groups ca. 2100 B.C., a late occupation that according to some authors must be explained by its insular nature and its central location in the western Mediterranean. Mainly the groups that arrived on the island were epicampaniform-dolmenic with a way of life characterized mainly by livestock and, at later times, by agriculture. These first human groups lived in shelters and caves and deposited their deceased in hypogea with megalithic entrances, such as No.11 and 12 of Cala Morell. In these spaces the funeral ritual was characterized by collective burial with scarce elements of grave goods.

Later, in this same period the dolmens appear, chronologically framed from 1880 to 1520 B.C. [Micó, 2005], although there are radiocarbon dates that reduce the chronology until the beginning of the second millennium B.C. (Ses Roques Llises, Alaior). As in the previous case, the funeral ritual was characterized by collective burial with few associated materials related to the grave goods.

In the middle of the II millennium B.C., in the context of increasing social complexity in the European continent, there is also a change in the Menorcan settlement patterns. It is at this time when the first naviform settlements appear. The Naviform period (ca. 1600 - 1100/1000 B.C.) was characterized by a room structure with an elongated floor, in the shape of a horseshoe (naviform) and whose social organization was based on communities of large families with little or no economic differentiation. In this period, we find different associated mortuary manifestations [Lull et al. 2004; Lull et al. 2008]. For example, depending on their typology, it is assumed that elongated plan hypogea are framed in this period. Despite not having radiocarbon dating, a chronology of these spaces has been proposed between 1600 and 1450 B.C. At a later stage in this period, around 1450 B.C., we documented the use of other types of funerary spaces such as natural caves with a cyclopean closing wall, most notably exemplified by Cova des Carritx (Ciutadella).

Towards the end of the II millennium BCE the naviform settlements were abandoned and the existing establishment pattern was replaced by a totally different one in which the household structures congregated around large cyclopean structures and truncated conical morphology, more commonly known as talayots. This period, known as Prototalaiotic (1050 - 850 B.C.), shows a series of gradual changes that led to the structuring of the Talayotic social organization from the 9th century B.C. In this transitional period, the last fungal structures of megalithic cut appear, the navetas: structures built using a cyclopean technique, with an elliptical or elongated oval plan which is accessed through a rectangular or trapezoidal antechamber and sometimes with two stories high. The funeral ritual in this type of funerary space remains the same as in previous times, collective burial, however, features

that indicate a differential treatment of the deceased are observed. This differential treatment is the ritual of dyeing and cutting of postmortem hair, a ritual that is also evidenced in the continued use of caves with a cyclopean closing wall like the Cova des Càrritx already mentioned above [Lull et al. 1999; Rihuete et al. 2000; Lull et al. 2008]

The variety of funerary spaces in this period has been interpreted by some authors as a preference on the part of different population groups, that is, new groups from other island environments or the continent that when they settled on the island adapted to the existing social organization, but they had a preference for one type or another of funerary structures.

From 9th century B.C., the Talayotic period begins (ca. 850-550 B.C.), characterized by economic exchanges with exogenous groups and in which a new population model was developed with the proliferation of talayots, structures whose function has been discussed extensively considering that they could be elements of visual control of the territory and spaces from which communal ceremonies were held [Micó 2005]. From this period, we have a deep ignorance of the funeral practices that were carried out, but recent studies suggest that some simple hypogea such as No. 21 of Cales Coves could be operational in 9th century BCE [Gornés et al. 2006; Gornés and Gual 2018]. Some of Cala Morell's single chamber hypogea such as No. 1 have certain parallels and could also be framed in this chronology.

3. OBJECTIVES

One of the main objectives of this work is to generate high-quality documentation, both graphic and photogrammetric (archaeological drawing, detail photographs, record of all internal elements) of the hypogea of Cala Morell. We focus our attention on this type of funerary containers because we have a lack of funerary archaeological contexts and we believe that architecture is a good material reflection of the changes derived from the interaction between differentiated cultural groups. To varying degrees, contact between differentiated socioeconomic groups can result in adaptations and structural innovations that materialize in all types of architecture (defensive, domestic, religious, etc.). The distance from the necropolis to our work center led us to look for quick, effective and precise solutions to generate a good documentary apparatus and an exhaustive record of all those structural elements present or absent in each of the hypogea.

After outlining a sketch with the conditions which we have to face, we propose a range of factors that have to be taken into account in order to develop a good strategy. On one hand, the quality and diversification of the documentation was quite limited, so we were interested in generating high-quality metric and morphological information that was as accurate as possible. On the other hand, we have limited time and scarce human and economic resources. This forced us to distance ourselves from the traditional techniques of archaeological drawing and focus our attention on the acquisition of plans and sections through the application of new technologies. The methodology we propose in the following lines originates from carefully weighing all these factors.

The second main objective of this work was to treat the Cala Morell study case as an analysis lab and methodological testing through statistical applications. We hypothesized that within the same necropolis there could be social differences and that one of the ways to identify this were the

structural elements present in the hypogea. Obviously, the analysis derived from each necropolis must be related to the rest of the archaeological manifestations and approaches addressed so far for each chronological period treated.

4. DOCUMENTATION METHODOLOGY

The first phase consisted merely of descriptive documentary aspects. We focus on collecting data from all the hypogea, obtaining descriptive, metric and geographic information. For this, we designed an in-situ documentation sheet that allowed us to make an exhaustive commentary on each hypogeum, including metric data and the presence or absence of certain structural elements (niches, raised platforms, columns or pilasters, etc.). All the sheets included a space to represent, through a sketch, the structure plan and detail elements. Likewise, in these sheets - which were later computerized in a database created in Access - we also reflect measurements.

In addition, we geographically locate each of the hypogea by using a Garmin eTrex 30. We use a GPS of this type knowing the metric error that can be derived from it because we considered an accuracy of several meters as sufficient. We were interested in representing a distribution map of the hypogea and relating all of them with respect to each other.

The next step was to determine the graphic registration method that best fits our specific objectives. There are multiple methods of 3D scanning, being able to use one or the other depending on the conditions and objectives. When determining the best digitalization method, we took into account the criteria established by the Cultural and Educational Technology Institute in relation to aspects such as the cost of the technique, the type of material to be digitized, the size of the object, productivity and precision of the technique and the skills required to use said method [Pavlidis et al. 2006]. In our case, we sought to obtain three-dimensional models of the hypogea of this necropolis by means of a low-cost, non-invasive technique that offered us results with acceptable graphic and metric quality. That is why we opted for photogrammetry as the best documentation technique for graphic record.

Currently there are other ways to create 3D models; one of them is the Laser Scanner. This documentation method is based on the registration of a space or volume from an instrument (Terrestrial Laser Scanner). This scanner shoots a laser beam at the surface of an object and generates a 3D point cloud [Mañana-Borrazás et al 2008]. Among the advantages and applicability of this method, it must be mentioned that very precise results are obtained and that the capture of data on site requires little investment of time. However, two disadvantages have led us to reject the application of this method in our study: the high economic cost it presents and the complexity of data processing.

Photogrammetry is a non-invasive passive measurement technique (in contrast to, for example, laser scanners or structured light scanners that emit signals). In recent years, this technology has become one of the most versatile, effective and precise techniques when applied to the fields of heritage and archaeological research [Aparicio et al. 2014].

This technique is based on the application of Image-based Modeling (IBM), which uses algorithms like Structure from Motion (SfM) or what is the same, "structure of the movement". Basically, it tries

to generate a three-dimensional model from images taken with a sensor in motion, either a person moving around an object or vice versa [Charquero 2016]. The IBM allows to generate in the first instance a cloud of scattered points from the overlap detected between the images; from this first cloud, we proceed to obtain the dense cloud, a set of points or vertices arranged in XYZ coordinates that, in addition, contain colorimetric information in the RGB model [Pereira, 2013].

The capture of terrestrial data was made with a reflex camera "Canon EOS 1200D" of 18 megapixels and an 18-55 mm lens with a tripod.

As in other photogrammetric processes, the first step was planning the photographic shot. We were interested in registering mainly the inside of these spaces, so we proposed a perimeter shot with two photographic series at different angles (frontal, upper and lower shot) at a focal length of 28 mm (e.g. Fig. 2). The second shot was made from the perspective of the central elements, such as columns, to record the perimeter walls of the hypogeum; the logic of this second photographic series resides in the fact that there were areas in blind spots after the recording made with the first shot. The separation between pairs of images ranged from one step to a step and a half in order to achieve a 60-70% overlap. One of the main problems of these spaces is the lighting: there are strong light contrasts, so we chose to set a high ISO (ISO 6400) due to the large number of areas with low lighting. The light contrasts could be corrected as far as possible with the use of two 30w LED spotlights. Not having a professional team, the correction that we could not get with the spotlights was solved by the manual mode (MF) presented by all the cameras; in this case we modified the speed (f) depending on the exposure to the light of the area to be photographed. In some cases, depending on the size of the hypogea (ranging from 3 to 9 m), it meant a more exhaustive and, consequently, heavier photo shoot to process later with the photogrammetry software.

Accompanying the photographic shot, we made measurements of distances between natural control points. Easily identifiable points in the hypogeum that were present in most of the photographs. These control points were taken to later scale the 3D model.
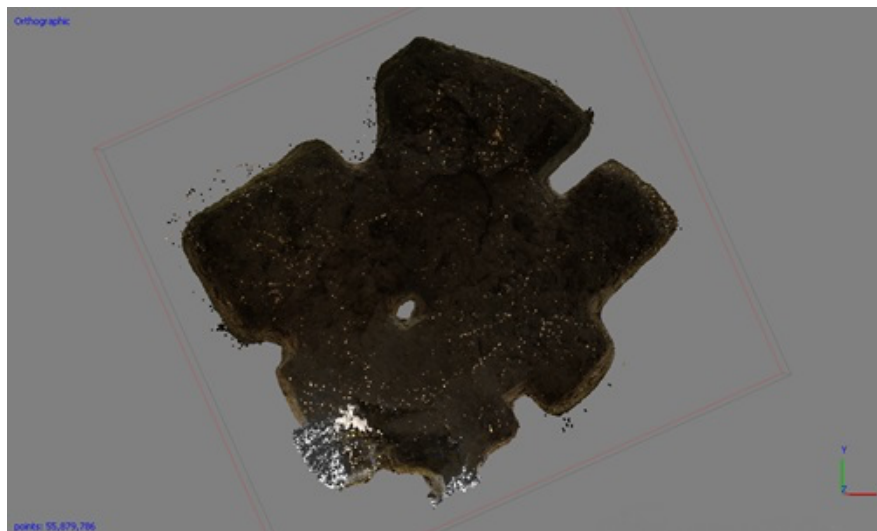

Figure 3: Dense point cloud

The third phase of this methodology consisted in the laboratory treatment of all the information generated. For obtaining the photogrammetric model, Agisoft PhotoScan (now called Metashape) has

been used, a software with high calculation speed that also has the advantage that it does not require a previous internal calibration of the camera [Peinado et al. 2014].

For the different models generated, we took between 200 and 800 photographs. The density of the point cloud obtained ranged between 40,000,00 and 50,000,000 points, which meant a slowdown in computer performance. After this step we apply different filters to reduce the overall reprojection error of the model and improve its accuracy. In the same way, in this step we oriented the computer box and the model, optimized the position of the cameras and proceeded to create the dense cloud again. Once this was done and before proceeding to the creation of the mesh, we clean the model, we reduced noise and eliminate invalid points (e.g. Fig. 3).

The meshes generated had a total of between 1,000,000 - 2,000,000 points which meant that we had to decimate / reduce them in some cases. Finally, we applied the texture introducing dimensions of 8192 x 1 (unit) with the aim to achieve an even better finish in the orthophotography (e.g. Fig. 4).
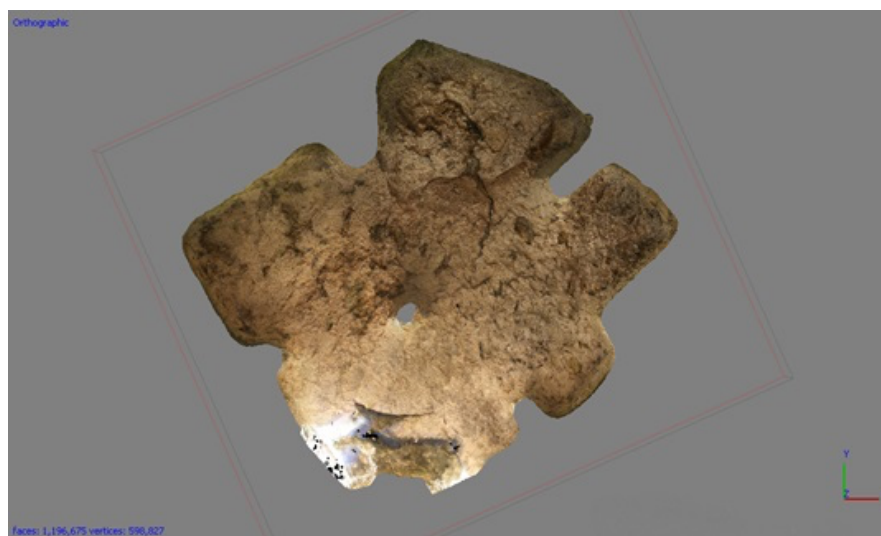

Figure 4. Texturized model.

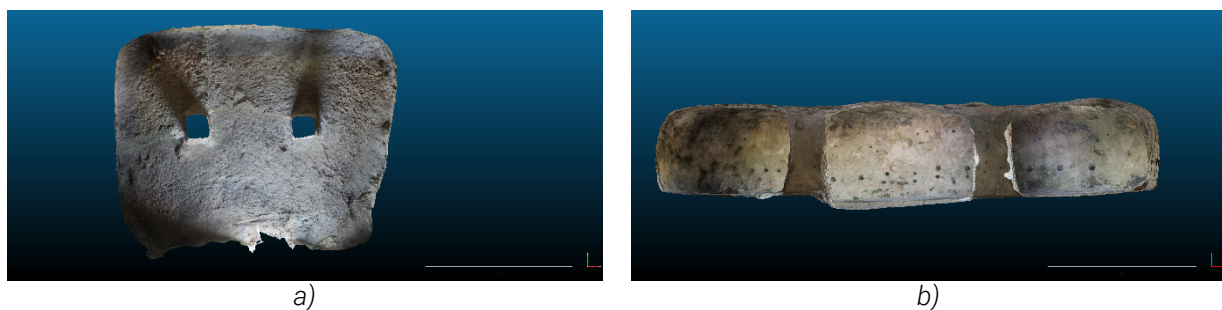a)   b)

Figure 5. Hypogeum 4 of Cala Morell necropolis treated in CloudCompare: a) Plant; b) Longitudinal section

Once the texturized model was obtained, we proceeded to scale the hypogeum considering natural reference points (we did not use targets, we simply made a sketch in which we placed these reference points easy to identify because they were corners, ends of cracks, etc.)[1]. After scaling the model in PhotoScan, we export the model to .obj format and opened it in another software, CloudCompare, a free software that allows us to section the model easily and also offers easy but useful features like having a graphic reference scale visible. So, we performed the cross sections and longitudinal sections of each of the hypogea and exported the views to .jpg format (e.g. Fig. 5).

After this process, we opened the different cuts (plan and sections) in a computer-aided design program such as Autodesk AutoCAD to proceed with vector drawing and, consequently, to obtain the final product that interested us in the first instance (e.g. Fig. 6).

All this documentation process allowed us to obtain the morphology of the plan and sections of each of the funerary rock-cut tombs that we chose to, later, be able to perform the statistical analysis.

In our opinion, many issues need to be solved when characterizing this type of funerary spaces. C. Veny and other authors cite a whole series of structural elements and morphological issues related to this type of hypogea, but the diversity they present leads us to propose a characterizing proposal or an interpretation of this variability in social, economic and/or symbolic terms. For the proposed analysis, we have separated Units 8A-8B and Hypogea 11 and 12 because of their structural characteristics and the existence of parallels of this type of spaces in other parts of the island that place them in earlier times.

We believe that the realization of a characterization of the complex-plan hypogea that mostly comprise the whole of Cala Morell constitutes another added value to the knowledge of the necropolis. Therefore, we believe that multivariate statistics and, more specifically, classification by hierarchical conglomerates (cluster) could help us to capture in the same graph all the structural variables presented by the hypogea of Cala Morell. We must not forget that this type of analysis is merely descriptive, they only serve to sort the data [Fernández 2015] but they always require an interpretation by the researcher.

The logic of carrying out this analysis responds, at first, to elaborate an essay of statistical application to the study of the funerary world of the Menorcan prehistory and protohistory as we think that not all the funerary spaces traditionally encompassed in the complex-plan hypogeum set would be synchronous in time. Due to the impossibility of carrying out archaeological readings derived from reliable excavation contexts, we believe that the only option to approach the knowledge of this type of funerary spaces is the application of statistical analyses that gather information about the main structural characteristics. Just as C. Veny raised for the Biniparratx necropolis, we think that there might be transitional hypogea, halfway between simple hypogea or Type I according to the author's own typology and artificial caves that in their entirety would correspond to Type III [Veny 1982]. Although the simple visual analysis of the necropolis of Cala Morell and that of Biniparratx does not allow us to establish enough comparisons to be able to talk about intermediate or transitional hypogea, we believe the hypothesis proposed by this author is more relevant. In the case of

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[1] All 3D models created can be viewed and downloadable here: https://sketchfab.com/lunnaris/collections/necropoli-cala-morell

Biniparratx, there are three missing structural elements that occur in all hypogea of the set: absence of external courtyards, exempt columns and terraced pilasters; however, common features are also evident, such as vertically angled rectangular type entrances, the height location of hypogea and small-sized chambers [Veny, 1974]. All these characteristics are observed in the Cala Morell complex, but not all hypogea of this necropolis have the same elements.

Thus, the hypogea to be analysed in this section are No. 1, 2, 3, 4, 5, 7, 9, 10, 13, 14, 15. The structural elements or characteristics that we have taken into consideration start from a previous study that S. Gornés made for the Cales Coves necropolis. This author proposed a typological classification of hypogea from correspondence analysis. The previous step for this type of statistical analysis was the identification of all the architectural or structural elements that presented these funerary spaces without attending to their chronological ascription [Gornés 1994]. Next, we expose those elements that we have taken into consideration when documenting the hypogea of Cala Morell and that subsequently served as the basis for the multivariate cluster analysis.

As we have explained previously, we have 11 cases (hypogea), a very small sample that, however, has allowed us to perform the multivariate cluster analysis that we proposed using the IBM SPSS statistics program. The variables used in the analysis correspond to the structural elements mentioned above. Thus, those variables present in a hypogeum receive the value 1 and those that are absent receive the value 0. Next, the results of the above-mentioned analysis and an interpretation of them are presented.

In the first place, with the realization of this type of analysis we have achieved a proximity matrix (Table 1), that is, a table in which all the study cases - hypogea (abbreviated with an "H" and the corresponding number) - and the distance between them depending on their homogeneity or heterogeneity are shown.

Table 1. Proximity matrix based on square Euclidean distance measurements

STUDY CASES	H1	H2	H3	H4	H5	H7	H13	H14	H15	H10	H9
H1	0	6	3	8	7	11	9	9	5	5	6
H2	6	0	5	8	7	9	7	7	7	3	4
H3	3	5	0	5	6	8	6	8	6	4	5
H4	8	8	5	0	9	7	9	9	9	7	6
H5	7	7	6	9	0	8	8	6	10	4	5
H7	11	9	8	7	8	0	4	10	8	8	7
H13	9	7	6	9	8	4	0	10	8	8	9
H14	9	7	8	9	6	10	10	0	10	8	9
H15	5	7	6	9	10	8	8	10	0	8	7
H10	5	3	4	7	4	8	8	8	8	0	1
H9	6	4	5	6	5	7	9	9	7	1	0

In this case we observe that the maximum distance is exemplified between hypogeum No.1 and No.7 (distance of 11) while the minimum distance is evidenced between hypogeum 9 and No.10 (distance of 1). These data are better represented in the dendrogram that we present below, that is, a graph where the distance at which the different segments that make up the cluster are combined.

When analysing the data there are multiple methods, the most prominent being the "Ward method" and the "link method between groups". The first one is the one that we have chosen for our analysis since it is characterized by minimizing the variability within each group while the second is to represent the groups based on the average distance of all the variables contained [Fernández 2015]. However, and as a precautionary measure, we have also proceeded to analyse the data with the "link method between groups" to compare the results offered by both dendrograms and to be able to provide a reasonable basis for our research. Regarding the measure of similarity between cases, the program has the default option of "Euclidean distance", the most common in this type of analysis and the one we have considered most optimal. The dendrogram resulting from the cluster analysis has allowed us to differentiate three groups (e.g. Fig. 7).
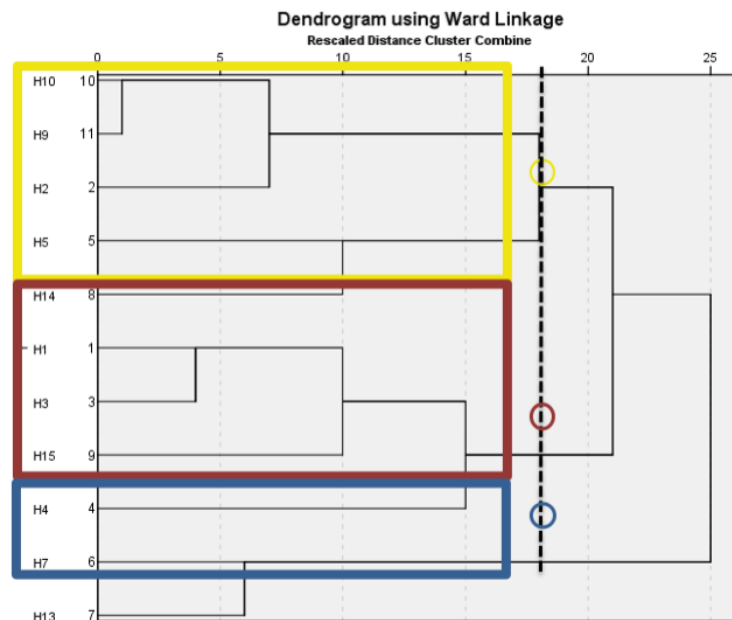

Figure 7. Dendrogram using Ward Linkage. The colored rectangles mark the groups we have established.

Group 1 is formed by hypogea No.2, 5, 9, 10 and 14. In turn, within this group we observe a minimum distance between hypogea No.9 and No.10 since they are the only two that have courtyard and a central column with compound capital; they are followed at a distance by hypogeum No.2, characteristic in this case for presenting an exempt column with differentiated capital and a cocó (small round cavity dug into the ground). The next segment closest to each other is observed between hypogea No.5 and No.14 that are characterized by being the only two hypogea of this necropolis with more than one exempt column. The common and, therefore, defining characteristics of this group,

would be the internal presence of exempt columns - with and without compound capitals regardless of the number -, cocons and a vertical entrance tending towards rectangular with raised threshold.

Group 2 is formed by hypogea No.1, 3 15 and 4. In this group the minimum distance is observed in hypogea 1 and 3 and could be explained by the presence of internal cocons in both cases and by presenting a vertical entrance. They are followed at a distance by the hypogeum 15 whose inclusion in the group would be determined by assimilation of characteristics, that is, it presents one or two common characteristics with the other three hypogea, with this the Ward method used interprets a minimum variance and, therefore, a possible relationship in terms of distance. We could say that this group is the most disparate because, apart from the hypogeum 15, we also find an element of discord: hypogeum 4. Like hypogeum 15, the only common characteristic of this space regarding the other three is the vertical entrance. Perhaps in this group we should prioritize disharmony, dissimilarity, over similarity or homogeneity since, both hypogeum 15 and hypogeum 4 have structural characteristics which differentiates them from others.

Finally, Group 3 is formed by hypogea No.7 and No.13. Both have a chamber with several lobes from the arrangement of one or two pilasters (hypogeum No.7 and No.13 respectively). Other characteristics common to both are the presence of external *capades de moro* (a kind of oval trend niches) and a possible open-pit excavated courtyard also outside.

As we have commented previously, we thought convenient to check the results obtained by applying a different method in the cluster analysis. The dendrogram resulting from the use of the "link method between groups" and a binary measurement of the "Euclidean squared distance" is featured below.

 The resulting graph shows that two new groups have been created (e.g. Fig. 8). The difference with respect to the "Ward method" lies in the separation of hypogeum No.4 and No. 14 into two distinct groups. The reason why the hypogeum No.4 appears separated, and we have been announcing it little by little, it is because it is a quite unique hypogeum due to the particularities it presents. With the "Ward method" this hypogeum appeared in Group 2 by assimilation of some of its characteristics such as the vertical rectangular entrance or the presence of a cocó inside. However, with the "link method between groups", it appears in a group differentiated from the rest, somewhat congruent with our visual perceptions. The exclusion of hypogeum No.14 in this case would be determined by the absence of vertical rectangular entrance (part of the facade of this hypogeum have fallen) and by the lack of cocons, two of the defining characteristics of Group 1 according to the cluster analysis by Ward method.

We would like to mention that in this "characterization" test, we will dismiss both hypogeum No.4 and No.15 because of the high variability they present and because they will later be retaken in a separate section.

Both Group 1 and 2 are generally characterized by presenting a vertical rectangular entrance. In this sense, Group 3 is dissonant mainly due to façade conservation problems such as the hypogeum No.13. Another feature present in all groups they are the cocons, small hollows practiced in the rocky ground that, normally, appear individually and near the side walls, of the exempt columns or pilasters, but never in a central position except in certain cases such as that of the hypogeum No.4 that we will see later . Finally, it should be noted that those hypogea that have exempt columns (Group 1) do not have attached pilasters that compartmentalize the space in lobes (Group 3); Group 2

could also be defined by the presence of pilasters since the hypogeum No.1 contained in this group, despite having a simple camera, shows carvings on both sides of the entrance viewed from the inside that could well be the start of pilasters, However, we decided to state the absence of pilasters in this hypogeum because we did not have enough evidence to affirm such an appreciation.
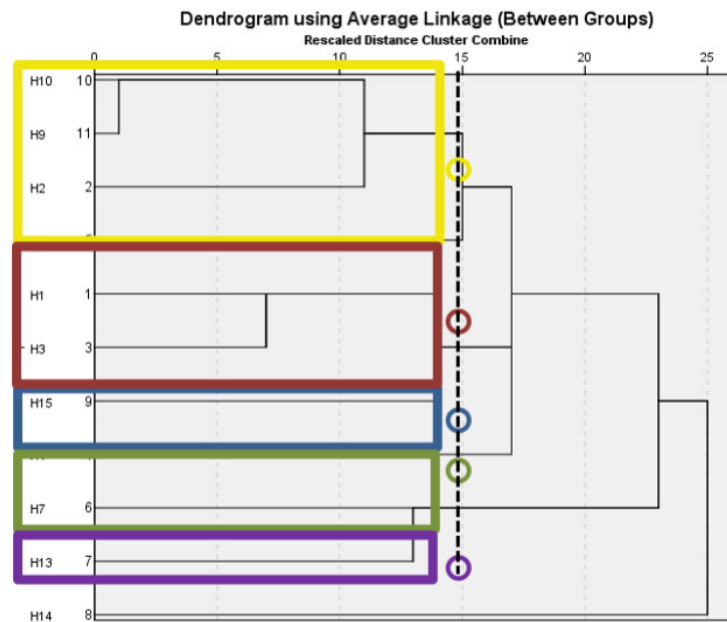

Figure 8: Dendrogram using Average Linkage (Between Groups). Different groups are marked with rectangles of different colors.

Thus, we conclude that the common characteristics shared by all complex-plan hypogea of Cala Morell are the vertical rectangular and cocons excavated in the rocky soil of the internal chambers.

On the other hand, we also determine that those hypogea that have attached pilasters do not usually have exempt columns and vice versa except for certain cases such as hypogeum No. 4, which we will deal with later.

It is evident that the structural variability that we observe in Cala Morell could also occur in other island necropolises. However, due to lack of resources and the fact that we are trying to present a test application, we believe that the work limitation to a single necropolis is justified. We therefore leave for future studies the realization of this type of analysis and the joint collation of all of them to elucidate the possible existence of a structural pattern that can respond to symbolic, territorial or functional criteria.

On the other hand, we must not forget that this type of analysis is an applied technique and that in no case should our study conclude with a description or graphic representation of the data. Therefore, we consider it convenient to propose a study base, a working hypothesis in order to be developed and verified or refuted in the near future. Obviously, the sample of hypogea taken into consideration does not allow us to generalize guidelines and, in any case, it would be very interesting to compare this

analysis with those of other necropolis of similar characteristics to raise or dismiss the existence of some type of structural configuration pattern.

The distribution by groups has only evidenced a series of characteristics shared by all complex plan hypogea in the necropolis of Cala Morell, which may ultimately will be what would define this type of space.

The most disparate hypogeum of Cala Morell according to the resulting dendrograms that "objectify" our previous visual appreciation is No. 4. The uniqueness of this space lies in its monumentality materialized mainly in a facade decorated with mouldings that frame the entrance door. There are also other elements that distinguish this hypogeum from the rest, such as the combination of exempt column and attached pilasters that compartmentalize and condition internal circulation or the presence of an elevated platform in the centre of the internal chamber in association with the central column. It is evident that there was an express intention to highlight this hypogeum over the rest, which would imply in greater socioeconomic terms a greater investment of work and specific architectural-decorative knowledge that are not present in other manifestations built during this period, such as cercles or posttalayotic household units, or the taula sanctuaries. Perhaps this hypogeum belonged to a high-ranking character who wanted to combine their customs with others perceived during their stays in extrainsular areas. On the other hand, as we will develop, we believe that this type of necropolis, monumental in many aspects - both structural and landscape - could be shared by several families and act as territorial landmarks with increased commercial interaction with foreign groups, mainly Punic-Ebusitan. It would not be strange to think that some local individuals, perhaps enriched by the appropriation of surpluses derived from commercial pacts, would like to stand out above the rest and reaffirm their control over the territory through the architectural singularization of a burial space. Like the hypogeum No. 4, which presents structural elements that differentiate it from the rest of the necropolis, the hypogeum No. 21 of Cales Coves differs from the rest by its prominent position because its entrance is visible from the two bracers of the Biniadrís ravine [Gornés 1994].

The case of the Menorcan funerary world is very interesting as well as complex because of the different problems that are presented to us in order to obtain a secure knowledge about the past social realities that used and modified natural cavities for funerary purposes. In addition, we must consider problems related to the Archaeology of Death due to the intentionality of the funerary contexts and the cover-up or exaltation of the qualities that defined buried individuals in life [Saxe 1970]. That is why any reading we make should not be restricted only to economic issues, although these affect the whole aspects of past societies and usually relate directly to the burial of the dead and the grave goods deposited in these contexts.

The other disparate case is the simple plan-hypogeum No. 15, which does not have well-defined chamber morphology. This funerary space is very interesting because it is unfinished, so it can offer data on the process of hypogea construction, on the techniques of rock extraction and its subsequent finishing. It is due to this that in the dendrograms show dissimilarity with respect to the rest of the hypogea of this necropolis. We include it in the group of complex-plan hypogea because, like the rest, it presents a vertical rectangular entrance, a shared characteristic to all complex-plan hypogea that makes the difference with respect to funerary spaces of earlier times. Another important aspect of

this hypogeum is that it has *capades de moro* carved on the external wall, elements that, traditionally and without evidence to argue otherwise, are associated with complex plan hypogea without constituting a sine qua non condition for their characterization.

Although we have exposed how we have carried out this method of documentation, we are aware of the need to raise issues that go beyond the scope of this article. For example, we have not addressed issues around the preservation of the information generated. There are many current studies that defend the need to establish protocols for storing digital information. It is useless to make 3D models and other types of data if we do not ensure that they can be recovered, consulted or be manipulated by future users.

We are far from proposing an action protocol such as that proposed by some research groups [Grimaud and Cassen, 2019] but we believe it is necessary to raise these problems around the digital preservation of the data, as other authors have already done.

5. DISCUSSION

Our main task as archaeologists is to make interpretations of past societies based on a series of data with special characteristics: materials and archaeological contexts. Now, our objects of direct observation in the field may have been modified by multiple post depositional processes, including both anthropogenic and natural agents.

With this paper we intend to highlight the need to carry out studies on those spaces that, although they cannot be analysed using a "traditional" methodology, have immense inherent potential for knowledge.

The rock-cut tombs or hypogea that have been looted, modified and reused over time are also archaeological materials. The study case that we have chosen is the necropolis of Cala Morell (Menorca) but we are aware that the documentation, registration and analysis methodology proposed here can be extended to other types of cultural manifestations such as rock art shelters, mausoleums, etc. The combination of different methods and techniques has allowed us to test the applicability of this entire work process. Without a doubt, for a bigger necropolis composed of multiple funeral units, it would be extremely useful in order to manage all the information.

We are aware of the shortcomings of not georeferencing rock-cut tombs with a total station, but due to the economic impossibility and the difficulty of positioning the device inside these spaces, we opted to limit ourselves to obtaining scaled three-dimensional models with measurements taken by hand. This provided us with results that fit enough the questions and the type of information we were looking for. Obtaining 3D models gave us information on the morphology of both plans and hypogea sections. These data were later incorporated into a database that also displayed information on the presence or absence of structural elements that may appear in these spaces. In this sense, we want to emphasize that one of the advantages of obtaining photogrammetric models was that it allowed us to review all these spaces at the laboratory and verify that the elements registered during the field work were present.

Statistical management has been a way of approaching the knowledge of this type of funeral spaces. We believe that it would be very useful to perform the same statistical analysis in other necropolis on the island of Menorca to determine the possible existence of necropolis management patterns on a mesospatial scale and see if they all present the same degree of variability. This, together with population studies and spatial distribution patterns, would provide very valuable information to understand the socioeconomic aspects of these past societies.

6. CONCLUSIONS

One of the first obstacles for a global study of the Cala Morell necropolis (Ciutadella, Menorca) was not to have reliable documentation of the hypogea that composed it. This work has served as a test to put into practice a documentation method that has proven to be effective in terms of results and resources invested. The application of photogrammetric techniques to obtain reliable three-dimensional models in terms of both morphological and metric accuracy -although not millimetric- has proven to be very effective in achieving the proposed objectives.

The photogrammetric models of the necropolis of Cala Morell (Ciutadella, Menorca) has allowed us, not only to obtain plans and sections from a post-processing of information, but also to facilitate the continuous consultation of these spaces in spite of the spatial distance that separates us from them.

It should be noted that a good photogrammetric survey at low cost is not an end in itself, but a means to obtain complex data that necessarily requires an archaeological interpretation. The work presented in this article is a methodology to be able to obtain quality data to characterize the hypogea of the several necropolises of Menorca. That is, to see what are the main characteristics that are recurrent in these spaces and try to identify if the cultural interaction between different groups materializes in the hypogeal funerary architecture.

Moreover, applying the multivariate statistical method on the set of the 11 complex hypogea of Cala Morell has allowed us, on the one hand, to test the applicability of this type of analysis for the funerary materiality that constitutes our object of study. For necropolis such as Cales Coves, composed of a very high number of hypogea, this type of analysis allowed to represent in a graph almost a hundred study cases, so we believe that for future work it can be a very useful tool.

On the other hand, the performance of the analysis of hierarchical conglomerates, or better-known as clusters, has allowed us to determine the existence of three different hypogea groups within the necropolis of Cala Morell. Each of these groups has been formed based on the structural characteristics they presented, that is, a greater similarity or dissymmetry between the study cases -11 hypogea- has allowed their differentiation into groups. We are aware of the problem of carrying out this type of analysis for such a small sample, but we believe that the future comparison of our results with the analysis of other complex plan hypogea necropolis could shed light on the enormous variability within the same funerary set and translate this to socio-cultural explanation.

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