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ORIGINAL ARTICLE

Statistical analysis on metric and geometric features of dolmens in the Gor river megalithic landscape (Granada, Andalusia, Spain)

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Abstract

The construction of dolmens took place in Europe from the Neolithic to the Early Bronze Age (fifth millennium BC–second millennium BC) and had a rapid development along the Atlantic façade, with an important focus in Andalusia. Within this area, the megalithic necropolises located in the banks of the Gor River (Granada, Andalusia, Spain) are studied.

In this paper, multivariate techniques are applied to characterize the dolmens associated with the Gor river megalithic landscape by means of two analyses. First, a new classification of the dolmens in necropolises using their location variables produces an optimal number of 8 necropolis instead of the traditional 11. In addition, this classification improves the traditional spatial division of the dolmens because there is no overlapping between necropolises. Secondly, a multivariate analysis of the dimensional variables, which aims to detect possible constructional patterns, is performed obtaining three main variables of grouping. The first two, length and width of the chamber, can be summarized as the area of the chamber and, in terms of this, the dolmens can be classified into two main groups. The third one, the length of the corridor, can be considered as a factor for intragroup discrimination.

KEYWORDS

constructional patterns, Gor River necropolises, megaliths, multivariate analysis, spatial statistics

INTRODUCTION AND OBJECTIVES

The megalithic phenomenon constitutes a subject of study of great importance for the understanding of Late Prehistory, especially due to its relationship to the process of monumentalization of the landscape, creating specific messages "from and toward" prehistoric societies (Cámara et al., 2018; Carrero-Pazos et al., 2019; Holtorf, 1996; Lozano et al., 2014; Wheatley et al., 2010). This practice began in the Neolithic period, with a rapid development in several areas of Western Europe, in parallel to the development of the first European farming communities and being closely linked to the emergence of very important social and ideological changes (Blank et al., 2020). In addition, beyond their diversity in typology and chronology, most of them can be linked to the world of funerary beliefs and rituals of European Neolithic communities, although with differences in burial treatment (Blank et al., 2020). The oldest chronologies established in Europe reveal the existence of several megalithic centers located in the Atlantic façade, from where they had a rapid expansion to the rest of the Western Europe including inner Iberia (see Figure 1a), although some earlier developments are also suggested in Western Mediterranean (Schulz-Paulsson, 2019). One of the most important areas in terms of number and variety of megalith structures is Southern Iberia (Boaventura and Mataloto, 2013; Esquivel et al., 2017; García, 2009), where differences between a western zone, with mainly great dolmens located in small groups quite distant from each other, and the eastern zone, with mainly small tombs clustered in large necropolises have been proposed (García, 2009). In addition, social differences could be traced from certain consumption strategies (both in diet and grave goods (Afonso et al., 2011; Fernández et al., 2016) and representations (Bueno et al., 2018). The largest number of dolmens is located in Eastern Andalusia, specifically in Almería (600) and Granada (550), whereas in Western Andalusia a smaller number has been registered (70 megaliths in Huelva, 70 in Málaga and Sevilla, 50 in Córdoba and 40 in Cádiz (García, 2009)), showing an important difference between both zones. In addition, Eastern Andalusia megalithic groups are constituted by a great number of small-sized dolmens, where the western group is composed of lewer dolmens that, however, are clearly larger in size, so there exists a discriminatory pattern. In particular, the largest necropolises are located in the

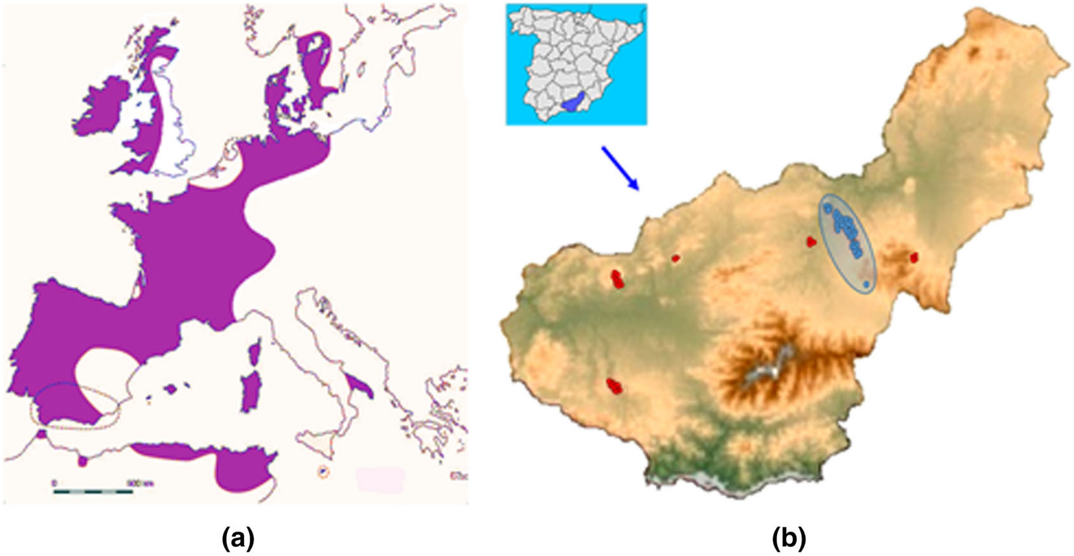


FIGURE 1 Megalithic phenomenon Notes: (a) in Europe (Aguayo & García, 2006), and (b) main megalith clusters in the province of Granada showing the megaliths in the Gor River area (modified from García, 2009)

west area of Almería province, as shown by Tabernas corridor necropolises (Cámara, 2001; Cámara et al., 2014) as well as in the western section of Granada plateaus, where Gor River tombs are placed (Spanedda et al., 2014).

The Gor River megalithic area includes a great number of preserved graves, being one of the biggest clusters not only in Spain but in Europe. The first reference to the dolmens of the Gor River was made in 1868 by Manuel de Góngora, who carried out the excavation of three megaliths (Góngora, 1868). In the late 19th century, L. Siret and P. Flores carried out the first extensive work of documentation and excavation in the area, recording 238 dolmens and excavating 103 of them, in which they found the remains of 760 individuals (Siret, 2001). In the 1940s, G. and V. Leisner published in detail 82 of the dolmens registered by Siret and Flores (Leisner and Leisner, 1943), and later in the 1950s M. García Sánchez and J. C. Spahni carried out the most systematic and complete study to date, recording 198 megalithic monuments and excavating a good part of them, also showing the dramatic effect of the lack of protection that had led to the disappearance of 40 dolmens since the late 19th century (García and Spahni, 1959). After this, megalithic monuments in the area were only revisited as recently as the late 1990s by two parallel teams with very concrete goals: the partial restoration of some dolmens in order to create three touristic itineraries (Manarqueoteca, 2001) and to evaluate the remaining monuments in order to get a better legal protection for them as Assets of Cultural Interest (Bienes de Interés Cultural, BIC) (Montufo Martín, 2019). Unfortunately, the strictly archaeological results of this ambitious second activity have only been partially published (Spanedda et al., 2014).

The importance of the Gor River necropolises can also be seen compared to the megalithic density in the nearest areas. Figure 1b shows all dolmens located in Granada province, with the dolmens of the Gor River symbolized by blue circles and those of other necropolises by red ones. Close to our study area, in the east of Granada province, two other big necropolises are located with most of the tombs in them suffering from anthropic actions, plundering, modern constructions, or farming. One of the most important necropolis of the area is the Fonelas one, located to the west of the Gor River megalithic group (about 3.5 km far). This necropolis could have been constituted by about 70 dolmens (Ferrer et al., 1988; Leisner & Leisner, 1943), of which most of have disappeared. The second eastern necropolis is Panoría (Darro), where a systematic research program is providing significant results regarding chronology, raw materials, deposit patterns, and information about the diet of the buried individuals (Aranda et al., 2018; Aranda et al., 2018), although no results have been published in relation to the dolmens' placement and typology. Other necropolises are located in the western part of Granada, with features (as semihypogea construction) related to Western Andalusia megalith groups (Cámara, 2001). Pantano de los Bermejales necropolis is placed in the Cacín River valley, and most of the 13 excavated dolmens (mainly between 1964 and 1968) are nowadays under the waters of the swamp, although, one of them was moved to a higher ground and can be easily visited (Arribas and Ferrer, 1997). Finally, the best known necropolis of the western part of Granada province is Las Peñas de los Gitanos, at Montefrío municipality, containing about 50 dolmens although many graves could have been lost, especially due to farming, or remain hidden by vegetation and rocky outcrops in a well-preserved natural area, which also includes an important prehistoric village occupied from the late fourth millennium cal BC (Arribas and Molina, 1979; Cámara et al., 2016).

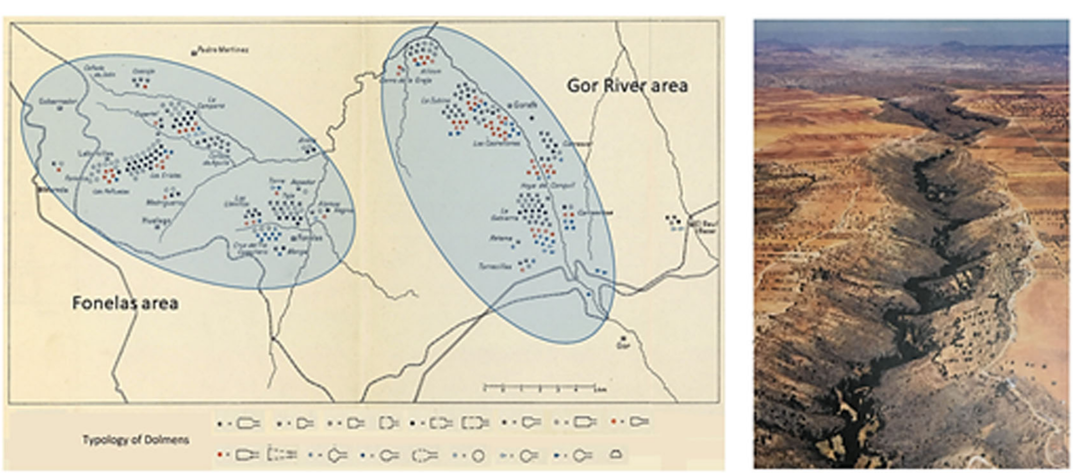
This study focuses on the megalithic complex of the Gor River Valley, as it represents one of the largest concentrations of dolmens in Europe. The following section presents the complete database (including UTM coordinates and constructional variables) of the Gor river consolidation, registered in 2019 by the authors and composed of 151 currently preserved dolmens (Cabrera et al., forthcoming). Location studies were previously carried out and the issue of visibility from the megalith as well as the relationship between the geomorphological characteristics of the terrain and several characteristics of the dolmens were addressed (Cabrero, 2018;

Cabrero et al., 2020) based on location variables using the old data set of García and Spahni (1959) and Afonso et al. (2006). Regarding the division of the megalithic complex into different necropolises, Leisner and Leisner (1943) and García and Spahni (1959) introduced a classification based on toponymic and cadastral information as a criterion for division. However, this megalithic complex has never been studied from the point of view of its geographical placement and constructive patterns, aspects that can certainly provide different and diverse information about the megalithic society of the area. This fact has, consequently, motivated the two main objectives of this work: first, to classify the dolmens according to their location characteristics identifying differences and similarities with the traditional classification through cluster analysis (Section 4); and second, to detect constructional patterns from the analysis of the dimensional variables of both the chamber and the corridor of the dolmens (Section 5). Finally, conclusions are derived and suggested directions for further research are identified in Section 6.

MATERIALS AND METHODS

The database has been obtained from the systematic surface survey carried out in 2019, starting from the previously available data (García and Spahni, 1959; Spanedda et al., 2014). From this work, a significant part of the dolmens has been relocated (UTM coordinates system), and a complete database has been recorded obtaining an exhaustive and complete catalogue (Cabrero et al., 2021). It is composed of 151 preserved dolmens located on both banks of the Gor River, which appears as a narrow and deep channel almost 17 km long, in the Guadix-Baza high plateau. Among these 151 documented dolmens, 5 have been discovered during these works (see Figure 2).

In addition to the problems related to the long use of graves during the sixth, third, and even second millennia BCE, most of the monuments were excavated in the past using old research works with methods that cause limitations such as the absence of radiocarbon dating, the loss of a large number of the materials that are expected to be found and generated during these works (only some drawings are available), and the absence of a systematic analysis of the recovered materials. These circumstances, jointly with the hypothesis that at the end of the third



(a) (b)

FIGURE 2 Spatial location of dolmens Notes: (a) Gor River area and Fonelas area (almost disappeared today) from historic maps (Leisner & Leisner, 1943), and (b) panoramic view of Gor River valley millennium BCE all the monuments would have already been built (Murrieta-Flores et al., 2011) lead us to consider all the dolmens as contemporary in use.

In previous works, the necropolises have been classified taking only into account the toponymy of the area. Multivariate techniques have shown very good results analyzing archaeometric data (Baxter, 1999). Here, a spatial analysis is carried out on the geographic variables (X_UTM, Y_UTM, and altitude) choosing a more automatic way to evaluate the number of necropolises by using different methods of statistical clustering applied to the full catalogue of 151 dolmens. The results obtained could be useful to relate types, contents, placement, and other variables to time and social variation. Regarding the typological analysis, the constructional metric variables (length, width, and height of the chamber, and length and width of the corridor) are analyzed although there is a significant part of the dolmens lacking a corridor (77 of 151). In addition, among the 74 dolmens having a corridor, there is a problem of missing values as to both the variables of the chamber and the corridor. Specifically, 43 of the 74 dolmens with corridor are sufficiently well preserved allowing the registration of the five variables (see Figure 3). In this paper, the study of the constructional typology of the dolmens is carried out analysing only the 43 completed ones because, on the one hand, this sample includes a sufficient number of dolmens and, on the other hand, the sample can be considered to be random due to the fact the dolmens are not related to the general values of the same variable or other variables (Rubin, 1976).

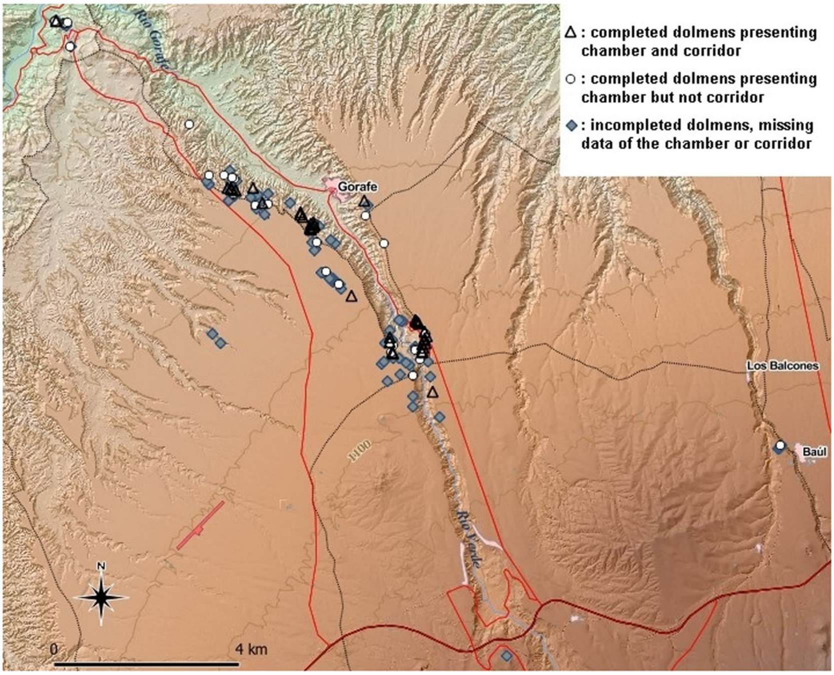


FIGURE 3 Location of the 151 dolmens marked with a triangle if they are well-preserved and they present chamber and corridor, with a circle if they are well-preserved and they only present chamber, and with a diamond if they are not well-preserved

STATISTICAL PRELIMINARY ASPECT

The great amount of available information in the complete database (in elements and variables) allows the application of multivariate techniques to extract the underlying information contained in the data. Regarding the spatial location of the dolmens, the aim is to perform a classification according to placement variables (coordinates) using the cluster analysis technique of the *k-means* algorithm. As for the constructional variables, a detail classification of the dolmens in groups and subgroups is performed by means of the cluster analysis technique as expressed in the obtained dendrogram. In addition, the fact of having five available metric variables leads us to study a possible reduction of the dimensionality applying the principal component analysis allowing to determine possible associations between the variables mentioned above as well as constructing an exploratory representation of possible groupings of the dolmens. Below, a brief description of the methodologies applied is presented.

Principal component analysis (PCA)

In data sets with more than three variables presenting significant two to two correlation, the exploratory PCA (Sokal & Rohlf, 2010; Venables & Ripley, 2002; Zencher & Christensen, 2012) is very useful to reduce the number of study variables in such a way that as much information as possible is explained by defining new variables that are not correlated with each other. In most cases, the reduction of the dimension allows to represent in 2D and 3D plots the elements under study and, in this visual way, to detect possible structural groupings. This technique has been used in the study of the constructional variables because, as we have just mentioned, there are five variables available.

Cluster analysis (CA)

It is a statistical tool to obtain a cluster model which classifies a set of objects in similar groups (denoted clusters) maximizing the intergroup homogeneity and the intragroup heterogeneity. This is a common technique to analyze multivariate data in many fields, including the construction of typologies, pattern recognition, machine learning, image analysis, information retrieval, and so on, being a basic method in big data and data mining techniques (Everitt et al., 2011; Hennig et al., 2015; Izenman, 2008; Sokal and Rohlf, 2010). This method consists of a set of geometrical and statistical algorithms focused on generating a typology of multivariate objects that allows to obtain the structure of data classified into groups of objects with the members in each group being as similar as possible to each other and the members of different groups as dissimilar as possible to each other. From a statistical point of view, the classification can be formulated as a problem of optimization with multiple objectives in which a configuration of appropriate parameters must be chosen including the distance function to be used, the clustering algorithm, the number of clusters, and so on (Esquivel et al., 2019). There are diverse cluster models and different agglomeration algorithms. Among the most used ones, the centroids models and the connectivity models are found.

The centroid-based clustering organizes the data in a non-hierarchical classification. The most used algorithm the k-means, which is focused on the partition of great quantity of observations into k clusters in which each observation belongs to the cluster, with the nearest mean serving as a prototype of the cluster. The result produces a partitioning of the data space into Voronoi cells minimizing within-cluster variances (squared Euclidean distances) but not regular Euclidean distances. The *k-means* clustering analysis algorithm defines clusters with the total within-cluster sum of squares WSS minimized. This technique is appropriate when there are a high number of observations, but it is sensitive to outliers and requires a previous specific number of clusters. There are more than 30 different methods to choose the optimal number of clusters, and the result depends on the method used. Among the most used ones are the Elbow (Murphy, 2015) and the Silhouette (Kaufman and Rousseeuw, 1990) methods. This technique has been used in the spatial classification of the dolmens because there are no outliers and the objective is to determine a main classification in groups. Furthermore, the large number of dolmens available for this analysis makes it difficult to detect subgroups by means of a dendrogram.

Connectivity-based clustering or hierarchical clustering constructs a clustering tree, which establishes classifications in groups and subgroups. It is based on the idea that every object is more related to the near objects. There are different methods and each one can use different statistical distances to measure the level of proximity between groups. One of the most widely used ones is the Ward's method, where, at each step, the criterion for determining the pair of groups to merge is to choose the two groups that have the minimum increase in total within-cluster variance after merging (Almeida et al., 2007; Krieger et al., 2014). The results are displayed in a dendrogram very informative allowing to establish groups and subgroups of the observations. Some problems appear when there are a great number of observations because the dendrogram can be very difficult to interpret. This technique has been used in the study of the constructive typology of the dolmens because the objective is to establish groups and subgroups based on the constructive characteristics and also because the number of dolmens in this case allows their detection from a dendrogram.

SPATIAL STATISTICS

As mentioned above, since 1986, different excavations of the megalithic complex of the Gor River have been carried out. Regarding the spatial distribution of the dolmens, Leisner and Leisner (1943) and García and Spahni (1959) established a classification in 11 necropolises. This previous classification followed the toponymic and cadastral information, but these criteria may not be the most adequate to define and divide the necropolis and are not always related to clear geographical features. Furthermore, in Figure 3, it appears that the spatial distribution of the dolmens shows spatial clustering. There are various techniques to measure the intensity of points such as H function, L function, or the pair correlation function (Bevan et al., 2013; Carrero-Pazos et al., 2020; Davis et al., 2020). Figure 4 shows the pair correlation function g obtained using the *Ripley* and *Translate* methods of estimation; also, the theoretical value of g (r) for the Poisson process (vector of values equal to 1) is displayed to identify the presence of clustering (values greater than 1) or dispersion (values less than 1). In all distances (r), it can be seen that the estimated values for g using both methods are above 1, which reflects that there is clustering in the spatial distribution. Thus, an interesting result can be derived from the comparison between the traditional classification and a new classification obtained by applying multivariate statistical techniques to the spatial location of the dolmens. In particular, a classification of the 151 dolmens is performed according to the location variables (X_UTM, Y_UTM), the altitude, and the distance to the Gor River using the k-means method because there is no problem of outliers and the number of objects is high.

In order to detect groupings within the Gor River megalithic necropolis, the first step is to determine the optimal number of clusters, an objective that requires the calculation of the most used methods. Figure 5 shows the Elbow method (upper left), the Silhouette method (upper right), and a character bar displaying the optimal number of groups obtained for the 26 most widespread methods. From a joint interpretation of the three graphs, the optimal number of clusters is established as eight because: (a) according to the Elbow method from six clusters the distortion/inertia begins to decrease linearly, (b) according to the Silhouette method the average

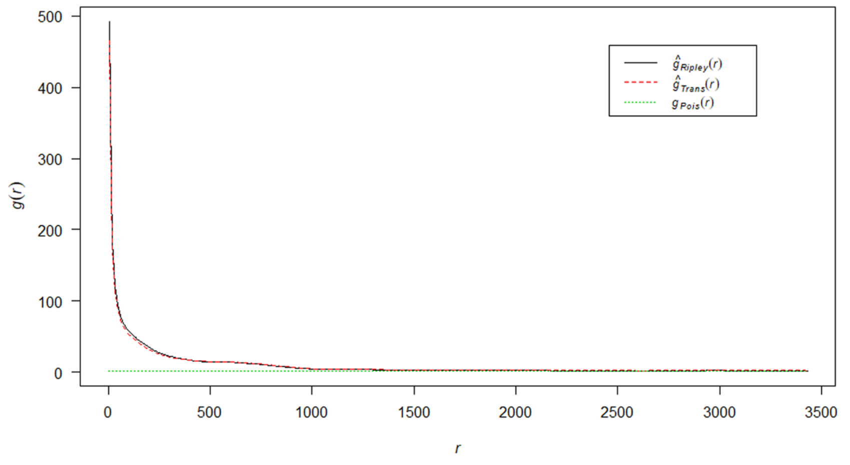


FIGURE 4 Curves of the estimates of the PCF for both methods (Ripley and translate) and the theoretical value of g (r) for the Poisson process

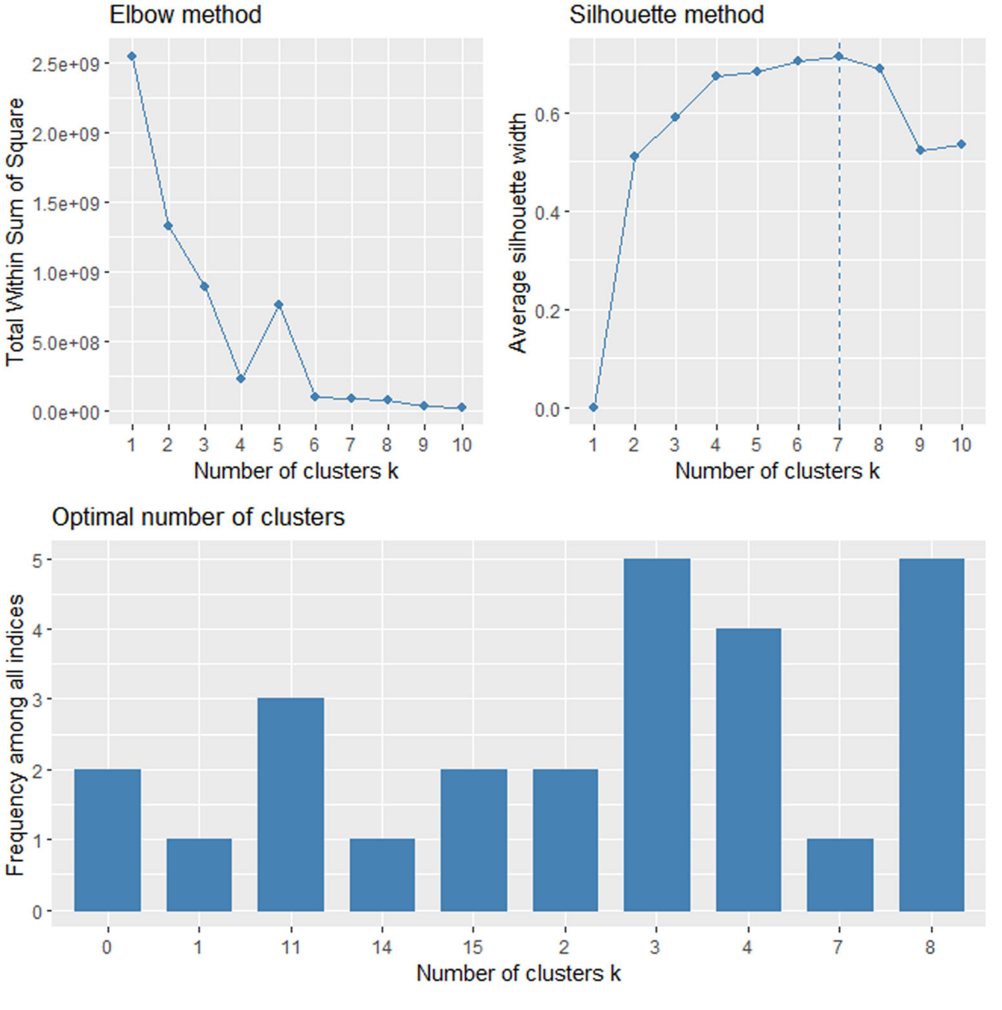


FIGURE 5 Elbow method (on the left top), Silhouette method (on the right top) and a char bar displaying the optimal number of clusters obtained for the 26 most extended methods (on the bottom)

width for eight clusters is very close to the maximum (in seven clusters), and (c) most of the main methods indicate eight clusters as the optimal number (together with three).

Once the optimal number of clusters chosen is eight, the classification is performed using the *k-means* clustering method. Figure 6 shows the 2D spatial representation of the dolmens (longitude and latitude UTM coordinates) considering as marks the group assigned by the k-means algorithm (on the left) and the group of the historical classification (on the right). Comparing both images, we can clearly see that there are important problems of overlapping between groups in the historical classification, whereas in the k-means classification these problems are notably reduced. On the one hand, results point out that the traditional classification in 11 necropolises is not adequate, as it has also been hypothesized in a previous publication. On the other hand, a possible classification of the dolmens that points out a better division for the Gor River megalithic group considering eight necropolises is proposed.

STUDY ON THE CONSTRUCTIONAL FEATURES AND SHAPES

Here, a characterization of the structural typology is performed using multivariate statistical tools applied to the constructional metric variables recorded (namely length, width and height of chamber, and length and width of corridor). Thus, this section studies the constructional characteristics of dolmens with corridors (77 out of 151), although there is a significant number of dolmens with missing values due to a poor state of preservation. In total there are 43 dolmens

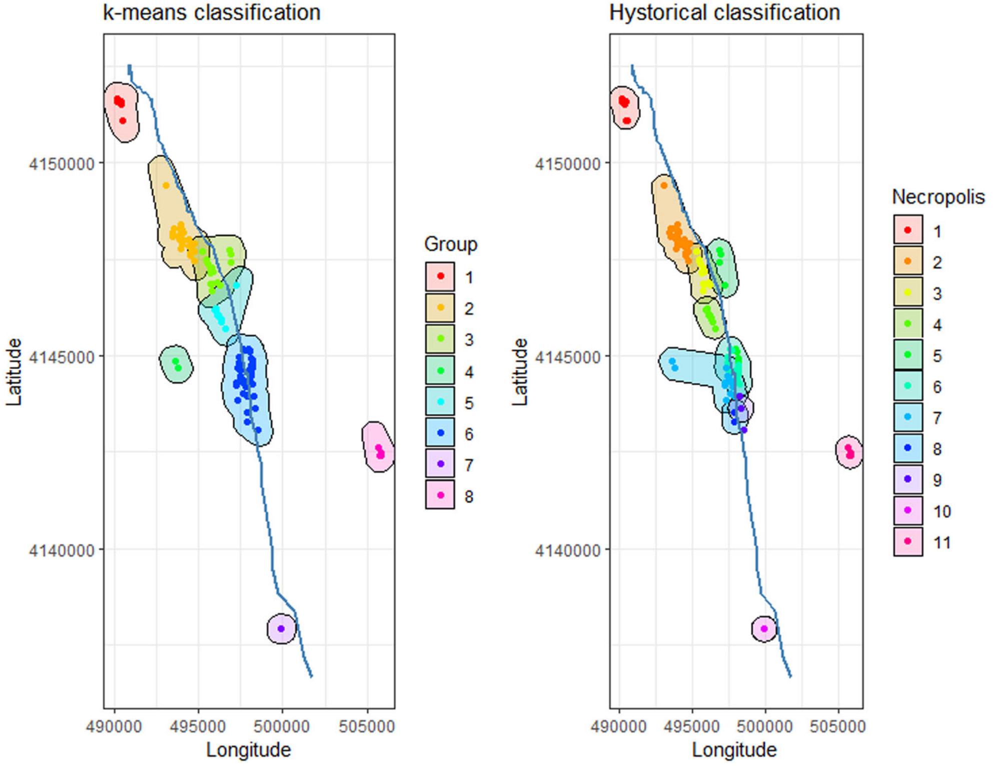


FIGURE 6 2D spatial representation of the dolmens (longitude and latitude UTM coordinates) considering as marks the group assigned by the *k-means* algorithm (on the left) and the group of the historical classification (on the right)

with a well-preserved corridor (55.8%). Given that it is a significant number of the total and that it can be considered as a random sample because it is not conditioned by factors that may affect the interpretation, such as location or size, the results obtained can be extrapolated to the total number of dolmens with corridor. Specifically, two analyses are carried out. First, a factorial analysis is carried out to reduce the dimensionality with the aim of determining associations between the variables as well as having a visual representation of possible groups of dolmens according to their constructional characteristics (shape). Secondly, a cluster analysis is performed to establish groups and subgroups among the dolmens by means of a dendrogram.

Factorial structure

The constructional variables of dolmens usually present a significant two to two linear correlation. In this case, the most used method to carry out an exploratory study is the PCA (Sokal and Rohlf, 2010; Zencher and Christensen, 2012). This procedure is very useful to reduce the number of variables in such a way that as much information as possible is explained by defining new variables that are not correlated with each other. In most cases, the reduction of the dimension allows to represent the objects under study in 2D and 3D as a dispersion plot and, in this way, to visually detect possible structural groupings. In our case, the lineal correlation matrix between the variables shows some significant correlations between all variables except for the corridor length, which does not present a lineal association with any variable. To confirm that the variables are correlated, the Bartlett test of Sphericity is carried out obtaining a p-value (1.848 e-53) very close to 0. Thus, the PCA or other methods of reduction of dimensionality are appropriate. The results obtained by the PCA indicate a factorial structure based on either two factors explaining 82.11% of the total variance, or three factors explaining 92.36% of the total variance. Besides, a 2D representation is appropriate because the first two factors have eigenvalues greater than 1 ($\lambda_1 = 3.069$ and $\lambda_2 = 1.036$) (see Figure 7).

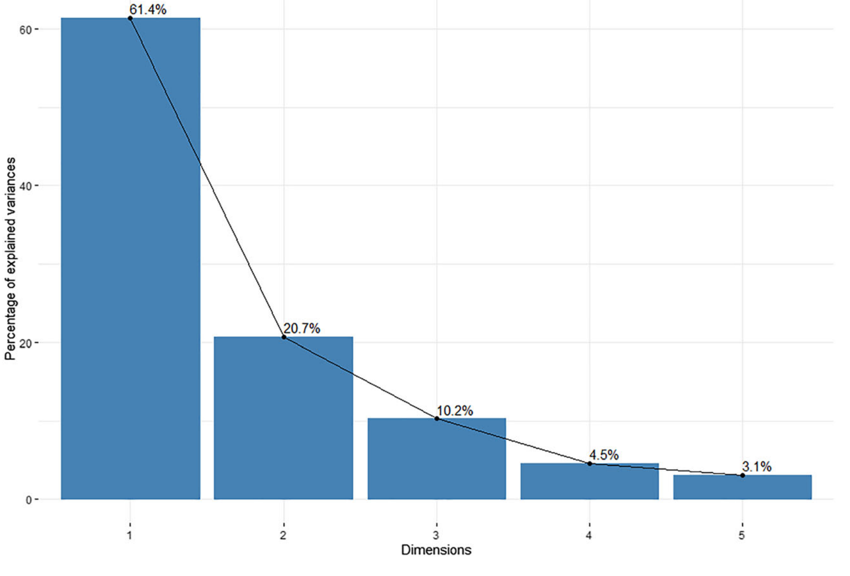
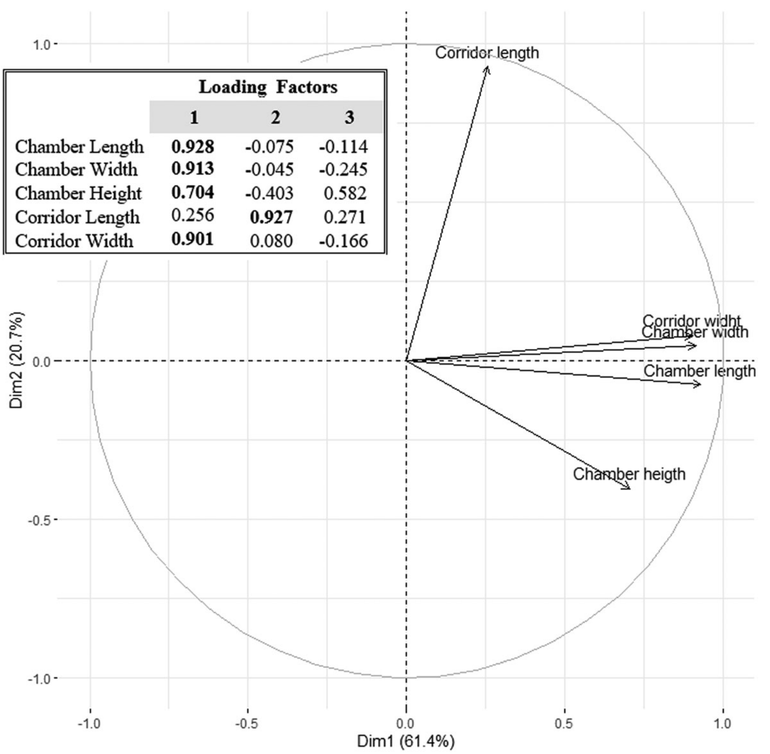


FIGURE 7 Bar chart showing the percentage of explained variance by the first five principal components and the table containing the eigenvalues, the explained variance, and the accumulated explained variance of the three first principal components

Regarding the loading factors of each component, for the component 1 (Dim1) all variables except for the corridor length have a significant loading (greater than 0.74), whereas for the component 2 (Dim2) only this variable has an important loading (see Figure 8). As for component 3, there are no variables with significant loadings. This, jointly with the higher accumulated explained variance for the first two components and the fact that the third eigenvalue is less than 1, can indicate that the underlying structure of the data can be significantly explained by means of the first two principal components. Then, an exploratory image of possible groupings of dolmens could be constructed by means of a 2D representation (see Figure 8).

As the length and the width of the chamber have loading factors greater than 0.9 in the definition of Dim1, the area of the chamber ($Area = Length \cdot Width$) could be a discriminatory feature of dolmens. The distribution of the chamber area shows three clear clusters, which can be arbitrarily called small, medium, and big. Besides, an inverse relation between the size of the chamber area and the number of dolmens is also found (see Figure 9).

To finish the factorial structure of the constructional features, a 2D plot PC1 versus PC2 is performed to try to detect patterns in the constructional characteristics of the dolmens, incorporating marks in terms of the area of the chamber (see Figure 10). On the one hand, PC1 discriminates very clearly in three groups according to the size of the area. This fact indicates that the length and width of the chamber are closely associated with length of the corridor and height of the chamber, which present great loadings in PC1. Also, we can observe a big number of dolmens with a small area, a few of them with medium area, and very few with a large area. On the other hand, PC2 (with only length of the corridor as variable with significant weight) does not discriminate the whole set of dolmens, but it points out characteristics in each area group. As to the small chamber area dolmens, they present any size of length of corridor. Regarding



Loading Factors	1	2	3
Chamber Length	**0.928**	-0.075	-0.114
Chamber Width	**0.913**	-0.045	-0.245
Chamber Height	**0.704**	-0.403	0.582
Corridor Length	0.256	**0.927**	0.271
Corridor Width	**0.901**	0.080	-0.166

FIGURE 8 Circular representation of the loading factors of the variables for the two first principal components and table containing the loading factors of the variables for the three first principal component (top left)

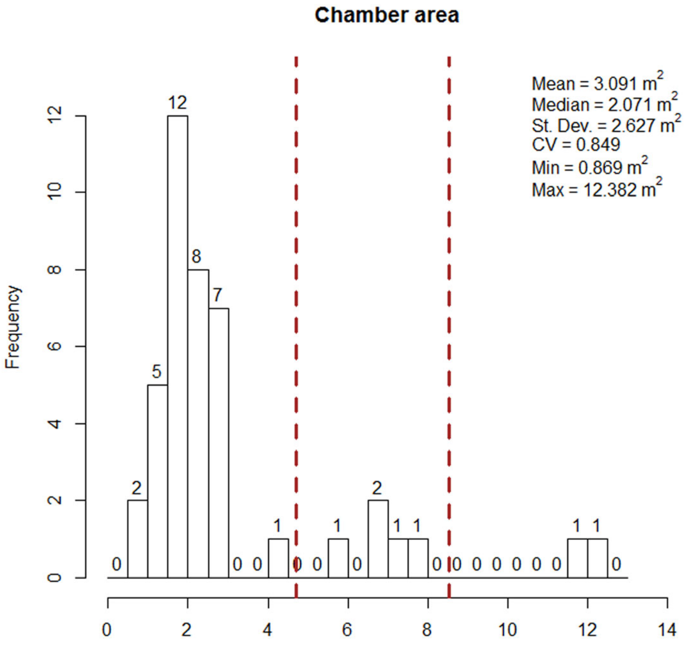


FIGURE 9 Histogram of the chamber area distribution of the dolmens

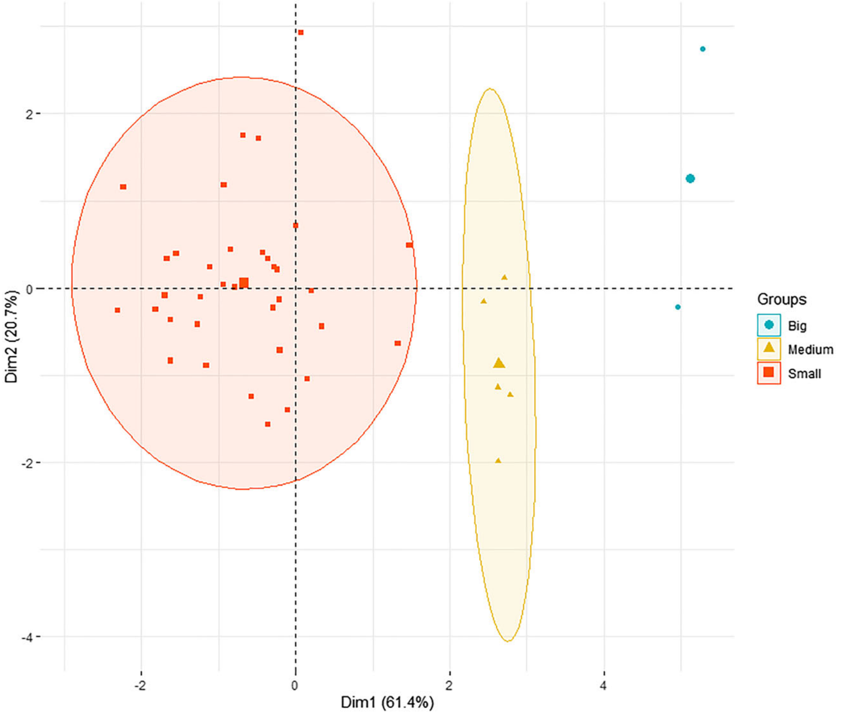


FIGURE 10 PC1-PC2 plot using the size of the chamber area as mark

the dolmens with a medium area, there are not any dolmens with a big length of corridor. Finally, the two big dolmens have a large and a medium length of corridor. As referred above, it must be considered that the study does not include those tombs lacking a corridor.

Constructional typology study of dolmens

Here, a classification of the dolmens in terms of their constructional variables is performed by using the dendrogram generated by the cluster analysis classification technique SAHN (sequential, hierarchical, agglomerative, and non overlapping) considering the Euclidean distance as the similarity measure and the Ward's method (minimum variance) as the clustering procedure. This technique has been chosen because it is more flexible to outliers and because the number of available dolmens with the five constructional variables (43) allows the identification of groups and subgroups in the dendrogram. Figure 11 shows the dendrogram obtained including a mark for each dolmen according to the values of the length, the width, and the height of the chamber, as well as the length and the width of the corridor (symbolized as CHL-CHW-CHH-CL-CW) considering five categories: extra-small (XS), small (S), medium (M), large (L), and extra-large (XL). Five divisions have been chosen to lose the minimum of information from the quantitative variables while maintaining the interpretative capacity of a categorical variable.

The dendrogram shows two main groups (with a higher level of discrimination), Group A (represented by the colours red and orange) and Group B (represented by colours the blue, light blue and green), (with a distance around 4.5 units) characterized by the length and the width of

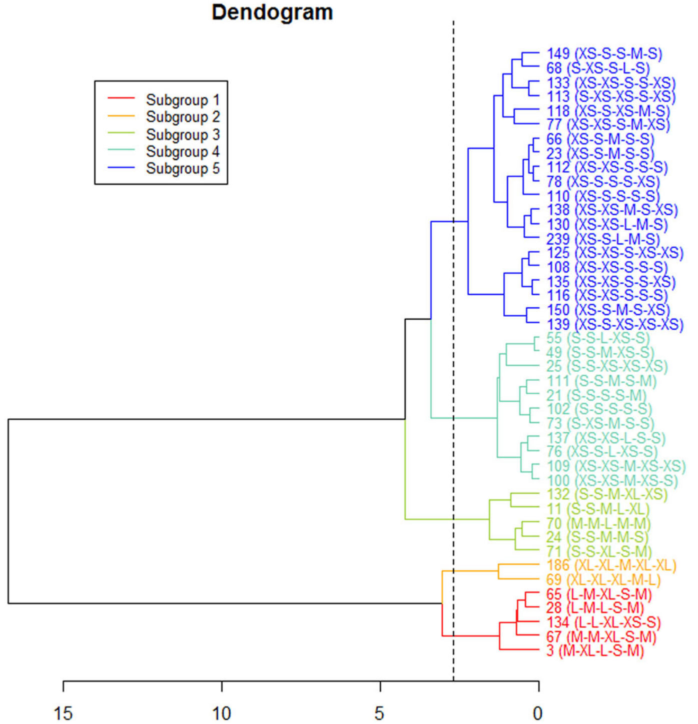


FIGURE 11 Dendrogram obtained from the constructional variables using the Euclidean distance and the Ward's method

TABLE 1 Classification of dolmens in groups and subgroups extracted from the dendrogram

		Chamber			Corridor	
		Length	Width	Height	Length	Width
Group A	Subgroup 1 (5 dolmens)	Medium large	Medium large	Large	Small	Medium
	Subgroup 2 (2 dolmens)	Very large	Very large	Medium/very large	Medium/very large	Large/very large
Group B	Subgroup 3 (5 dolmens)	Small	Small	Medium large	Medium/large	Medium
	Subgroup 4 (11 dolmens)	Small/very small	Small/very small	-	Small/very small	Small
	Subgroup 5 (20 dolmens)	Very small	Small/very small	-	Small/medium	Small/very small

the chamber. The Group A is associated with big and very big values of these variables and the other one with small and very small. A refined classification into five subgroups can be considered taking a distance of 2.7 units. This classification is summarized in terms of the constructional variables in Table 1 (the cases with too much variability are denoted with '-'). Here, we can see how the length and the width of the chamber, and the width of the corridor, discriminate in the same way, whereas the length of the corridor points out intragroup differences between the main groups A and B. On the other hand, the height of the chamber shows a great variability, which leads us not to consider this variable as a discriminatory factor. These results corroborate those obtained in the PCA analysis. In addition, the chi-square independence tests, one for each variable, conclude that there exists an association between the variables and the grouping performed, being very significant (p-value < 0.0001) in the case of the length and the width of chamber and the width of the corridor.

These results point toward a main classification into two groups (A and B) based on the length and the width of the chamber, and these effects can be combined considering the area of the chamber ($length \cdot width$). Furthermore, these groups can be internally divided from the variable length of the corridor into five subgroups. In this way, the constructional patterns of the Gor River megalithic aggrupation can be summarized in terms of the area of the chamber and the length of the corridor. At this point, it is necessary to remember that, as referred above, the dolmens without corridor or with a corridor excessively damaged have not been considered. For example, the inclusion of other dolmens without corridor could have partially changed the results regarding the group of the biggest megaliths, because two of the biggest ones in the whole set, numbers 4 and 9, both in the necropolis of Baños de Alicún, do not present corridor. Further, the 2D locations of the dolmens have been represented incorporating as marks the classification into two groups and the classification into five subgroups, obtaining randomness in both cases (For reasons of simplification, the representations are not included). This indicates that the constructional pattern of the dolmens do not depend on the necropolis they belong to or their spatial situation.

CONCLUSIONS

The megalithic phenomenon took place mainly in Western Europe from the fifth millennium BCE to the second millennium BCE, and it was associated with very profound changes in Neolithic society. These changes radically modified the vision and patterns of conduct of these communities in many aspects, being one of the most important ones the relationship between life and death, and, mainly the use of ancestors in social reproduction, leading to the construction of more permanent graves and the performance of rituals affecting the corpses and associated items (grave goods) during long periods.

In this work, we focus on the Megalithic Gor River valley group, one of the most important concentration of dolmens in Europe, despite the fact that it lacks a systematic project of research and that only over the last years it has been provided with an adequate protection system. Starting from the available previous data, an exhaustive systematic survey was carried out in the summer of 2019 documenting 151 megaliths, 5 of them being unknown till that moment, although problems of correlation among the recorded graves have always been present in relation to the different survey campaigns, and only the new UTM global positioning will avoid the same problems. In fact, the new survey has also allowed to relocate the preserved dolmens into their exact placement, recording the UTM coordinates, longitude, latitude, and altitude, and other variables (for a total set of 65), although some of the graves are deeply deteriorated. Here, a new spatial classification of the different necropolises included in the Gor River megalith group and an analysis of the possible constructional patterns of the dolmens are carried out by applying statistical multivariate techniques. In the first case, the variables referred to the spatial location (longitude, latitude, altitude, and the distance to the Gor river) have been used. In the second one, the metric constructional variables (length, width, and height of chamber; and length and width of the corridor) have been jointly analysed.

Regarding the spatial analysis, a new classification of the dolmens in eight necropolises is proposed showing no spatial overlapping, in contrast to the traditional classification, which took into account the toponymy of the areas, showing some overlapping around the central part of the megalithic complex. In addition, six of the necropolises present great intragroup homogeneity and intergroup heterogeneity. The two other (Baúl area and Fonelas area) have very few dolmens, and they are far from the others. According to the results, these two necropolises could be considered not to be part of the Gor River megalithic landscape. Differences among very near dolmens could derive from not easily visible oppositions between comunities, as have been proposed for Tabernas Corridor (Cámara, 2001). In fact, although we have previously negated political divisions in Gor River set (Cabrero, 2018), this proposal was formulated from the visibility net created by the central necropolises (Hoyas del Conquín and Majadillas) without taking into account the real variability and the separated distant necropolises as here shown.

As for the constructional analysis, the obtained results from the PCA allow to stablish a factorial structure in two components. The PC1–PC2 plane shows an aggrupation with a large number of dolmens of small chamber area (84%), possibly corresponding to individual or family burials. A small group of dolmens with intermediate area (12%) is strategically located along the Gor River within 3 km range and may be associated with possible settlements. Finally, there are two very large dolmens (4%) located at the extremes of the river valley, in the zones with less density of dolmens. This structure points to the existence of a hierarchy of dolmens, which probably reflects a social division of territory based on different family groups or lineages with few social differences inside them, which cannot be stated exhaustively due to the almost complete absence of material remains to be studied. Cluster analysis confirms a typological classification into two large groups formed by small-sized dolmens versus large and very large ones. These groups are subdivided into five large subgroups or subtypes, and a multidimensional classification in terms of the constructional variables suggests that the main discriminatory factors are both the area of the chamber, which could be associated with chronological differences of the dolmens or family and social status; and the length of the corridor, probably associated with the increasing periodical rituals aimed to justify lineage ties to certain ancestors (Cámara et al., 2018). On the other hand, height of the chamber is not a discriminant variable and in many cases could be related to the depth of foundations. Only in masonry graves, as Los Millares ones, area and height of chambers can be related, but even in these examples highest chambers with corbelled roofs are only used in chambers extend less from 4 meters in diameter (except some of them with deep foundations or great reinforcements) (Calvín, 2019). Large chambers with plain roofs can offer the richest graves goods as in Los Millares 40 (Afonso et al., 2011).

A future line of enquiry is that the characteristics of the surrounding landscape can be taken into account to measure the distance between dolmens, for example considering the isotropic or anisotropic cumulative cost of moving between different geographic locations (Hussain and Floss, 2015). In fact, previous studies, not based in GIS data and also considering megaliths without corridors, have suggested that greatest dolmens, sometimes with relevant grave goods according to García and Spahni (1959) data, could serve as special markers of a route along the Gor River (Spanedda et al., 2014). Locational hierarchy between megalithic graves according size have been also referred in other Iberian areas (Cámara et al., 2014; Carrero-Pazos et al., 2019). Another significant future line is to discriminate between environmental and social factors in the spatial ordering of the dolmens. For example, making a classification incorporating the underlying environmental characteristics in the point process. Then, the differences with respect to the basic model may be due to social aspects.

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DATA AVAILABILITY STATEMENT

Data available on request due to privacy/ethical restrictions.

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