Journal of Archaeological Science: Reports 50 (2023) 104093

Contents lists available at ScienceDirect

Journal of Archaeological Science: Reports

journal homepage: www.elsevier.com/locate/jasrep

Statistical proposals for a formal classification of Chalcolithic stone masonry passage graves with circular chamber in the Southeast of the Iberian Peninsula

Mª Eugenia Calvín Velasco [a,*,1], Juan Antonio Cámara Serrano [a,*,2], Francisco Javier Esquivel Sánchez [b,3]

[a] Departament of Prehistory and Archaeology, Univeristy of Granada, Campus de Cartuja s/n, 18071, Granada, Spain
[b] Departament of Statistics and Operations Research, University of Granada, Campus de Fuente Nueva s/n, 18071, Granada, Spain

ARTICLE INFO

Keywords:
Chalcolithic period
Southeast of the Iberian Peninsula
Megaliths
Stone masonry grave
Flat roof
False dome
Statistics

ABSTRACT

This study offers a classification of 106 megalithic stone masonry passage graves forming part of the Los Millares archaeological complex characterised by circular chambers. The study has employed a statistical method implementing the *OneR*, *JRip* and *Part* classification algorithms as well as multivariate analyses. The research yielded four groups: large tombs capped with flat roofs, small tombs covered by false domes, and two types of medium-large tombs capped either by flat or false-domes that can be distinguished according to the angles of their chambers walls and the presence of construction reinforcements, including the number of stone retainer rings walls serving to brace the thrust.

1. Introduction and objectives

The Southeast of the Iberian Peninsula has the distinction of encompassing both the eponymous site of Los Millares (Santa Fe de Mondújar, Almería), among the most celebrated fortifications of the European Copper Age (Molina and Cámara 2005), and one of the largest concentrations of megalithic tombs in Europe (Leisner and Leisner 1943; García et al. 2022). Moreover, this region reveals the greatest density and the oldest Iberian cases of stone masonry passage graves with circular chambers, tombs that differ from orthostatic dolmens in terms of construction type and size (Leisner and Leisner 1943; Aranda et al. 2021).

Nevertheless, these stone masonry tombs have never been the subject of a detailed typological classification based on morphometric criteria such as the case of a series of orthostatic models analysed in recent study (Esquivel et al. 2022). They likewise also have never been examined from the viewpoint of several fundamental aspects, notably construction and roofing types, whether the cover resorts or not to a false dome, and to the degree of finish of this roof type (Blance 1971; Molina and Cámara 2009; Calvín 2014, 2019). These are in fact key factors when assessing aspects such as chronology, spatial distribution and, above all, when delving into questions of social relevance based on tomb size.

The objective here is therefore to develop a classification system based on statistical tools so as to 1) facilitate comparisons with other research, 2) define groups of homogeneous tombs in spite of the incomplete data by projecting the results of the better studied cases, and 3) offer an approach to constructive variations based on tomb size and shape, with a special focus on roofing.

The intention is thus to pave the way for future lines of research attempting to establish correlations between the different constructive types and social and chronological factors, as we will point out later.

Abbreviations: **MGD**, Stone masonry passage grave with a circular chamber covered by a false dome; **MGF**, Stone masonry passage grave with circular chamber and flat roof; **OPGPC**, Orthostatic passage grave with polygonal chamber; **PSD**, Polygonal simple dolmen; **CIS**, Cist grave; **RC**, Rock cut tomb.

* Corresponding authors.
E-mail addresses: mariu18@correo.ugr.es (M.E. Calvín Velasco), jacamara@ugr.es (J.A. Cámara Serrano), jesquivel@ugr.es (F.J. Esquivel Sánchez).
[1] https://orcid.org/0000-0002-0339-5023
[2] https://orcid.org/0000-0003-4007-0639
[3] https://orcid.org/0000-0001-8296-1013

https://doi.org/10.1016/j.jasrep.2023.104093
Received 1 February 2023; Received in revised form 15 May 2023; Accepted 18 June 2023
Available online 10 July 2023

2. Background

Megalithic funerary architecture in southeastern Iberia has been the object of numerous studies (Leisner and Leisner 1943; García and Spanhi 1959; Blance 1971; Acosta and Cruz-Auñón 1981; Cruz-Auñón 1983–84; Afonso et al. 2008; Calvín 2014, 2019; Esquivel et al. 2022). Much of this research has been limited to advancing typologies based on descriptive features. Certain studies, for example, refer to aspects such as layout complexity based on the presence or absence of access passages. These benchmarks led to favour the perspective of an evolution from simple to more complex constructions (Leisner and Leisner 1943), a viewpoint which today no longer holds up due to recent dating methods (Aranda et al. 2017).

Whilst Blance's study (1971) on stone masonry tombs resorted to various statistical techniques supporting her proposals on the existence of different types of roofs, it was carried out without actually identifying which tombs adopted one type of roofing system or another. Other work along these lines, resorted to increasingly complex statistical applications in other spatial contexts, applied to similar structures (Cavanagh and Laxton 1981; Buck et al. 1993; Como 2006; Rovero and Tonietti 2014; Barratt 2022). However, these studies focused on well-preserved features, which is far from the case of the megaliths of southeastern Iberia.

This study can also show not only the type of roof of the stone masonry tombs, but also help to assess aspects such as their chronology, their expansion and, above all, their social relevance in terms of their dimensions.

3. Materials, method and preliminary results

3.1. Initial descriptive classification

The study area is confined to the westernmost regions of southeastern Iberia, basically the Basins of the Andarax River and its Nacimiento tributary. It is an region thought to have formed part of the Los Millares archaeological complex which is characterised by large fortified settlements and smaller forts, dense funerary areas adjacent to settlements, and scattered tombs interpreted as territorial markers, features that contrast with those of other territories farther west and east (Molina and Cámara 2009: 48–49; Calvín et al. 2022: 86) (Fig. 1). The territory to the east, in the Vera Basin of Almería, is in fact characterised by fortified settlements surrounded by small groups of simple round dolmens or round stone masonry graves, devoid of passages called *rūndgraber*, and to a lesser extent, other orthostatic passage graves or masonry passage graves. The territories to the northeast offer simple rectangular dolmens near fortified sites or are devoid of graves. To the west, especially in the western area of the Province of Granada there are scattered passage dolmens and some necropolises near fortified settlements. Stone masonry passage graves however are restricted to the area linked to Los Millares in the Guadix Basin.

Of the approximately 150 megalithic groups recorded within the study area, the current investigation focused on 1067 tombs. Despite differing states of preservation and/or registration, it was possible to garner sufficient architectural data to establish a first descriptive classification. This, like that cited above, was based, in the first place, on construction techniques and, in the case of orthostatic tombs, the presence or not of a passage. Secondly, two criteria were retained to define the subdivisions within each group: funerary chamber shape and roof type (Table 1).

It is necessary to clarify that the definition of the subgroups of Groups 2 and 3 is based on chamber shape whereas that of Group 1 stems from

Table 1
Typological groups and types of the Los Millares archaeological complex.

Typological group	Type
Group 1. Stone masonry tombs with access passage and circular chamber	False dome Flat roof
Group 2. Orthostatic tombs with passage and polygonal[1] chamber	Rectangular Quadrangular Trapezoidal Polygonal[2] Circular
Group 3. Orthostatic tombs without passage and polygonal chamber	Rectangular Quadrangular Trapezoidal Polygonal Circular
Group 4. Cists	–
Group 5. Artificial caves	–

[1] "Polygonal": generic term to refer several possible chambers.
[2] "Polygonal": term to refer less common chamber types like pentagonal or hexagonal.

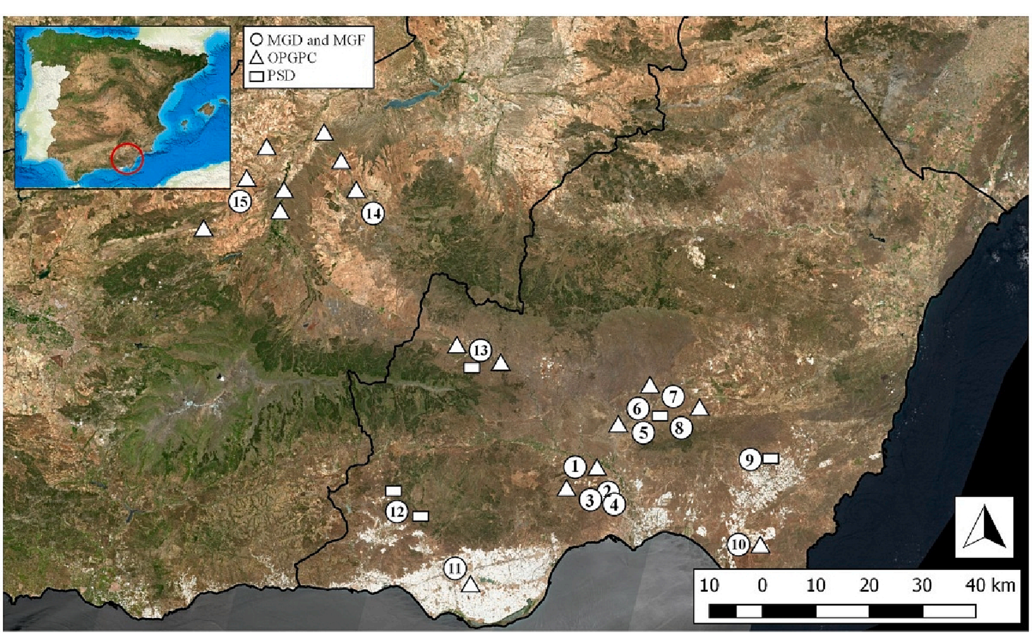

Fig. 1. Map of southeastern Spain indicating the distribution of the main necropolises of the Los Millares archaeological complex containing either stone masonry tombs or orthostatic tombs. 1. Los Millares (also featuring orthostatic tombs), 2. La Churruta, 3. La Partala, 4. El Chuche (consisting of the orthostatic tomb complexes of Alhama de Almería, Gádor and Benahadux), 5. Los Rubialillos, 6. Rambla del Búho, 7. Cerro de las Yeguas, 8. El Alhamillo (orthostatic tomb complex of Pasillo de Tabernas), 9. Las Peñicas and El Tejar, 10. El Barranquete, 11. Santo Domingo, 12. Cerro Cánovas (including orthostatic tombs), 13. Los Milanes (orthostatic tomb complex of Tacita de Plata), 14. Torrecilla (orthostatic tomb complex of the Gor River Valley), 15. El Espartal (orthostatic tomb necropolis including masonry tombs next to the orthostatic complex of Fonelas, Morelábor and Pedro Martínez).

the type of roofing as all its tombs have circular chambers and an access passage. In addition, it should be noted that the hypothesis advanced by Blance (1971) initially served to establish the type of roofing for stone masonry tombs. This is based on the assumption that masonry passage graves with burial chambers measuring a greater than or equal to 4 m in diameter probably required a flat roof as they could not support a false dome, because they hadn't enough retaining features. According to Blance (1971), the concentric inner stone rings were too far from the funerary chamber to be able to support a false dome. In any case, as will be noted, this assessment requires additional criteria.

Otherwise rock cut tombs (*covachas*) and cists (Groups 4 and 5) in this study do not form subgroups as they are not common to the study area.

Of the total 1067 cases, 83.3% correspond to orthostatic passage graves while only 11.7% are masonry passage graves. The remaining 5% comprise, in descending order, simple orthostatic dolmens devoid of passage, cists, and rock cut tombs. These last three subgroups are also more or less homogeneously distributed throughout the territory.

The concentration of that of masonry passage graves adjacent to fortified settlements, at times in great density around particular sites such as Los Millares, together with their architectural peculiarities (especially their different types of roofings), justify delving deeper into them. They are thus the main object of this paper.

3.2. Characterising the stone masonry passage graves with circular chambers

The current study recorded a total of 15 cemeteries featuring masonry tombs preserved well enough to offer sufficient data. In fact, 21 of the 127 masonry passage graves with circular chambers had to be discarded as they do not offer sufficient information. This is the case of most or all of the tombs of certain groups such as those in the Province of Almería at El Chuche (Benahadux) in the Lower Andarax Valley and Los Milanes (Abla) in the Nacimiento River Valley which led to reducing the sample to 106 (Annexe).

Prior to the analysis, it must be taken into account that the masonry tombs characterised by passages and circular chambers, regardless of their type of roofing, share very similar features that complicate qualitative differentiation. These elements do, however, facilitate acquiring homogeneous measurements that serve to carry out statistical research. In general terms, these comprise a passage, sub-divided into sections or not, offering access to a circular chamber raised with irregular stones, often lined with a plinth of vertical slate slabs, occasionally revealing evidence of red paint decor. The passage and the chamber sometimes reveal niches, and port-hole slabs are common both at the point of the entrance to the passage, between the sections of the passage, or at the point of access to the funerary chamber or the niches. Trapezoidal vestibules preceding the passage are also recorded at times. All of these features, except for the vestibule, were covered by a mound (*tumulus*) of earth and stones. The internal structure of these *tumulus* usually featured concentric inner stone rings (depending on the roofing type), walls or upright slabs serving to retain the structure. In this way, the tombs with low chamber diameters or big tombs that exceed 4 m, did not need so many concentric retaining rings, against the slow-medium tombs that needed three to nine to support the load of the false domes (Calvín 2014). The exterior of the *tumulus* was likewise at times delimited by one or several stone rings along the outer foot of the tomb (Almagro and Arribas 1963; Molina and Cámara 2005).

These stone masonry tombs usually reveal courses of corbelling, initiated at least at a certain height, serving to form the false dome covering the chamber. In any case, evidence of corbelling does not guarantee the presence of a false dome with conical section. These constructive elements were often truncated at a certain height before ending covered by a flat slab or a wooden plank yielding a truncoconical section. In sum, it is necessary to take into account the following elements (Calvín et al. 2022) to determine whether the roof consisted of a false dome or not:

1. Chamber diameter as the load or thrust of the roof is more difficult to uphold as it increases.
2. The depth of the cutting (usually vertical) of the burial chamber into the bedrock. This can attain a third of the total height among *tholoi*, that is, tombs covered by false domes.
3. The diameter of the *tumulus*, which in southeastern Iberia is usually between two and three times the diameter of the chamber. In order to withstand the load of the false dome (depending on the height, see criterion 2), the *tumulus* must exceed the last proportion so as to also cover the false dome. Beyond these requirements, social factors may have also influenced *tumulus* dimensions.
4. The number and arrangement of concentric rings or retaining features integrated into the *tumulus*. Flat-topped tombs most often featured only one exterior ring and only rarely internal retainer rings, while false-domed burials contained between three and nine (Calvín 2019).
5. The verticality of the walls or the corbelling from points near or above from ground level, in combination in particular with criterion 1.

Taking into account these factors, and using data from complete graves according to G. and V. Leisner designs (Leisner and Leisner

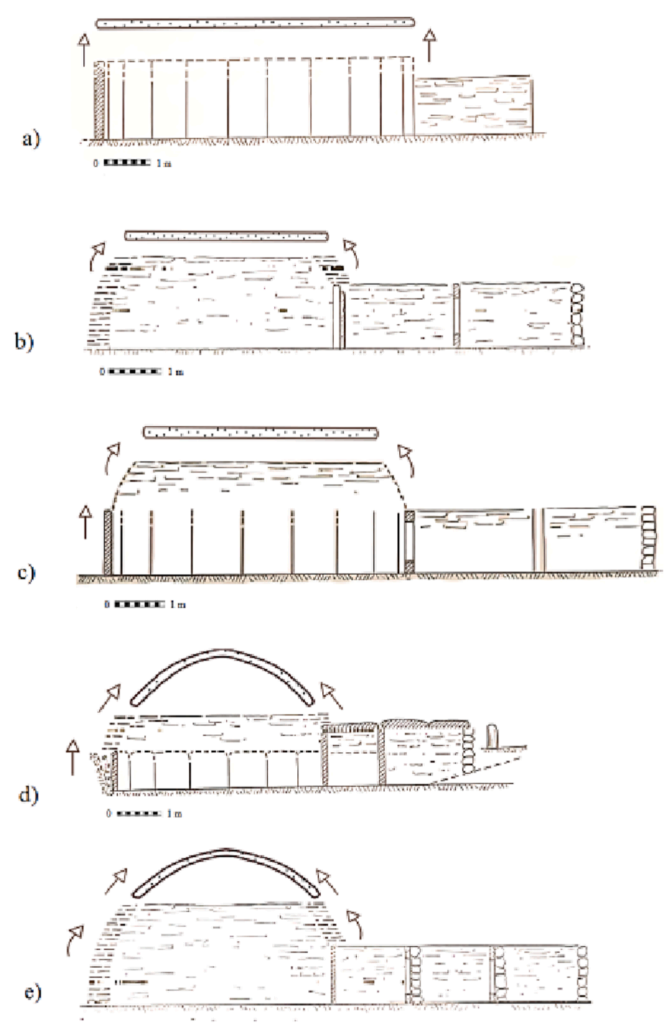

Fig. 2. Masonry tomb sections based on the drawings by the Leisners (1943): a) Las Peñicas 4, b) Los Millares 53, c) Loma de la Rambla de Huéchar 2, d) Los Millares 10, and e) Los Millares 49 (Calvín et al. 2022).

1943), the circular chambers of the masonry passage tombs may present the following types of sections (Fig. 2) (Calvín et al. 2022):

a) Cylindrical. Tombs with straight upright walls and flat roofs with chambers measuring a diameter of 5 m or more were not usually cut into the bedrock.
b) Trunco-conical. Tombs with converging walls not cut into the bedrock with corbeled courses, flat roofs and chambers measuring 4 m diameter.
c) Mixed (cylindrical base and trunco-conical at the top). These feature flat roofs, cut (or not) into the bedrock with chambers ranging between 3 and 5 m in diameter.
d) Mixed (cylindrical base and conical at the top. These tombs, not always dug into the bedrock, were covered by whole false domes over chambers less than or equal to 4 m in diameter when featuring systems of retention.
e) Conical. Tombs with true false domes initiated from the base, with lining over the surfaces cut into the bedrock, and diameters less than 4 m.

The problem related to the majority of the tombs of southeastern Iberia is the impossibility of identifying their veritable shape as they were either looted at an undetermined moment or 'excavated' toward the end of the 19th century, actions that led to the removal of their chamber roofs. Hence most of them do not offer data as to their entire structure. This is the reason behind the necessity of statistically testing the hypotheses, at least of the main groups.

3.3. Statistical analysis

The sample, as noted above, consists of 106 stone masonry passage graves. Their study, apart from compiling qualitative characteristics, begins by assessing the main constructive metric values linked to their circular chamber and passage:

- DICHA1 and DICHA2: maximum and minimum diameter of the funerary chamber
- HECHA: height of the funerary chamber
- LECOR and WICOR: passage length and width

The study first identified an issue linked to DICHA2, notably the absence of a significant amount of data (51 cases) when compared to DICHA1, values that could be obtained for all the 106 tombs. Moreover, it was possible to measure the ALCAM, LECOR and WICOR values for a great number of them (Table 2).

No construction standardisation was observed as the variables do not reveal high levels among the respective coefficients with that of WICOR at 0.22 being the lowest. When comparing the main descriptive statistics, differentiating whether or not they were covered by a false dome, it is only possible to infer chamber maximum and minimum diameter differences. It must be noted that the standardisation is significantly greater when taking into account the DICHA1 and DICHA2 variables. This suggests an association between false domes and chamber diameter, a notion highlighted in previous research (Blance 1971; Calvín 2014, 2019). In addition, the tombs characterised by flat roofs reveal chamber diameter values that are considerably larger.

When delving into the degree of correlation between constructive variables, this study only discloses a high correlation between DICHA1 and DICHA2 (Fig. 3).

To mathematically verify the hypothesis that false domes only served for tombs where chamber diameter did not exceed 4 m (except for those with features serving to reduce the load), this paper advances two options.

The first is to approach their study as a classification problem of supervised learning where the explanatory variables are the maximum and minimum diameter of the chamber and the training set is the sample of passage graves with values for each variable (45 of 106 cases). This yields a classification model that can be compared with the hypothesis initially proposed by Blance (1971) which has later served in other research (Molina and Cámara 2009; Calvín 2014, 2019). The second option is analysing the DICHA1 variable.

Obtaining the classification model required resorting to the *JRip, OneR and Part* algorithms (Holte 1993; Lantz 2019) implemented by the statistical software *Weka* with the training set as a validation set. Although the three models classify 100% of the tombs correctly, the decision rule changes. The first two associate flat roofs with tombs whose maximum chamber diameter is greater than or equal to 3.95 m (*OneR*) and 4 m (*Jrip*), suggesting both models to be similar. The model obtained with the *Part* algorithm, in turn, classifies tombs with a minimum chamber diameter greater than 3.70 m as flat-roofed.

In practice, it is convenient to work with the DICHA1 variable since this value is available for all tombs. By applying the classification algorithms to all tombs adopting DICHA1 as the only explanatory variable, yields a decision rule classifying tombs as 'flat roofed' when they have a maximum chamber diameter greater than or equal to 3.95 m (*OneR*) and

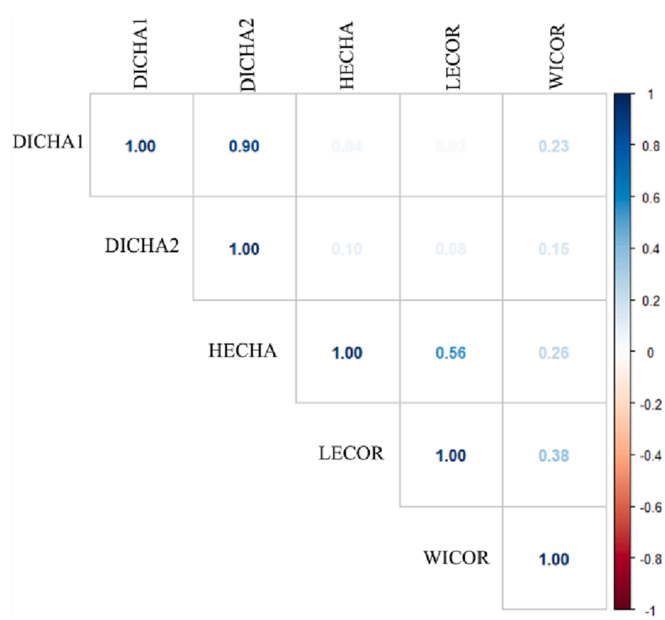

Fig. 3. Correlation of constructive variables.

Table 2
Statistics for each variable. N: sample size, $\bar{x}$: Arithmetic mean, σ: standard deviation, CV: coefficient of variation.

	Total data				MGD				MGF			
	n	$\bar{x}$	σ	CV	n	$\bar{x}$	σ	CV	n	$\bar{x}$	σ	CV
DICHA1	105	3.51	0.82	0.23	81	3.21	0.55	0.17	24	4.52	0.78	0.17
DICHA2	45	3.20	0.98	0.31	37	2.88	0.68	0.23	8	4.70	0.74	0.16
HECHA	88	1.51	0.56	0.37	73	1.53	0.58	0.38	15	1.4	0.43	0.31
LECOR	94	3.15	1.00	0.32	75	3.11	1.04	0.33	19	3.13	0.82	0.26
WICOR	94	1.05	0.23	0.22	75	1.04	0.23	0.22	19	1.11	0.25	0.22

4 m (*JRip* and *Part*). This corroborated the initial hypothesis as it yielded a correct classification rate of 99.0566% with the exception of one misclassified case (Barranquete 9, Níjar, Almería).

The false positive corresponds to a tomb with a burial chamber 4.10 m in diameter surrounded by a thick wall and four concentric rings between 1 and 1.25 m wide under a 12 m *tumulus* (Almagro 1973: 148), all features that serve to withstand the thrust of the roof. Although its chamber is not dug into the bedrock, it bears a preserved height of 4.10 m, a value that also appears to confirm a false dome as tombs with flat roofs do not usually exceed 2 m in height. The section of this tomb is thus of the mixed type, cylindrical at its base and conical at the top, as opposed to completely conical since, despite its chamber not featuring a lining of orthostats, no corbelling is observed near the base.

Finally, multivariate statistical techniques were applied to tombs featuring data on passage in order to determine the existence of burial construction patterns. This study thus attempted to classify the tombs into groups and subgroups based on five construction variables by means of a dendrogram to determine if these divisions are characterised by specific values of one or more variables (Almeida et al. 2007; Krieger et al. 2014). The dendrogram was generated by R programming language using the *SAHN* cluster analysis classification technique (sequential, agglomerative, hierarchical and non-overlapping). It resorted to the Euclidean distance as a measurement of similarity and the Ward method (minimum variance) to identify clustering. This aspect of the study was based on data from the 35 tombs benefitting from the five variables.

The dendrogram (Fig. 4) reveals three divisions and four subgroups. Each tomb bears a mark corresponding to its identification number and whether it has a flat cover, and an identifying code for each variable according to its value. The order of the variables is chamber maximum and minimum diameter and height, and passage length and width. The code is obtained by dividing the range of values of the observations of each variable into 5 modalities of equal size in meters identified as extra-small (XS), small (S), medium (M), large (L) and extra-large (XL) (Table 3).

To further facilitate the interpretation of the dendrogram's divisions, a table was created listing the coded values of each of the variables (Table 4). The order of the modality reveals which is the most frequent and, if there are two with equal modalities, they are indicated by a -.

The dendrogram reveals from the first division (A) that two tombs (in red: Los Millares 40-XXXVI and Las Peñicas 4) in the Province of Almería differ from the others according to their diameter (both maximum and minimum) and a chamber height which exceed by far that of the others.

Los Millares 40-XXXVI measuring 6.40 × 5.70 m and preserved at a height of 2 m is characterised by a circular chamber dug into the bedrock up to 2.20 m deep. The surface cut into the bedrock is lined by stone masonry courses which continues above the bedrock in the form of vertical stone courses (conserved at a height of 20 cm). Its lower face is lined by a skirt of slate orthostats constituting a decorated plinth. The chamber is beneath one of the largest burial mounds recorded to date (16 m). The dimensions of its chamber suggest it could not have withstood the thrusts of a false dome even if the mound was larger as the feature lacks of any type of retaining structure. Therefore, the roofing of this tomb, based on these dimensions, would have been raised over vertical stone masonry courses yielding a practically cylindrical section.

The only values available for the tomb of Las Peñicas 4 are the size of its funerary chamber (5.60 × 6.40 m), its height (1.40 m) and that it was not dug into bedrock. There is no information as to a *tumulus* or any other potential construction feature. This tomb therefore must have yielded a cylindrical section devoid of courses of corbelling.

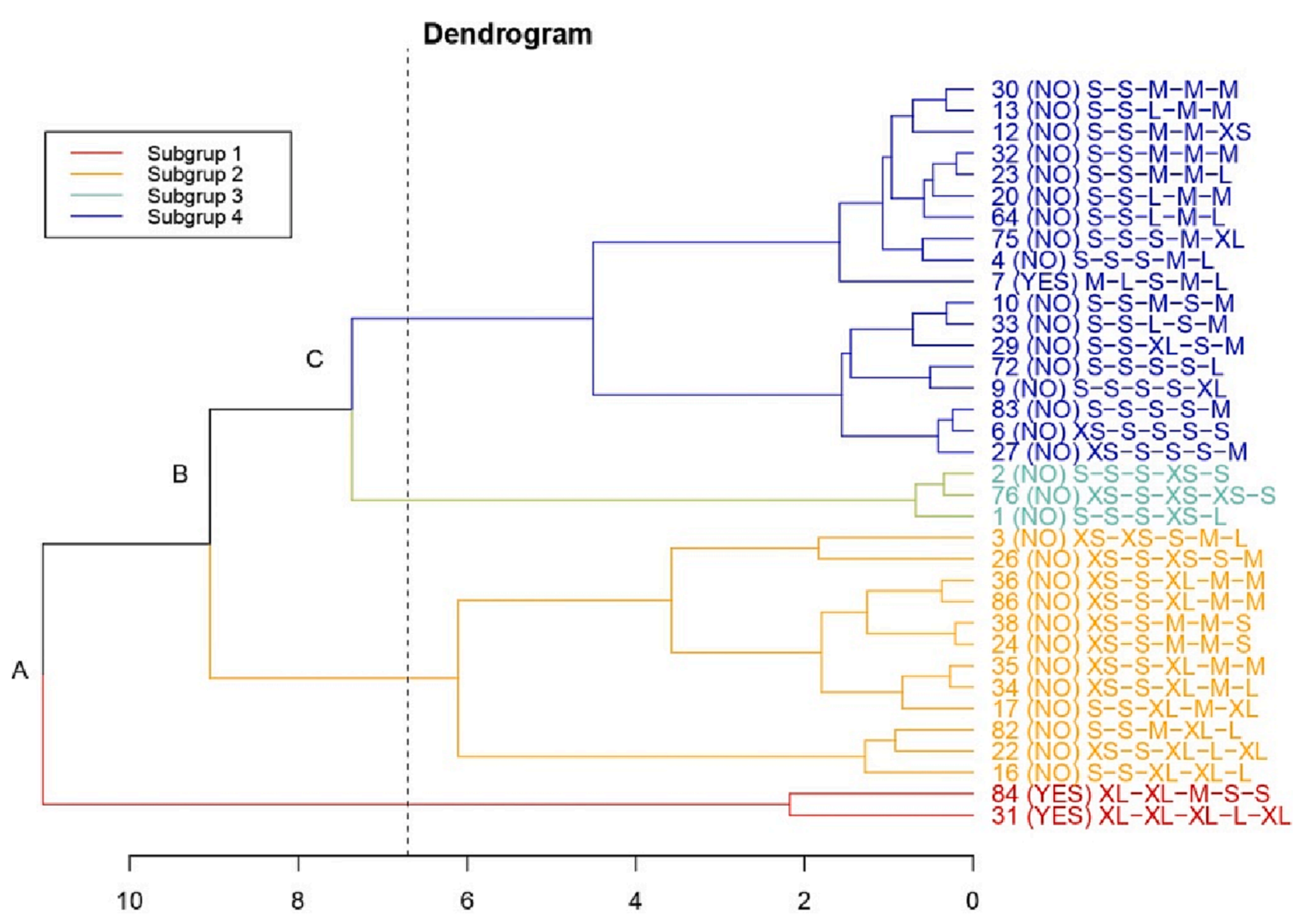

Fig. 4. Dendrogram of the results of the five variables.

Table 3
Ranges of the different modalities for each variable.

	XS	S	M	L	XL
DICHA1	[2.5–3.28)	[3.28–4.06)	[4.06–4.84)	[4.84–5.62)	[5.62–6.4]
DICHA2	[1.15–2.06)	[2.06–2.97)	[2.97–3.88)	[3.88–4.79)	[4.79–5.7]
HECHA	[0.6–0.92)	[0.92–1.24)	[1.24–1.56)	[1.56–1.88)	[1.88–2.2]
LECOR	[1–1.96)	[1.96–2.92)	[2.92–3.88)	[3.88–4.84)	[4.84–5.8]
WICOR	[0.6–0.78)	[0.78–0.96)	[0.96–1.14)	[1.14–1.32)	[1.32–1.5]

Table 4
Coded values of each variable.

DIVISION			CHAMBER		PASSAGE		
A	B	C	Max. diameter	Min. diameter	Height	Length	Width
1			XL	XL	M–XL	S-L	XL-S
2	2		XS, S	S, XS	XL, M, XS-S	M, XL, S-L	M, L, S-XL
3	3	3	S, XS	S	S, XS	XS	S,L
4	4	4	S, XS, M	S, L	S, M, L, XL	S, M, L, XL	M, L, XL, XS-S

The second division (B) separates subgroups 2 from 3 and 4. This appears to stem from the fact that subgroup 2 retains very small values and small maximum and minimum diameters compared to the greater values in subgroups 3 and 4. Finally, in division C the main difference between subgroups 3 and 4 appears to depend on the height of the chamber and the length of the passage, whereas the values of these two variables are higher among the tombs of subgroup 4. On the other hand, the WICOR variable does not affect any of the established divisions.

4. Classification of stone masonry passage graves with circular chamber based on statistical analyses

A comparison of the results of the dendrogram and the coded values (Table 3) points to divisions stemming from the 35 tombs bearing all the variables. Thus the balance of the established criteria garnered through the analysis of the five constructive variables yielded four groups of tombs to which this study has attempted to integrate the remaining 71 to reach all 106:

a) Group 1. Masonry tombs with very large chambers (5–6.50 m in diameter) of variable preserved height (1.50–2 m) with medium-sized passages (3–4 m in width) and flat roofs. The sections of their chambers are cylindrical and rarely trunco-conical.
b) Group 2. Masonry tombs with small (2.20–2.95 m in diameter) but very high (up to 2 m preserved) chambers and medium-sized passages (3–4 m in length). The roofs of the chambers are false domes of either conical or mixed section comprising a cylindrical base capped by a conical upper part.
c) Group 3. Masonry tombs with medium-sized chambers (3–3.95 m), measuring around 1 m in height with very short passages (1–2 m in length) rarely slightly exceeding these values. They are covered with false domes and normally reveal conical section.
d) Group 4. Masonry tombs with medium and large chambers (3–4.95 m in diameter) with preserved height between 1 and 2 m. The length of their passages vary from short (2.10–3 m) to medium (3–4 m) to long (5 m). They are covered either with false domes or flat roofs. Their sections are either trunco-conical or mixed with a cylindrical base under a trunco-conical or conical upper part.

It is noteworthy that the tombs of Group 1 with the largest chamber diameter differ totally from those of the other groups. This is the only stone masonry group characterised entirely by flat roofs, although it shares certain characteristics with Groups 2 and 4 in terms of chamber height (up to 2 m) and passage length (3–4 m).

Group 2, for its part, despite bearing the smallest burial chambers of the lot, differs from Group 3, the next smallest, in chamber height and passage size (twice as long).

Group 3 comprises medium-sized tombs that are remarkable in terms of the chamber height (barely 1 m) and passage length (rarely attaining 1.7 m). This is an exclusive feature for this group as the medium-sized chambers of the tombs of Group 4 may have greater preserved heights and passages ranging from 2.50 to 5 m in length. As noted, the length of the passages is a key classification criterion, an aspect highlighted for the assemblage studied by G. and V. Leisner (1943: 260), especially with tombs that exceed 4 m, which had proportional size between chamber diameter and passage length but mounds did not increase in the same way.

Regarding to the entire sample and not only the well measured graves, Group 4, like Group 1, includes tombs with flat roofs albeit with somewhat smaller chambers (between 3 and 4.95 m in diameter). It is at this point that the current study places special emphasis on the necessity in certain cases of taking into account more constructive criteria such as architectural reinforcements (1 – 5) as certain tombs of Group 4 measuring 4 m or more in diameter, as noted previously were capped with false domes.

The general classification (Table 5) reveals Group 4 to also be the

Table 5
Classification by groups of the sample of 106 tombs. The tombs featuring all five variables are indicated in the first row and those with four variables or less in the second row. Bold italic: graves with flat roofs; underlined: tombs with false domes measuring 4 m in diameters.

Group 1	Group 2	Group 3	Group 4
LM 40-XXXVI, PEÑ4, LRH 2	LM 17-I, LM 3-XXXVIII, LM 47-II, LM 23-LI, LM 25-XLVIII, LM 45-XXXI, LM 18-XXVI, LM 44-XLVI, RT3	LM 1, LM 2, BARR5	***LM 7-VII,*** LM 37-V, LM 10-XV LM 32-XXXII, LM 6-VI, LM 21-XVI, LM 24-XLIX, LM 42-XLII, LM 41-XL, BARR1, LM 4-XXXIX, LM 11, LM 31 LM 38-XLI, LM X, BARR4, LM 13-XLIII, LM 14-XXIII, PEÑ2, LM 43-XLVII, PEÑ1
AL-TA-98, AL-TA-95, CANO1	LM 52, LM 56, LM XI, AL-TA-63, AL-TA-65, ALAM, PZM, ESPA22, ESPA17	BARR6, BARR11, RUBI2	***LM 5-IX, LM 9, LM 12-XXXVII***, LM 19, LM 20, LM 16-VIII, LM 15-XXX, LM 22-L, LM 30, LM 34-XXXIV, LM 46-XXVII, LM 48, LM 49, LM 50, ***LM 53, LM 54,*** LM 55-XXXI, ***LM 57***, LM 58, LM 59, LM 60, LM 61, LM 62, LM 64, ***LM 65,*** LM 67, LM 68-XXX, LM 69-XIV, ***LM 70,*** LM 71-XIV, LM 72-XVII, ***LM 73, LM 74,*** LM 75, LM XII, LM XIII, LM XVIII, LM XIX, ***LM XX,*** LM XXI, BARR2, BARR3, BARR7, BARR8, BARR9, RT2, RT4, ***LLE2,*** LL9, ***RP8, RUBI1, RUBI3, CÑM1***, ***AL-TA-90, AL-TA-205***

most common of the lot. Although most of this group's tombs (75) were potentially covered with flat roofs, the false positive cited in the previous analysis, and certain other cases forming part of the group, once again demonstrate the necessity of considering other variables. This specifically pertains to the retaining rings associated with the *tumuli*, a type of feature rarely recorded in the archaeological record. Although this issue in certain cases, such the tombs adjacent to Los Millares, could be settled by new excavations, there is little hope to resolve this problem in other necropolises given their deterioration and/or total destruction. In any case, the data currently available suggest that since the *tumuli* reveal no evidence of these features, the tombs of this group with chamber diameters greater than 3.95 m were presumably covered by flat roofs.

5. Discussion

The main result of the current study is the classification of these masonry passage graves into four groups by means of a total set of variables based on the instances presenting complete data. This bolsters the key role of chamber size and passage length when attempting to assess the differences between Chalcolithic stone masonry tombs in the Southeast of Iberia (Leisner and Leisner 1943; Blance 1971; Calvín 2014, 2019).

Of the 106 tombs of the sample, a first analysis yielded a classification according to the roof type of 44 and one 'false positive'. This was confirmed for the entire set by resorting to DICHA1, the only variable available for all tombs.

Finally, the third analysis, incorporating all the variables, garnered the most complete data classification for 35 of the 106 initial samples. From this statistical classification, through a hierarchical cluster analysis of 34% of the cases, it was possible, in any case, to assign the remaining tombs bearing insufficient measurements to the different groups.

As noted, the classification is mainly based on burial chamber diameter, a factor that also generally determines the type of roof but that is qualified by the preserved dimensions of chamber height and passage length. Hence, this study has yielded a classification resorting to a series of well-defined characteristics while also incorporating the form of the sections of the chambers based on the existence or not of corbelling, course angles, as well as whether the chambers were cut into the bedrock or not (Table 6).

In general terms, despite the fact that this study advances that flat roofs are characteristic of most of the larger tombs with chambers surpassing 3.95 m in diameter, it has not been possible to identify any constructive standardisation on the part of the 'builders'. Nor has any standardisation been observed along the lines of the retention systems (especially those inside the *tumuli*), possibly as a consequence of the widespread lack of architectural data as to their earth and stone *tumuli*. The tombs in these cases with chamber diameters ranging from 2.80 m to 3.80 m are predominantly associated with three to nine concentric masonry retaining rings, whereas those that do not attain 2.50 m or exceed 4 m only reveal one or two. This supports the notion that the larger burial chambers were not capped with false domes. Moreover, medium-sized chambers potentially required stone retainer rings inside the mounds to support the load of the false domes whereas the smallest chambers did not.

Furthermore, there does not appear to always be a relationship between the dimensions of the *tumuli* and that of the chamber or the number of retaining stone rings. Therefore, the size of the mounds could have been influenced by social patterns. Despite this, and unlike other areas of southern Iberia such as the Depression of Antequera (Málaga) or the region of Aljarafe (Seville) (Márquez and Fernández 2009; Baceiredo et al. 2014; Fernández et al. 2016), there is no evidence that huge burial mounds were raised over tombs covered by false domes. In fact, the *tumuli* of Montelirio Tholos (75 m) helped to support the load of an earthen false dome with no others construction features like inner concentric rings, except eleven wooden posts (Fernández and García 2016), whilst in Los Millares Archaeological Group the stone masonry graves have a clearly evidence of collapses stones from the roof, such us El Barranquete tombs, and they needed retaining features to support the load of a stones roof.

To conclude the discussion, we must point out that a possible relationship can be suggested between the size of the tombs, conditioning their roofing, usually flat in the greater ones, and social differences, measured by preserving grave goods. Problems have been referred, regarding to scarcity of data (depending on ancient excavations) and the relationship of rich grave goods to a high number of corpses (f. e. Micó 1991), but, in any case, the hypothesis that there are differences in labour force mobilization by the different lineages or families can be maintained (Cámara et al. 2018). Even taking into account problems of recovery and preservation of grave goods, the comparison of the data obtained with the grave goods of the stone masonry passage graves suggest that the larger the grave, the greater the social status it possessed. In fact, all these graves present materials such as copper tools, ivory, bone idols and symbolic or bell-beaker pottery, among others. Such is the case of LM 40-XXXVI, the biggest grave with one of the largest tumulus (16 m) in Los Millares and a greatest social status (Molina and Cámara 2005, Calvín 2014). However, some small tombs with false dome present grave goods with these singular objects, so we must take into account that the size of the chamber (including its roof) was not the only factor to be considered, but rather aspects such as the location and constructive perfection might have been also important.

Table 6
Proposal of classification of the stone masonry passage graves of the Los Millares archaeological complex.

Typological group	Type	Subtype	Variant	Section	Subvariant
Stone masonry tombs with passage and circular chamber	Stone masonry tombs with passage and circular chamber and false dome	Small chambers (2.20–2.95 m)	High roofs (1–2 m)	Conical section Cylindrical-conical section	Medium passage (3–4 m)
			Low roofs (0.95 m)		Very small passage (1 m)
		Medium chambers 3–3.95 m)	High roofs (1–2 m)	Conical section Cylindrical-conical section Trunco-conical section Cylindrical-trunco-conical section	Small passage (1–2.50 m) Medium passage (2.50–4 m)Large passage (4–5 m)
	Stone masonry tombs with passage and circular chamber and flat roof	Large chambers (4–4.95 m)		Trunco-conical section Cylindrical-trunco-conical section Cylindrical section	Small passage (1–2.50 m) Medium passage (2.50–4 m)Large passage (4–5 m)
		Very large chambers (5–6.50 m)	High roofs (1.50–2 m)	Cylindrical-trunco-conical section Cylindrical section	Medium passage (2.50–4 m)

This is particularly the case for LM 17-I, with a smaller chamber than LM 40-XXXVI, but the tumulus also big (16 m) and a greatest social status too.

In addition, we could suggest some chronological differences in the relative interval of the first construction of every main type can be suggested, although more data are necessary prior to prove this proposal statistically. The available dates suggest a range of use for graves with flat roofs from Early Copper Age until Recent Cooper Age (3300——2500 cal B.C.), while the false-domed tombs continued to be used throughout all the Chalcolithc, possibly beginning at a later date (Aranda et al. 2021, Calvín et al. 2022).

6. Conclusions

The current study offers a specific means of classification of the stone masonry passage graves with circular chambers of the Los Millares archaeological complex. The proposal stands even in spite of the problems posed by the absence (total or partial) of data for certain tombs of the sample. This led to applying different treatments to more or less extensive tomb assemblages resorting to one, two or five variables. The problems of such an approach can lead to the dilution of the very significance of one of the variables, notably maximum diameter, as indicated in the analyses section. In fact, among the 106 tombs where this variable (DICHA1) could be measured, it was possible to confirm the hypothesis of a link to the flat roof type that must have served (with one exception) for the larger tombs (Blance 1971; Calvín 2014, 2019). Moreover, the statistical findings suggest no constructive standardisation in spite of a certain relationship between the possibility of covering the largest chambers with a false dome and the presence of stone ring retainers under the *tumuli*.

The classification into four groups of these masonry tombs advanced by this study requires a certain caution as the five variables (chamber maximum and minimum diameter, chamber height, passage length and width) could only be determined for 34% of the initial sample. However, it is evident that there are differences between the large tombs characterised by few retaining features, relatively short passages, flat slab covers and practically vertical walls, and the smaller tombs with corbelled walls presumably covered with false domes. Moreover, intermediate varieties among the sample are not easily distinguishable. Their statistical analysis places them into two other groups based on the lengths of their passages, a notion already proposed by the Leisners (1943), and on the mixed sections of their chambers, and at times on the fact that part of their chamber was cut directly into the bedrock.

As previously proposed, even from Leisners' work, differences in shape and size can be related to chronology and/or social status, although data about grave goods are problematic and radiocarbon dates are scarce. However, as we can see, even with the problems of quality of data referred to grave goods and scarcity of dates, our classification can help to understand social and chronological differences between the megalithic graves of Iberian Southeast.

Such is the case of Los Millares, where the previous research (Molina and Cámara 2005, Calvín 2014, 2019) showed that the bigger graves with flat roof had a greatest social status and were located in a central area of the necropolis, closely to the settlement, to the rest of smaller tombs that were located outer edge of this area. In fact, this spatial organization seems to be related to four different levels of wealth (Chapman 1991, Afonso et al, 2011). In any case, as referred before, some of the corbelled tombs also belong to the first levels of this classification.

On the other way, reasons for these differences in grave goods can be found not only in wealth differences between lineages or families (Chapman 1991; Molina and Cámara 2005; Afonso et al. 2011) but also in the number of corpses included in every tomb depending on factors as ability of lineages to mobilize labor force (Micó 1991). However, this possibility also shows social differences among social groups as suggested by the size, situation and type of graves. This last aspect have been analyzed here in relation to stone masonry tombs and the present study could help to find out if this social model was exported through the funerary architecture to other areas like El Barranquete (Níjar) or Los Rubialillos (Tabernas). In fact, especially in the first of these examples, not only differences among the stone masonry tombs can be traced but also the presence of orthostatic graves can be located in the same necropolis and other orthostatic passage graves can be found near the main necropolises, as can be also seen at Los Millares (Cámara et al. 2014).

While sparse orthostatic dolmens were mainly used to mark routes and land property, orthostatic graves in necropolis consisting mainly of stone masonry graves could be older but also could be related to integration processes affecting new populations and identity mechanisms to perpetuate differences (Cámara et al. 2021) even inside the elite (Afonso et al. 2011). In this sense, it's not strange that flat roof stone masonry graves but also fully corbelled ones and orthostatic passage graves were used as burial places of privileged social groups, while intermediate types of stone masonry tombs situated in lower and peripheral places (Cámara et al. 2014) were aimed to other social groups.

Another question is the entity of that social differences. Regarding Iberian Southeast, some authors suggest low and non-hereditary differences (Chapman 2008; Gilman 2013; Risch 2018) but other ones consider a long process of increasing hierarchy concealed by ideological structure materialized in several rituals, including collective burial (Molina et al. 2016; Cámara et al. 2018). These differences can be also found between researches that study Southwestern Iberia Chalcolithic (Nocete 2006; García and Murillo 2013, respectively), although new data, especially from Montelirio (Fernández et al. 2016) and isotopic data are showing a more hierarchical society that previously supposed (Cintas-Peña and García 2022).

Finally, we think our results can be useful for studying the megalithic graves that in other areas of Iberia have been proposed to be covered by a false dome and which are being considered later than Southeastern ones (Aranda et al. 2022), especially taking into account that they are very different in terms of their size and depth of the foundations excavated into bed-rock, with rare cases covered with a true "false dome".

Funding

This study forms part of the research project '*Producción artesanal y división del trabajo en el Calcolítico del Sudeste de la Península Ibérica: un análisis a partir del registro arqueológico de Los Millares (PARTESI)*' financed by the Agencia Estatal de Investigación del Ministerio de Ciencia e Innovación (PID2020-117437 GB-I00/ AEI/ https://doi.org/10.13039/501100011033).

Author declaration

All authors contributed to writing the original draft, to reviewing and to editing. MECV conceptualized the idea, the data curation and the formal analysis. She drafted most of the text and its visualization. JACS collaborated with this investigation and the methodology, and supervised the writing and the text which led to its improvement. He is the responsible of the project administration, the funding acquisition and the resources. FJES developed the software and carried out the analyses, drafted the statistical report, and prepared the tables and graphs. Both researchers have being the responsible to the final validation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Annexe 1

Site			Constructive variables					Architectural reinforcements			
Necropolis	Tomb	Code	DICHA1	DICHA2	HECHA	LECOR	WICOR	Tumulus	Exc. into bedrock	Int. ring	Ext. ring
Los Millares	LM 1	1	3.65	2.95	1.2	1	1.15	0	–	–	–
	LM 2	2	3.3	3.15	1	1	0.9	6	–	2	–
	LM 3-XXXVIII	3	3.2	1.15	1.2	3.25	1.2	10	0.3	–	–
	LM 4-XXXIX	4	3.55	3.5	1	3.5	1.2	0	–	–	–
	LM 5-IX	5	4.15	0	1.6	3.5	1.2	15	–	2	1
	LM 6-VI	6	3.2	3	1.2	2.5	0.9	10	–	4	–
	LM 7-VII	7	4.3	4.2	1	3.65	1.15	15 × 14	–	2	–
	LM 9	8	4	0	1.1	4.2	1.13	13	–	2	1
	LM 10-XV	9	3.8	3.1	1	2.4	1.5	13	0.7	2	–
	LM 11	10	3.5	3.2	1.4	2.5	1.1	10	–	1	–
	LM 12-XXXVII	11	4	3.8	0	2.4	1	0	–	–	–
	LM 13-XLIII	12	3.5	3.4	1.3	3	0.6	10	–	1	–
	LM 14-XXIII	13	3.8	3.7	1.6	3	1	12	–	1	–
	LM 15-XXX	14	3.3	0	1.1	3	1	12.7	0.5	1	–
	LM 16-VIII	15	3.75	0	1.5	2.5	1.25	11	–	3	1
	LM 17-I	16	3.43	3.3	2	5.8	1.2	16	1.8	2	1
	LM 18-XXVI	17	3.48	3.3	2.2	3.4	1.05	12	0.6	–	–
	LM 19	18	3.6	0	1.5	3.3	1.1	10	0.6	–	–
	LM 20	19	3.15	0	1.3	3	1	10	–	–	–
	LM 21-XVI	20	3.7	3.6	1.8	3.5	1.1	15	–	3	1
	LM 22-L	21	3.3	0	1.7	3.5	1.5	12	–	1	–
	LM 23-LI	22	3	2.8	2.15	4.6	1.5	13.5	–	–	–
	LM 24-XLIX	23	3.65	3.5	1.4	3.4	1.2	11.5	–	1	–
	LM 25-XLVIII	24	3	2.6	1.5	3.3	0.8	8	–	–	–
	LM 30	25	3.15	3.1	1.25	0	0	10	–	–	–
	LM 31	26	2.5	2.1	0.6	2	1	0	–	–	–
	LM 32-XXXII	27	3	2.8	1	2.4	1	8	–	1	–
	LM 34-XXXIV	28	3.4	0	1.7	4	1.2	8	1.1	–	–
	LM 37-V	29	3.5	3.1	2	2.85	1	25.75	2.5	4	–
	LM 38-XLI	30	3.8	3.6	1.3	3	1.05	8	0.8	–	–
	LM 40-XXXVI	31	6.4	5.7	2	4	1.5	16	2.2	–	–
	LM 41-XL	32	3.75	3.5	1.5	3.3	1.1	12 × 11	0.9	–	–
	LM 42-XLII	33	3.3	3.2	1.6	2.6	1	10	0.9	–	–
	LM 43-XLVII	34	3.1	2.75	2	3.5	1.25	11	0.7	–	–
	LM 44-XLVI	35	3.1	3	2	3.5	1.13	0	0.9	–	–
	LM 45-XXXI	36	2.7	2.6	2.2	3	1	11	1	–	–
	LM 46-XXVII	37	3.2	0	1.3	2.3	1	8	–	–	–
	LM 47-II	38	3.05	2.75	1.5	3.2	0.9	12 × 11	–	4	–
	LM 48	39	3.5	0	1.6	4	1	0	–	–	–
	LM 49	40	3.8	0	1.8	4.6	0.9	0	–	–	–
	LM 50	41	3.3	0	2	4.5	1	0	–	–	–
	LM 52	42	2.9	0	1.8	4	0.9	0	–	–	–
	LM 53	43	4	0	1.6	4	1	0	–	–	–
	LM 54	44	4	0	1.5	4	1	16	–	–	–
	LM 55-XXXI	45	3	0	1.8	2.5	1.2	10	–	–	–
	LM 56	46	2.2	0	2	4	1	13	–	–	–
	LM 57	47	4	0	1.8	4	0.8	13	–	–	–
	LM 58	48	3	0	1.15	4	0.7	11	–	–	–
	LM 59	49	3	0	2.2	4	0.7	14.5	–	–	–
	LM 60	50	3.5	0	1.5	4	0.7	12.5	–	–	–
	LM 61	51	3.2	0	1.5	4	0.7	13	–	–	–
	LM 62	52	3	0	2.15	4	1	0	1	–	–
	LM 64	53	3	0	1.5	3	1	0	–	–	–
	LM 65	54	4	0	1.5	3.5	1	12	–	–	–
	LM 67	55	3.8	0	1.7	4	1	0	0.8	–	–
	LM 68-XXX	56	3.3	0	1.5	4	1.25	12	–	–	–
	LM 69-XIV	57	3	0	1.6	4	1	12	–	–	–
	LM 70	58	4	0	1.5	3	0.8	12	–	–	–
	LM 71-XIV	59	3.55	0	0.75	3	1.5	13	0.45	1	–
	LM 72-XVII	60	3.25	0	1.5	4	1	14	–	4	1
	LM 73	61	4	0	1	4	0.9	0	–	–	–
	LM 74	62	4	0	1.6	0	0	0	–	–	–
	LM 75	63	3	0	2	4	0.8	12.5	–	–	–
	LM X	64	3.9	3.2	1.6	3.15	1.2	20 × 15	0.4	2	–
	LM XI	65	2.5	0	1.25	2.8	0.9	20 × 15	0.4 – 0.6	3	–

Site			Constructive variables					Architectural reinforcements			
Necropolis	Tomb	Code	DICHA1	DICHA2	HECHA	LECOR	WICOR	Tumulus	Exc. into bedrock	Int. ring	Ext. ring
Los Millares	LM XII	66	3	0	1.15	3.5	1.25	13	–	3	–
	LM XIII	67	3.5	0	2.25	2	1	11.5	1	2	–

(continued on next page)

(*continued*)

Site			Constructive variables					Architectural reinforcements			
Necropolis	Tomb	Code	DICHA1	DICHA2	HECHA	LECOR	WICOR	Tumulus	Exc. into bedrock	Int. ring	Ext. ring
	LM XVIII	68	3.85	0	0.35	3	0.95	14	–	5	–
	LM XIX	69	3.5	0	1.1	3.25	1.1	10 × 9.5	–	1	–
	LM XX	70	4.3	0	0.4	4	1.2	10.5	0.3	2	–
	LM XXI	71	3.5	0	0	2.6	1	9.5	1.25	3	1
	LRH 2	72	5	0	2	4	1.1	0	–	–	–
El Barranquete	BARR1	73	3.8	3.5	1.2	2.25	1.3	13.3 × 10	–	5	–
	BARR2	74	3.3	0	1.1	3.3	0.9	12	–	6	–
	BARR3	75	2.8	0	0.9	2.63	0.9	13.7	–	9	–
	BARR4	76	3.8	3.6	1	3	1.4	16 × 15	–	7	–
	BARR5	77	3.1	2.9	0.9	1.1	0.9	14.1	–	5	–
	BARR6	78	3.2	0	0.5	0	0	11 × 10	–	–	–
	BARR7	79	3.2	0	3.5	2.9	1.3	12 × 11	–	7	–
	BARR8	80	3.5	0	1.7	3.5	1.2	11	–	4	–
	BARR9	81	4.1	0	4.1	2.3	1.2	12	–	4	–
	BARR11	82	3.7	0	1	1.3	1	11	–	5	–
Las Peñicas y El Tejar	PEÑ1	83	3.3	3.1	1.5	5	1.2	0	–	–	–
	PEÑ2	84	3.3	3	1	2.5	1	0	–	–	–
	PEÑ4	85	6.4	5.6	1.4	2	0.9	0	–	–	–
	RT2	86	3.3	0	1.6	6	1.2	0	–	–	–
	RT3	87	2.6	2.4	1.9	3	1	0	–	–	–
	RT4	88	3.4	0	0	3.5	0.9	0	–	–	–
Loma del Llano de las Eras	LLE2	89	4	0	1.6	3.2	1	0	–	–	–
Loma de los Liniales	LL9	90	3.2	0	2	0	0	0	–	–	–
Rambla de los Pocicos	RP8	91	4	0	1	3	1	0	–	–	–
Los Rubialillos	RUBI1	92	4.7	4.2	0	2	1.8	0	–	–	–
	RUBI2	93	3.6	0	1	0	0	0	–	–	–
	RUBI3	94	4	0	0	1.5	1.2	0	–	–	–
Cañada de los Meones	CÑM1	95	4.9	0	0	3	1.5	0	–	–	–
Pozo de los Marchantillos	PZM	96	1.5	1.4	0	0.9	0.6	0	–	–	–
Los Peñones	AL-TA-90	97	4.2	0	0	0	0	0	–	–	–
	AL-TA-98	98	5.2	5.1	0	0	0	10.2 × 8.8	–	–	–
	AL-TA-205	99	4	4	0	0	0	6.2 × 4.5	–	–	–
Cerro de las Yeguas	AL-TA-95	100	5	5	0	0	0	8.5 × 7.6	–	1	–
Rambla del Búho	AL-TA-63	101	2.6	2	0	0	0	10.6 × 9.7	–	1	–
	AL-TA-65	102	2.1	1.4	0	0	0	7.8 × 7.1	–	–	–
El Alhamillo	ALAM	103	1.3	0	0	0.7	0.6	0	–	–	–
Cerro Cánovas	CANO1	104	6	0	0	0	0	0	–	–	–
El Espartal	ESPA22	105	1.6	0	0	1.5	0.5	0	–	–	–
	ESPA17	106	1.6	1.25	0	1	0.5	0	–	–	–

References

Acosta, P., Cruz-Auñón, R., 1981. Los enterramientos de las fases iniciales en la Cultura de Almería. Habis 12, 273–360.

Afonso, J. A.; Cámara, J. A.; Haro, M.; Molina, F.; Montufo, A. M.; Salas, F.E.; Sánchez, I., Spanedda, L., 2008. Tipología y seriación en el Megalitismo granadino. El caso de Gorafe. En M. S. Hernández, J. A. Soler y J. A. López (coord.), *IV Congreso del Neolítico Peninsular*. Vol. 2. Alicante, 64-76. http://hdl.handle.net/10481/67661.

Almagro, M., Arribas, A., 1963. *El poblado y la necrópolis megalítica de Los Millares (Santa Fe de Mondújar, Almería)*. Biblioteca Praehistorica Hispanica III. CSIC, Madrid.

Almagro, Mª. J., 1973. *Excavaciones arqueológicas: El Barranquete*. Acta Arqueológica Hispánica VI, Madrid.

Almeida, J.A.S., Barbosa, L.M.S., Pais, A.A.C.C., Formosinho, S.J., 2007. Improving hierarchical cluster analysis: a new method with outlier detection and automatic clustering. Chemom. Intel. Lab. Syst. 87 (2), 208–217.

Aranda, G., Lozano, Á., Cámalich, D., Martín, D., Rodríguez, F.J., Trujillo, A., Samtana, J., Nonza-Micaelli, A., Clop, X., 2017. La cronología radiocarbónica de las primeras manifestaciones megalíticas en el sureste de la Península Ibérica: las necrópolis de Las Churuletas, La Atalaya y Llano del Jautón (Purchena, Almería). Trab. Prehist. 74 (2), 257–277. https://doi.org/10.3989/tp.2017.12194.

Aranda, G., Milesi, L., Díaz-Zorita, M., Sánchez, M., 2021. The radiocarbon chronology of tholos-type megalithic tombs in Iberia: exploring diverse social trajectories. Trab. Prehist. 78 (2), 277–291. https://doi.org/10.3989/tp.2021.12276.

Baceiredo, V., Baceiredo, D., García, L., Odriozola, P., 2014. Planimetría de alta resolución del dolmen de Menga (Antequera, Málaga) mediante escaneado láser terrestre, levantamiento 3D y fotogrametría. Menga: Revista de prehistoria de Andalucía 5, 259–269.

Barratt, R.P., 2022. Simulating a stone roof for the Maltese Neolithic temples: Analysing stress to understand specialisation. Digital Applications in Archaeology and Cultural Heritage 27, e00236.

Blance, B., 1971. *Die Anfänge der Metallurgie auf der Iberischen Halbinsel*. S.A.M. 4, Berlín.

Buck, C.E., Litton, C.D., Stephens, D.A., 1993. Detecting a change in the shape of a prehistoric corbelled tomb. J. Royal Stat. Soc. Ser. D (The Statistician) 42 (4), 483–490. https://doi.org/10.2307/2348480.

Calvín, M.E., Cámara, J.A., Molina, F., 2022. Revisión tipológica de los sepulcros calcolíticos del cuadrante Sureste de la Península Ibérica. Las sepulturas construidas en mampostería con corredor, cámara circular y cubierta plana del Grupo Arqueológico de Los Millares. Archivo de Prehistoria Levantina 34, 83–108. http://mupreva.org/pub/1588/es.

Calvín, Mª. E., 2014. Estudio, análisis y valoración social de la necrópolis calcolítica de Los Millares (Santa Fe de Mondújar, Almería). *@rqueología y Territorio* 11, 1-13.

Calvín, Mª. E., 2019. Arquitectura megalítica en el Sureste de la Península Ibérica. Análisis inicial de las sepulturas de corredor, cámara circular y cubierta plana de las necrópolis de Los Millares, Los Rubialillos Y Las Peñicas-El Tejar (Almería). *MARQ, Arqueología y Museos* 10, 25-46.

Cámara, J.A., Alcaraz, F.M., Molina, F., Montufo, A.M., Spanedda, L., 2014. Monumentality, Visibility and Routes Control in Southeastern Iberian Megalithic Sites. *Neolithic and Copper Age Monuments: Emergence, function and the social construction of the landscape*. In: Schulz Paulsson, B., Gaydarska, B. (Eds.), British Archaeological Reports. International Series 2625. Archaeopress. Oxford, pp. 89–106.

Cámara, J.A., Dorado, A., Spanedda, L., Fernández, M., Martínez, J., Haro, M., Martínez, G., Carrión, F., Molina, F., 2021. La demarcación de los espacios de tránsito en Los Millares (Santa Fe de Mondujar, Almería) y su relación con el simbolismo megalítico. Zephyrus 88, 65–86. https://doi.org/10.14201/zephyrus2021886586.

Cámara, J. A., Spanedda, L., Molina, F., 2018. Exhibición y ocultación de las diferencias sociales en el ritual funerario calcolítico. In M. Espinar (coord.): La muerte desde la Prehistoria a la Edad Moderna. Libros EPCCM Estudios 23. Universidad de Granada. Granada, 37-92.

Cavanagh, W., Laxton, R., 1981. The Structural Mechanics of the Mycenaean Tholos Tomb. The Annual of the British School at Athens 76, 109–140. https://doi.org/10.1017/S0068245400019493.

Chapman, R.W., 2008. Producing Inequalities: Regional Sequences in Later Prehistoric Southern Spain. J. World Prehist. 21, 195–260. https://doi.org/10.1007/s10963-008-9014-y.

Chapman, R.W., 1991. La formación de las sociedades complejas. La Península Ibérica en el marco del Mediterráneo Occidental, Crítica, Barcelona.

Cintas-Peña, M., García, L., 2022. Women, residential patterns and early social complexity. From theory to practice in Copper Age Iberia. J. Anthropol. Archaeol. 67, 101422 https://doi.org/10.1016/j.jaa.2022.101422.

Como, M. T., 2006. Analysis of the statics of the Mycenaean Tholoi. In *Proceedings of the second international congress on construction history* 1, 89-107.

Cruz-Auñon, R., 1983–84.. Ensayo tipológico para los sepulcros eneolíticos andaluces. Pyrenae 19–20, 47–76.

Esquivel, F.J., Cabrero, C., Cámara, J.A., Esquivel, J.A., 2022. Statistical analysis on metric and geometric features of dolmens in the Gor river megalithic landscape (Granada, Andalusia, Spain). Archaeometry 64, 815–832. https://doi.org/10.1111/arcm.12750.

Fernández, A., García, L., 2016. Arquitectura, estratigrafía y depósitos del tholos de Montelirio. In A. Fernández, L. García, M. Díaz-Zorita (coord.): *Montelirio: un gran monumento megalítico de la Edad del Cobre* 79-141.

Fernández, A., García, L., Díaz-Zorita, M., 2016. *Montelirio. Un gran monumento megalítico de la Edad del Cobre*. Arqueología Monografías, Consejería de Cultura de la Junta de Andalucía, Sevilla. https://doi.org/10.12795/spal.2018i27.12.

García, L., Murillo, M. (2013). Social Cmplexity in Copper Age Southern Iberia (ca. 3200-2200 cal B.C.). Reviewing the "State" Hypothesis at Valencina de la Concepción (Seville, Spain). *The Prehistory of Iberia. Debating Early Social Stratification and the State* (M. Cruz, L. García, A. Gilman, Eds.), Routledge, New York and London, 119-140.

García, M., Spanhi, J.C., 1959. Sepulcros megalíticos de la región de Gorafe (Granada). *Archivo de Prehistoria Levantina* VIII 43–113.

Gilman, A. (2013). Were there States during the Later Prehistory of Southern Iberia? *The Prehistory of Iberia. Debating Early Social Stratification and the State* (M. Cruz, l. García, A. Gilman, Eds.). Routledge, New York and London, 26-44.

Holte, R.C., 1993. Very Simple Classification Rules Perform Well on Most Commonly Used Datasets. Mach. Learn. 11, 63–90.

Krieger, N., Mutzel, P., Schäfer, T., 2014. SAHN clustering in arbitrary metric spaces using heuristic nearest neighbor search. In: Dortmund, T.U. (Ed.), Algorithms and Computation. Springer, Switzerland, pp. 90–101. https://doi.org/10.1007/978-3-319-04657-0_11.

Lantz, B., 2019. Machine learning with R: expert techniques for predictive modeling. Packt publishing ltd.

Leisner, G., Leisner, V., 1943. *Die Megalithgräber der Iberischen Halbinsel. Der Süden*. Römisch-Germanische Forschungen 17, Berlin.

Márquez, J. E., Fernández, J., 2009. *Dólmenes de Antequera. Guía oficial del Conjunto Arqueológico.* Consejería de Cultura de la Junta de Andalucía, Sevilla.

Micó, R., 1991. Objeto y discurso arqueológico. El Calcolítico del Sudeste Peninsular. *Revista de Arqueologia de Pone*nt 1, 51–70.

Molina, F., Cámara, J.A., 2005. Guía del yacimiento arqueológico Los Millares. Junta de Andalucía, Sevilla.

Molina, F., Cámara, J.A., Afonso, J.A., Spanedda, L. (2016). Innovación y tradición en la Prehistoria Reciente del Sudeste de la Península Ibérica y la Alta Andalucía (c. 5500-2000 cal A.C.). *Terra e água. Escolher sementes, invocar a deusa. Estudos em Homenagem a Victor A. Gonçalves* (A.C. Sousa, A. Carvalho, C. Veigas, eds.). Uniarq. Estudos & Memórias 9. Universidade do Lisboa, Lisboa, 317-339,.

Nocete, F., 2006. The first specialized copper industry in the Iberian peninsula: Cabezo Juré (2900–2200 BC). Antiquity 80, 646–657. https://doi.org/10.1017/S0003598X00094102.

Risch, R. (2018): Affluent Societies of Late Prehistory. *Surplus without the State. Political Forms in Prehistory* (H. Meller, D. Gronenborn, R. Risch, eds.), Landsmuseum für Vorgeschichte, Halle, 45-66.

Rovero, L., Tonietti, U., 2014. A modified corbelling theory for domes with horizontal layers. Constr. Build. Mater. 50, 50–61. https://doi.org/10.1016/j.conbuildmat.2013.08.032.

Sanjuán, L.G., Díaz, F.S., Rovira, B.M., 2022. The "Megalithisation" of Iberia: A Spatio-Temporal Model. L'Anthropologie 126 (5), 103072. https://doi.org/10.1016/j.anthro.2022.103072.