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Approach to plant craft techniques from the mat impressions on the bases of Early Bronze Age ceramic vessels: The case of Cova Fonda (Spain)

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ABSTRACT

Evidence of prehistoric plant crafts is scarce in the Iberian Peninsula. The few sites that have provided samples of baskets are restricted to the south-east of the Iberian Peninsula, where dry conditions have favoured the conservation of plant-based implements, like textiles, baskets, and ropes. In the north-east of the Peninsula, the environment is not appropriate for their conservation and examples are still rarer. However, indirect evidence of plant craft techniques is found in mat and basketry impressions on the base of ceramic vessels. They appear in the northeast of the Peninsula during the Early Bronze Age (circa 2000–1500 BCE). These vessels have usually been studied from the perspective of pottery analysis and little attention has been paid to their significance in terms of crafts technology. The objective of this paper is to explore the study of mat impressions to shed light on the evolution of plant crafts technology in the northeast of the Iberian Peninsula. 3D scanning and experimentation have been combined to identify craft techniques at Cova Fonda (Salomó, Spain), where eight pieces with impressions on their bases were recovered. The impressions allow us to identify coiling techniques and details of the production process for mats.

1. Introduction

Evidence of prehistoric plant crafts is scarce in the Iberian Peninsula. Most of the remains are restricted to the south-east of the Iberian Peninsula, where dry conditions have favoured the conservation of plant-based implements like textiles, baskets and ropes, among other artefacts. An indicative example is the famous site of the Cueva de los Murciélagos (Granada, Spain), a sepulchral cave dated in 5200–4600 cal BC (Alfaro, 1980, 1984, Cacho et al., 1996), where a collection of sandals and baskets was recovered at the end of the 19th century. In this site almost all ancient basketry techniques, including woven, twisted, braided, and coiled basketry made of esparto grass (*Stipa tenacissima*), were used and have been preserved. Remains of baskets and ropes, either preserved, dried or charred, are relatively abundant in the Chalcolithic and Bronze Age sites in this region (*ca.* 3000–1500 BCE), most of them made of esparto fibres (Jover Maestre and López Padilla, 2013) but other fibres have also been identified, such as linen (Basso et al., 2022). Among the most remarkable sites that should be mentioned are: Los Millares (Gleba and Harris, 2019), Cova del Toro (Martín Socas et al., 2004), Cabezo Redondo (Alfaro, 1984), Ifré (Alfaro, 1984), El Oficio; Tomb 3 at the Argaric site of Almizaraque (Alfaro, 1984), las Angosturas de Gor (Cacho et al., 1996), Terlinques (Jover Maestre et al., 2001), and Castellón Alto (Rodríguez-Ariza et al., 2004).

In the northeast of the Iberian Peninsula, the environment is not appropriate for organic material conservation and remains of prehistoric basketry are even scarcer. The Early Neolithic waterlogged site of La Draga 5324–4796 cal BC, has provided the oldest evidence of basketry in the region (Bosch et al., 2000, Bosch et al., 2006, Romero-Brugués et al., 2021a; Romero-Brugués et al., 2021b, Herrero-Otal et al., 2021, Andreaki et al., 2020, Piqué et al., 2021). Thanks to the anaerobic conservation conditions, it has been possible to recover remains of coiled basketry made of fibres of monocotyledons (Cyperaceae, Typhaceae and Poaceae) and bast fibres of lime (*Tilia* sp.). Charred fragments of coiled basketry have also been found in Coves del Fem (4898–4587 cal BC) (Bogdanovic et al., 2017, Palomo et al., 2018) documenting the use of Cyperaceae (Romero-Brugués et al., 2021a; Romero-Brugués

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et al., 2021b, Herrero-Otal et al., 2021). Evidence of Bronze Age basketry is almost non-existent in the northeast of the Peninsula. One of the few exceptions is a sepulchral context in Cova del Moro, in Alins del Monte (Huesca), 1530–1425 cal BC, where remains of coiled basketry were documented (Rodanés Vicente et al., 2017, Alcolea and Rodanés, 2019).

The scarce evidence of baskets and cords limits our knowledge of ancient cordage and basketry technology, as regards their technological variability, function, geographical distribution and further developments. Fibre-based productions would imply that societies possessed a good knowledge of the environment and the availably of plants as well as their properties (Hurcombe, 2014). However, indirect evidence such as the impressions that these objects leave on some type of easily moulded material of inorganic origin constitutes an extraordinary source of information on basketry and cordage technology. These impressions can be the result of setting down a ceramic vessel that was not yet dry on vegetable mats (Harris, 2014); using vegetable moulds or bases to shape the ceramic vessels during the building (Rovira Port, 2006); or waterproofing the vessels (Hollander and Schwartz, 2000). Through these remains it is possible to determine the technique used in basketry or cordage production, and, in some cases, even the raw material or its shape. The study of basketry through the impressions left on soft materials, such as raw clay or vegetable resin coatings from baskets, is an effective way to obtain information in the absence of material remains of basketry. Often these impressions survive the passage of time and provide a highly detailed imprint. The analysis of basketry techniques through the analysis of mat impressions has been successfully applied to pots related to salt extraction found in the Middle-Late Chalcolithic site of Provadia-Solnitsata (Bulgaria) (Andonova and Nikolov, 2021). They combine the use of stereomicroscopic observation and the production of wax casts to infer the weaving technique and the use of both, monocotyledonous and dicotyledonous species in their production. Another good example of this approach is the study of the site of Arma dell'Aquila in Italy (Harris, 2014; Starnini and Biagi, 2018).

In the Iberian Peninsula, the oldest impressions have been documented at the Caves of Santa Maira, dated to 12,900–10,200 cal BC, where impressions of woven basketry were found (Aura Tortosa et al., 2005; Aura Tortosa et al., 2019). In addition, basketry impressions dated to the middle and the end of the Neolithic have been recovered, as for example in the Prehistoric Mines at Gavà-Mine 16 (Calvo, 2019), Cova de la Pastora (Alfaro, 1984) and Campos (Papí Rodes, 1992–1994). However, this evidence becomes more frequent from the Bronze Age. In the northeast of the Iberian Peninsula basketry impressions have been documented on Bronze Age pottery at various sites, such as: Cova d'en Merla, Cova Fonda, Cova de La Guia, Cova El Garrofet, Cova del Foric, Cova de Vallmajor, Cova de Can Paloma, and Camí dels Banys de la Mercè, among others (Rovira Port, 2006).

Although evidence of basketry impressions on pottery vessels is relatively frequent, they have not been systematically studied in relation to the basketry techniques used. The published studies rarely mention the basketry techniques. The objective of this paper is to study the basketry impressions on pottery remains recovered from the Bronze Age site of Cova Fonda, in order to shed light on the coiling techniques and to contribute to the knowledge of the raw materials used and the function of the baskets. 3D scanning of the pottery impressions and experimentation have been combined to analyse the basketry techniques.

2. Materials and archaeological context

Cova Fonda is located between Salomó and Vilabella (Tarragona, Spain), on the right bank of the river Gaià, at 204 m. above sea level (Fig. 1). The site was discovered in 1896 and was excavated by the Institut d'Estudis Catalans in 1918. Several researchers have referred to the finds recovered in the excavation in the cave although no systematic research project has been carried out (Bosch Gimpera, 1923; Vilaseca, 1932; Vega, 1967; Vilaseca, 1973). Indeed, some authors have published

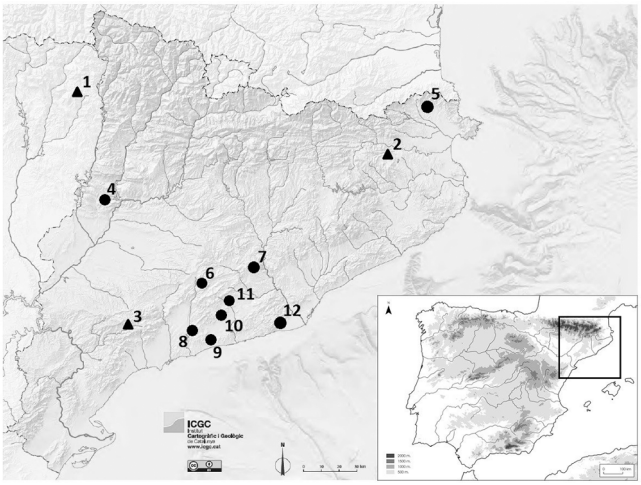

Fig. 1. Location of Cova Fonda and other related archaeological sites in northeastern Iberian Peninsula. 1. Cova del Moro (Alins del Monte, Huesca); 2. La Draga (Banyoles, Girona); 3. Coves del Fem (Ulldemolins, Tarragona); 4. Cova del Foric (Os de Balaguer, Lleida); 5. Camí dels Banys de la Mercè (Campmany, Girona); 6. Cova El Garrofet (Querol, Tarragona); 7. Cova de Can Paloma (Esparraguera, Barcelona); 8. Cova Fonda (Salomó, Tarragona); 9. Cova d'en Merla (Roda de Berà, Tarragona); 10. Cova de Vallmajor (Albinyana, Tarragona); 11. Cova de la Guia (Sant Jaume dels Domenys, Tarragona); 12. Prehistoric Mine-16 (Gavà, Barcelona).

studies about the ceramic assemblage (Rovira i Port, 1978; Aymamí i Domingo, 1992; Rovira Port, 2006).

The dispersion of the materials together with the lack of archaeological work following a scientific methodology makes it difficult to study and contextualise the finds. However, based on the typological characteristics, the potsherds correspond to various chronologies from the Late Neolithic to the Bronze Age, which allows the use of the cave to be dated in that period. The ceramic present different morphologies. In terms of decoration, the impressed decoration technique was observed, with patterns made with nails or fingers. Decoration with incisions and decoration with cordons was also documented. The site was used as funerary area although other uses cannot be ruled out.

The ceramic assemblage studied for this work has been attributed to the Early Bronze Age (Maya, 1997), due to the presence of basketry impressions on the bases of the ceramic vessels (Rovira Port, 2006; Maya, 1997; Palomo, 2006) and because of the use of additive clay elements (Pérez Conill, 2011).

The assemblage consists of eight potsherds, all recovered from Cova Fonda, with basketry impressions on their bases clearly visible to the naked eye (Fig. 2). The impressions occupy a large part of the external surface of the flat pottery bases. All the pieces are stored and exhibited in the Museu d'Arqueologia de Catalunya, in Barcelona. The pieces correspond to the following registration numbers: 25, 28, 13,717, 13,718, 13,736, 13,949, 13,950 and 13,951.

3. Methods

The study of basketry techniques through the impressions left on soft materials was conducted by combining two different methods. First, direct analysis of the negative evidence, which is the impressions on the ceramic vessels, was performed with a 3D scanner and the digital models of the potsherds. Second, an experimental program that replicated the basketry elements (based on original basketry remains) and the impressions (based on the preserved negative evidence found on the base of ceramic vessels) was carried out in order to create a reference collection allowing the validation of technological hypotheses generated

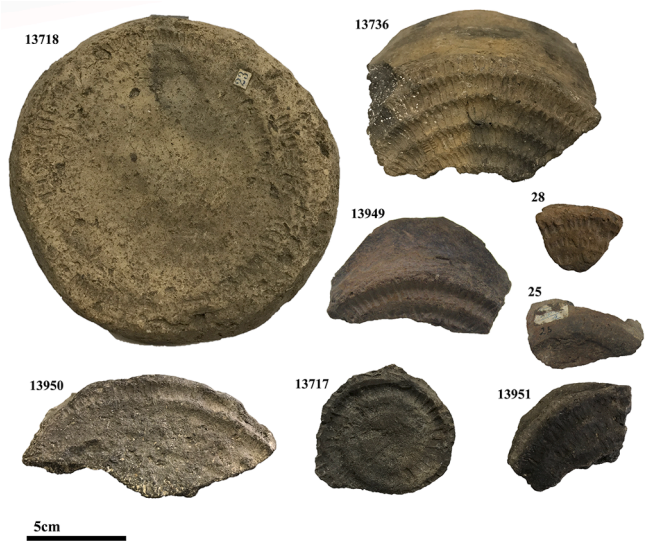

Fig. 2. Potsherds with basketry impressions recovered from Cova Fonda.

from the study of the impressions and the digital models.

The analysis of the ceramic assemblage from Cova Fonda included the basic morpho-technological characteristics of the potsherds, to provide a general view of the assemblage. The main objectives were the characterisation of the assemblage (building techniques, surface treatment, decoration etc.), visual observation to determine the part of the vessels preserving the impressions, and the macroscopic comparison of the impressions. In this way it would possible to identify similarities between them and determine if the impressions were made by using the same basket. The basic characteristics that were recorded for each potsherd are: the part of the vessel preserved, the type/morphology of the base, and the height of the potsherd in the cases where part of the wall had been preserved. No entire vessel profiles have been recovered. Moreover, the surface treatment, the thickness of the wall and of the base, the presence of manufacture traces and the condition of preservation have also been recorded.

Making casts of the impressions is an efficient method to obtain more meaningful data than with the direct analysis of the negatives. Several studies have been conducted in this regard since the late nineteenth century, including the use of lime with paper or silicone, or moulds made of clay, wax, latex, silicone, alginates for dental use, synthetic rubber or putty (López Campeny, 2011). These precursor studies were followed by others, such as that of Adovasio (2010), which involved moulds using ordinary modelling clay, liquid latex or gypsum. In this work we have used digital technologies to obtain digital models of the basketry impressions, facilitating in this way their morpho-technological analysis. 3D models of the basketry impressions were generated for comparison and characterisation. The aim of the characterisation was to determine the basketry techniques and the purpose of the comparison was to determine whether the impressions on the different potsherds could have been made by using the same basket, or at least by baskets made with the same coiling technique.

The 3D models were acquired using a high precision 3D scanner, the "CREAFORM GO! SCAN", equipped with a lens with a resolution of 0.1 mm. The software used for the capture, edition and analysis of the 3D models were "VXmodel" and "VXinspect" from Creaform. 3D images models can be found in the Supplementary Material 1. Furthermore, original 3D models are also available. Both hardware and software were provided by the "Digital Lab – UAB Open Labs". For the characterisation of the impressions on each potsherd the following parameters were measured (Fig. 3): minimum and maximum width of the bundles, minimum and maximum width of the sewing stitches, and minimum diameter of the basketry piece.

Based on the visual analysis, some hypotheses were established about the similarities between the different impressions. In order to verify these visual hypotheses, a statistical analysis of the different measurements obtained from the 3D models was carried out. The data used for the statistical analysis were the minimum and maximum width of the bundles and the minimum and maximum width of the sewing stitches.

Additionally, an experimental protocol was developed to obtain a reference collection of impressions left on clay by baskets made with different coiling techniques. This reference collection has been used as a frame of reference for the study of the basketry impressions from Cova Fonda. Firstly, experimental replicas of basketry elements were made, following the morpho-technological characteristics identified by the visual analysis of the impressions on the potsherds and of the 3D models. Different techniques and plants were used to make coiled basketry elements following the patterns obtained from the archaeological and modern record. The basketry objects were made by forming a base and with no vertical curvature, so that their entire surface would leave an impression on the clay. These experimental coiled mats were used to make impressions on pieces of soft clay, and thus examine whether the impressions were similar to the ones observed on the archaeological potsherds. During the experimentation, the impressions were made by

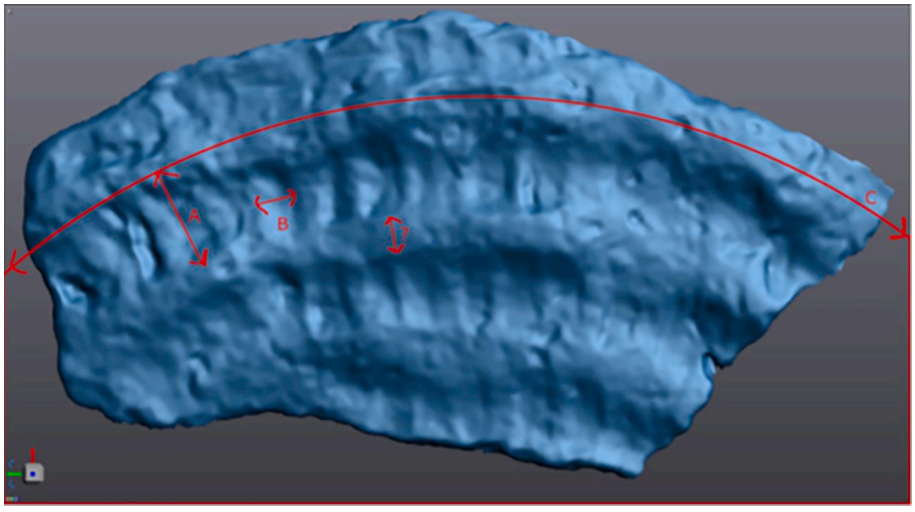

Fig. 3. Measurements taken to characterise the impressions on the potsherd. A: Minimum and maximum width of the bundles; B: minimum and maximum width of the sewing stitches; C: Minimum diameter of the basketry piece.

using both sides of the mat (worked and unworked). All samples were photographed to scale.

Although it is difficult to obtain data about the fibres used in basketry production from the impressions, either due to their state of conservation or due to the properties of the clay fabric used, in some cases, it is possible to deduce certain characteristics of the plant materials. Through qualitative differences marked in the impressions, it is possible to distinguish between animal or plant fibres and also to document the use of leaves, reeds, or wood (Prümers, 2006; Doumani and Frachetti, 2012). In order to identify the types (herbaceous, woody) and parts (leaf, bark, stems) of plants from the impressions on clay at Cova Fonda, in the experimental replicas we used different parts of plants from several species for both the bundles and stitches elements. Species that potentially could grow in the surroundings of the archaeological site, according to their localization and chronology, were selected; this also took into consideration their potential to be used in this technology (*Quercus* sp. deciduous, *Carex pendula*, *Rubus* sp., *Stipa tenacissima,* cereal straw). However, some other non-local plants were used (*Wisteria* sp., *Sabal minor*) as they might share some features and properties with local raw materials and provide comparative materials for other cases. The archaeological imprints were compared with the ones in the reference collection in order to approach the plant types used in basket production.

For the technological analysis of the impressions, the measurements of the potsherds (length, width and thickness of the wall) were taken into consideration, when possible, together with the measurements of the impressions, recorded through the 3D models of the potsherds, such as the width of the bundles and the sewing stitches (maximum and minimum). These data provide information on how the baskets were made and the final consistency that would have been achieved; therefore, these characteristics are related also to their possible uses. The criteria for the analysis of basketry elements according Adovasio (1977) are: the spacing of the coil (closed, open or a combination); the type and number of elements of the coil (rigid, flexible or semi-rigid elements); the arrangement of the elements of the coil (single element, horizontal foundation, stacked foundation, or bunched foundation); the shape of the stitch (interlocked, non-interlocked or split); and the type of stitch (simple, intricate or wrapped).

4. Results

4.1. Description of the potsherds

Traces of their manufacture and building were observed on all the potsherds (surface treatment traces, building traces of the join between the wall and the base, finger impressions). All the potsherds that preserve the base and a part of the wall, as well as one of the two bases, have traces of the work to join the wall with the base, which means that these two parts of the vessel were prepared separately and joined later. The building technique of the vessels cannot be identified with certainty; it could be, for instance, coil or slab building, but the sample is limited, and the indications are not sufficient to reach conclusions. All the impressions are on the external surface of the base.

Some observations were common to almost all the potsherds. First, in five potsherds large inclusions were observed (dimensions: ~7x9 mm). Minerals (quartz and calcareous fragments), in some cases even entire, were mainly used as inclusions. Voids were observed in some potsherds, possibly attesting the use of vegetal inclusions. Grog was also observed in some potsherds. The inclusions of non-clay materials did not alter the clarity of the basketry impressions. A more detailed analysis was difficult to be conducted macroscopically, taking into consideration that most of the sherds are in a bad state of preservation. The results of the pottery record and the macroscopic analysis of the potsherds are presented in Table 1.

Five of the potsherds provide further data about their production process or state of preservation. In potsherd number 25 the impressions cannot be clearly seen, and the clay seems to have been "dragged" to make the surface of the base smooth. In potsherd number 13717, even though the base is flat, there is a higher point in the centre of the base, as if the clay was pushed from the exterior towards the interior of the base. In potsherd number 13718, exactly the opposite can be observed, as if the clay was pushed from the interior towards the exterior of the base. Potsherd number 13,950 is the only one that is decorated. On its exterior surface, there is the typical decoration of thin "lines" made by adding clay to the surface. The impressions on the base are slightly visible, but it is not clear if this happened after the use of the vessel or not. In potsherd number 13,951 the exterior surface of the base is dark in colour, and the impressions are not clearly visible, but there is no indication of the cause of this dark colour.

Table 1
Morphotechnological characteristics of the ceramic assemblage (Cova Fonda, Salomó, Tarragona, Spain). Results of the pottery record and the macroscopical analysis of the potsherds.

Reference number	Length pottery base (mm)	Width pottery base (mm)	Min. width bundle (mm)	Max. width bundle (mm)	Min. width stitch (mm)	Max. width stitch (mm)	Num. of visible bundles	Spacing of foundation or coil	Minimum basket diameter (mm)	Stitch typology
25	42	16	–	–	–	–	2 (?)	–	Indet.	–
28	45	36	7,4	9,1	2,2	3,9	3	Open	77,13	Interlocking or non-interlocking intricate stitch
13,717	75	67	8,9	9,9	3,5	5,6	2	Open	95	Interlocking or non-interlocking intricate stitch
13,718	160	150	8,7	9,5	2,3	3,9	3	Indet.	141	Simple interlocking stitch
13,736	130	66	8,8	12,8	2,9	4,1	6	Open/close	176	Interlocking or non-interlocking intricate stitch
13,949	92	25	9,8	11,7	2,1	4,5	2	Open	123,48	Interlocking or non-interlocking intricate stitch
13,950	143	63	11	11,7	2	4	2	Indet.	164,91	Interlocking or non-interlocking intricate stitch
13,951	82	57	9,5	12,5	3,6	4,6	3	Open	151	Interlocking or non-interlocking intricate stitch

4.2. Description of the 3D models of the impressions

After the macroscopic analysis of the potsherds, sherd no. 25 was separated from the rest for further analysis, since the impressions on its base were modified or erased when the clay was still fresh. The measurements obtained from the analysis of the 3D models of the other pieces are presented in Table 2 and in Supplementary material 1. As can be seen, the width of the bundles ranges from 7.4 to 12.5 mm, while the size of the stitches varies from 2.1 to 5.6 mm.

As mentioned, the visual analysis allowed some hypotheses to be proposed about the similarities between the different impressions. Hence, in order to verify these hypotheses, a statistical analysis of the different measurements obtained from the 3D models was carried out. The data used for the statistical analysis were the minimum and maximum width of the bundles and the minimum and maximum width of the sewing stitches. Potsherd 13,950 was discarded and excluded from this analysis because the sewing stitches could not be characterised. The result of the statistical analysis is presented in Fig. 4.

This analysis shows that according to the size of bundles and stitches, the sherds can be broadly divided into two groups: 13736, 13,951 and 13,949 on one hand and 13718, 28 and 13,717 on the other. However, the most similar sherds are 13,736 and 13951, which in their time could have some relationship with 13949. Similarly, pieces 13,718 and 28 also present a certain degree of similarity, while piece 13,717 is the one that is least comparable to any of the other potsherds.

After the visual inspection, the statistical analysis and the analysis of the 3D models was carried out, with the result that the impressions on sherds 13,736, 13,951 and 13,949 could have been left by pieces of basketry with elements of similar dimensions and/or techniques. In the same way, the impressions on the sherds 13,718 and 28 may have been the result of pieces of basketry made with a similar technique. Finally, the impression on the sherd 13,717 does not appear to have a pattern comparable to any of the other impressions analysed.

4.3. Production of experimental replicas according to the hypotheses derived from the visual inspection and the statistical analysis of the 3D models

Eight basket models were made, all in the form of a flat base. Each one was imprinted on industrial clay, in order to contrast those impressions with the ones found on the ceramic assemblage from Cova Fonda. Technical characteristics of the experimental basket-making models are listed in Table 3 and the details about each model can also be found in Supplementary material 2. All the bases were made with the coiling technique, although some variations were introduced regarding the type of stitch and the raw material used. In relation to the raw material, different parts of plants were selected in order to show the main features of the impressions according to their texture, since the aim was not identifying the taxa used but the type of plant.

The simple interlocking stitches technique was used to make replicas

Table 2
Measurements obtained from the analysis of the 3D models of potsherds imprints.

Model	Bundles or foundations		Stitches		Minimum diameter (mm)
	Minimum width (mm)	Maximum width (mm)	Minimum width (mm)	Maximum width (mm)	
28	7,4	9,1	2,2	3,9	77,13
13,717	8,9	9,9	3,5	5,6	95,00
13,718	8,7	9,5	2,3	3,9	141,00
13,736	8,8	12,8	2,9	4,1	176,00
13,949	9,8	11,7	2,1	4,5	123,48
13,950	11,0	11,7	nd	nd	164,91
13,951	9,5	12,5	3,6	4,6	151,00

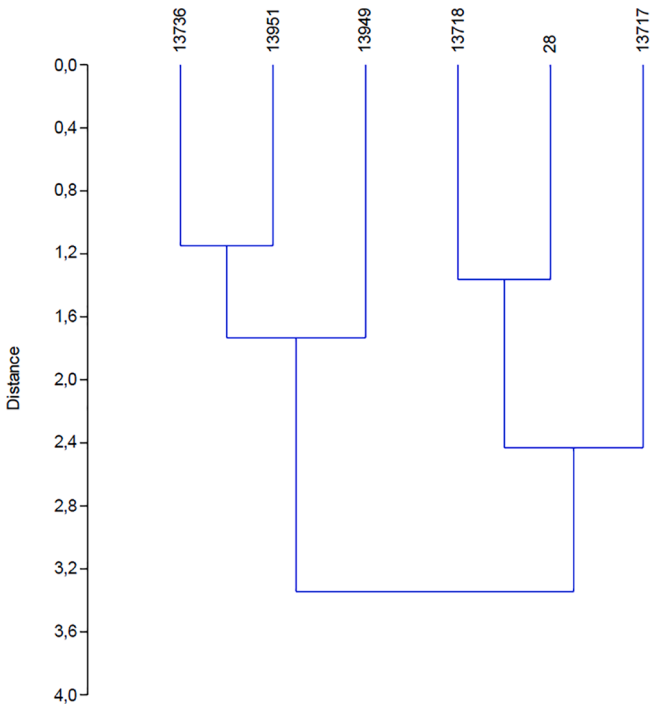

Fig. 4. Result of statistical analysis of the digital models.

Table 3
Technical characteristics of the experimental basket-making models.

Experimental replica	Type and shape of stitches	Raw material used		Similarity to archaeological samples
		Stitches	Bundle	
1	Simple interlocking stitches	*Sabal minor* leaves	Straw grasses	None
2	Simple interlocking and split stitches	*Carex pendula* stem	Straw grasses	None
3	Interlocking intricate stitches	Crushed *Stipa tenacissima*	Raw *Stipa tenacissima*	13,736 13,951
4	Interlocking intricate stitches	*Quercus* sp. deciduous, and *Rubus* sp. barks	*Sabal minor* leaves	28 13,717 13,949 13,950
5	Non-interlocking intricate stitches	*Wisteria* sp. bark	Crushed *Stipa tenacissima*	28 13,717 13,949 13,950
6	Non-interlocking intricate stitches	*Carex pendula* stem	Crushed *Stipa tenacissima*	13,736 13,951
7	Non-interlocking intricate stitches	Crushed *Stipa tenacissima*	Raw *Stipa tenacissima*	None
8	Simple interlocking stitches	Crushed *Stipa tenacissima*	Raw *Stipa tenacissima*	13,718

1 and 8. For replica 1 the raw material was dwarf American palm leaf (*Sabal minor*) for the stitches and cereal straw (grasses) for the bundles of the spiral. In the case of replica 8, crushed esparto grass (*Stipa tenacissima*) was used for stitching and raw esparto grass was used also for the spiral bundles. A metal or wooden needle was used to make the stitching pass between the stitches. In these replicas, no characteristic

differences were observed between the worked and unworked surfaces, beyond the obliquity of the stitches.

Simple interlocking and split stitches were used to make replica 2. Sedge (*Carex pendula*) was used for the stitches and cereal straw for the bundles. In this case, no tool was used for the stitching. This technique, similarly to the previous one, did not mark any differences between the worked and the unworked surface, beyond the obliquity of the stitches.

Replicas 3 and 4 were made using interlocking intricate stitches. In the case of replica 3, the raw material used was crushed esparto grass for the stitches and bundles of raw dry esparto for the spiral bundles. In this case, on the worked surface a pointed groove, similar to a crest, can be seen while on the unworked surface the groove is rather blurred. For replica 4, tender oak (*Quercus* sp. deciduous) tree bark was used for the central part of the piece and blackberry (*Rubus* sp.) bark for the outer part, as well as bundles of dried palm tree for the spiral. In this case, no characteristic differences were observed between the worked and the unworked surface. Regarding the tools used, in both cases a wooden or metal needle was used to make the stitching pass between the stitches.

Replicas 5, 6 and 7 were made with non-interlocking intricate stitches. For replica 5 wisteria bark (*Wisteria* sp.) was used for the stitch and bundles of crushed esparto grass for the spiral. Moreover, no tool was used to make it. In the case of replica 6, the raw material used was the floral stem of *Carex pendula* for the stitching and crushed esparto grass for the bundles of the spiral. For replica 7, the raw material used was crushed esparto grass for sewing, while raw esparto was also used for the bundles of the spiral. In these two cases, a wooden or metal needle was used to make the stitching pass between the stitches. No differences between the worked and unworked surfaces were observed in these replicas.

4.4. The raw materials

Although it is difficult to identify the plants used solely through the negative of a clay basketry impression, it is possible to appreciate characteristics of certain materials. Due to the fact that the impressions studied here were produced by coiled basketry techniques, two elements are distinguished: the stitches and bundles. In this sense, raw materials are described following the observation of these elements.

As the stitches are the external part of the basket or mat, their impression is always visible. This makes it possible to describe the raw materials used. The stitches observed in the impressions have a smooth, wide surface. This type of surface has been obtained experimentally using a bark of a tree or shrub for sewing. The use of this type of material leaves a separation between stitches. This would be the case for the stitches of pieces 28, 13,717, 13,949 and 13,950. Nevertheless, there are doubts regarding the use of the raw material in pieces 13,736 and 13,951. In these cases, the stitches become narrower when new stitches are added. It may be due to the use of herbaceous species, where the fibres can be crumbled with certain verticality, following longitudinally the veins of the fibre itself. Processing the fibres before their use causes loss of rigidity of the material and makes it possible to produce a tight and narrow seam, reducing the distance between stitches. However, with bark of trees or shrubs it is also possible to observe this morphology in the stitches. If the bark is peeled off before use and the fibres are separated from each other, the stitch may acquire a round shape in the part that tightens with new stitches, as in the case with the stitches made of herbaceous plants.

Regarding the raw materials used in the bundles, it is even more difficult to define them. This happens because, in most cases, there are no impressions of this element. Sometimes they are visible because of the space between the stitches or because some stitches were absent when the impression was made. When the impressions of the stitches are visible, the bundles are slight and do not leave marks, which complicates their identification even more. That is the reason why there are no anatomical features to identify any plant, beyond observing that its surface is smooth. However, in piece 13,736 the negatives of the material used for the bundles have been preserved due to the absence of some stitches. These bundles form lines parallel to each other and perpendicular to the stitches, which could be attributable to the use of small diameter stems. This evidence provides information about the type of the material that forms the spiral; in this case, they were made of bundles of certain stems of herbaceous plants.

5. Discussion

5.1. The technical variability of basket production in Cova Fonda: techniques, raw materials, and production process

According to the macroscopic observation of the impressions and their comparison with the basketry techniques described by Adovasio (1977), all the impressions studied here correspond to the coiled basketry technique. The two characteristic elements of this technique can be clearly distinguished in the material under study; the stitches and the bundles forming a spiral. As mentioned, the impressions are not visible in the sherd no. 25. The rest of the sherds form a group that presents similarities regarding the impressions on their base.

The comparison of the archaeological and experimental impressions has allowed some hypotheses to be proposed about the manufacturing technique of the basket bases. Table 4 shows the technical parameters identified in the archaeological potsherds that present similarities with the experimental replicas. The shape and surface of the stitch and the separation of the bundles observed in the archaeological sherds were compared with those observed in the experimental replicas. Therefore, it was also possible to determine similarities in the process of basketry making. Potsherds 28, 13,717, 13,949, and 13,950 resemble replicas 4 and 5; sherds13736 and 13,951 are similar to replicas 3 and 6; and finally, piece 13,718 presents similarities with replica 8. None of the archaeological potsherds displays similarities with replicas 1 and 2, since the stitches are distributed in a spiral, a technique that does not match the archaeological record. In the same way, replica 7 does not

Table 4
Technical parameters identified in the archaeological potsherds that present similarities with the experimental replicas.

Archaeological reference number	Type and shape of stitches	Raw material used		Replica similarity
		Stitches	Bundle	
25	–	–	–	–
28	Interlocking or non-interlocking intricate stitch	Bark	Indet.	4, 5
13,717	Simple interlocking stitch	Bark	Indet.	4, 5
13,718	Interlocking or non-interlocking intricate stitch	Bark	Indet.	8
13,736	Interlocking or non-interlocking intricate stitch	Bark or herbaceous?	Sedges, straw, etc.	3, 6
13,949	Interlocking or non-interlocking intricate stitch	Bark	Indet.	4, 5
13,950	Interlocking or non-interlocking intricate stitch	Bark	Indet.	4, 5
13,951	Interlocking or non-interlocking intricate stitch	Bark or herbaceous?	Indet.	3, 6

resemble any of the archaeological potsherds.

The separation between the bundles observed in pieces 28, 13,717 and 13951, 13736, 13,949 and 13,950 is noteworthy, since it may be the result of the use of an intricate stitch to join the bundles. The intricate stitches connect the previous bundle with the later one with an 8-shaped loop, first taking the later bundle and then going to the previous one. The clay impressions of the experimental replicas made with this coiling technique show that this type of stitch produces protuberances between the bundles in the form of more or less pronounced ridges. These types of stitches produce some separation between the bundles, with a rather open spacing of the coil. Potsherds 28, 13717, 13949, and 13,950 present similarities with replicas 4 and 5, while potsherds 13,951 and 13,736 are more similar to replicas 3 and 6. In potsherds 13736, 13,949 and 13,950 the separation between the bundles is much more evident, taking the form of a pronounced ridge.

Intricate stitches include knots or loops as they join the front bundle to the rear bundle. These intricate stitches can be interlocking or non-interlocking. The type and shape of the stitches is able to differentiate between the worked surface and the unworked surface, if any, in addition to making it possible to determine the basketry technique used. In an intricate, non-interlocking stitch, the stitch turns over itself in the middle of the two bundles, so, with the naked eye, the crossing of the stitch from the front to the rear beam is not visible and does not create differences between the bundles. When the intricate stitch is interlocked, the sewing work is observable on one of the two surfaces, causing a distance between bundles with a rather blurred groove, while on the unworked surface it is possible to observe a pronounced separation between the bundles. However, the observable differences to determine interlocking and non-interlocking stitches also depend on the raw material used, since the shape of each stitch changes with the chosen plant material. If it is herbaceous, and easily scrubbed, it makes the stitching tight and narrow, and the worked and unworked surfaces are easily identifiable. In contrast, bark makes separate stitches on both surfaces, and it is not possible to differentiate them. However, if the bark is processed, the material loses its rigidity and becomes more flexible, allowing tighter stitches. In the case of the archaeological potsherds under study, it was not possible to discriminate from the impressions whether the stitches were interlocking or non-interlocking.

The characteristics of the plants used become important in order to identify the coiling technique, since the stitch pattern left in the impression provides useful indications. Potsherds 13,736 and 12,951 have similar stitch patterns, as they are tightened in contact with the new bundle. The impressions on these two sherds were, according to the analysis of the digital models, the ones that were most similar and, therefore, it was suggested that they could have been made with the same basketry element or at least with baskets coiled with the same technique. The impressions on both sherd 13,736 and 12,951 coincide in their coiling technique, resembling replicas 3 and 6. The narrowing of the stitches could be attributed to the use of herbaceous species, which are less rigid and allow more malleability. With this type of material, the stitch takes a round form, as it narrows when the new bundle is sewn on top of the old one. However, barks can also form rounded stitch patterns if processed, so the fibres fray and act like grass fibres, adopting a smaller width and becoming more flexible. In both cases in replicas 3 and 6, herbaceous plants were used for sewing.

Potsherds 28, 13,717, 13,949 and 13,950 have rather straight and rectangular stitches, and the impressions on their bases coincide in their coiling technique with replicas 4 and 5. This type of straight stitch is more typical of tree and shrub bark, in addition to the outer bark of unprocessed dicotyledons. In both cases, in replicas 4 and 5, the stitches were sewn from tree bark. In the archaeological potsherds, the impression of the stitches was smooth, which suggests the use of raw materials for the baskets that do not leave this type of impression.

Regarding the separation of the stitches, it was observed that the impression on potsherd 28 has relatively separate and wide stitches, while in potsherds 13,717, 13,949, 13,950 and 13,951 the stitches are less separated. This may be, again, due to the use of different plant materials. Sewing with bark from shrubs or trees does not allow tight stitching if the intricate stitching technique is used. However, the use of bark from bramble or sedges allows greater approximation between the stitches, since they are not that rigid.

Finally, replica 8 resembles potsherd 13,718. The impression on the base of this potsherd has a different stitch typology from the others: a simple interlocking stitch. This type of stitch does not link between the previous and later bundles, so it is possible to find open, semi-open and closed spiral spacing. In practice, single stitches usually make an oblique pattern with respect to the beams, but it is also possible to obtain vertical single stitches if the stitches are made closer together, like those observed in potsherd 13,718. In interlocking stitching, the stitches are a short distance from each other, as in replica 8. In the case of potsherd 13,718 it can be affirmed that a basketry element different from the rest in Cova Fonda would have been used.

To sum up, thanks to the comparison with the experimental replicas, it has been possible to determine up to two different types of stitches among the impressions on the vessels bases: the intricate stitch and the simple interlocking stitch. In most cases the vessel base imprints indicate coils with an open spacing, which suggests the use of flexible and malleable basketry elements. Regarding the type of plant used, certain impressions suggest the use of various stems of cereal, straw, or dried grass to serve as a filling. For the stitches, bark of trees or shrubs with or without processing would have been used, besides monocotyledons, such as sedges. Likewise, it is possible to assume the use of herbaceous species in sewing.

5.2. *The function of basketry in pottery production*

A connection between basketry and pottery has long been highlighted, as transmission of technologies from one craft to another has been documented in other craft traditions (Rebay-Salisbury et al., 2014). On the one hand, ceramic production used basketry as a model; many shapes and decoration patterns made of soft materials were repeated in hard materials (Haas-Lebegyev, 2014). On the other hand, basketry was used in the process of pottery production. It has been proposed that basketry impressions on the bases of pots are the result of using mats or two-dimensional basketry pieces as turntables or to rest the pots during the production processes before the clay is completely dry (Harris, 2014). For this purpose, two-dimensional pieces of basketry made of flexible materials could be used. In the case of Cova Fonda, the fact that all the impressions have been observed on the flat bases of the ceramic vessels may be related and consistent with the use of basketry objects that have the function of serving as a working surface for the manufacture of ceramic vessels.

We have experimented the use of basketry elements as a base during the modelling of the clay and the building of the ceramic vessel. In this procedure, the resulting basketry impression occupies almost the entire base of the ceramic vessel, but does not leave an impression on its walls. Therefore, the use of a basket for the creation of decorative patterns or as a mould for building the ceramic vessels could be ruled out.

The ceramic vessels from Cova Fonda would have been made with the technique of superimposing clay coils, which would be joined to a clay base, consisting of an open and low wall of a small-sized container. With this technique, the base of the pots begins with a portion of clay, which can be moulded in the hands of the potter or placed directly on top of a base that acts as a turntable and that helps to turn the recipient easily, since the basket element glides easily on a smooth surface. If the initial portion of clay is hand-moulded and then it is placed on a support (which can be, for example, a basket base or mat), when clay coils are joined with the help of wet fingers to build the vessel, the impression left by the basketry element on the soft clay may be blurred and not clearly marked. Alternatively, if building the entire ceramic vessel begins and ends on the basket element, pressing the clay into it to model the base and then to add the coils and build the walls, the pressure exerted is

greater and makes the impressions much deeper. Potsherds 28, 13,717, 13,736, 13,949 and 13,951 have a much deeper and more clearly marked impression of the basketry base than Potsherds 13,718 and 13,950, where the impressions are more blurred. This differentiation may therefore be due to the building process followed for each of the ceramic vessels.

Consequently, the basket that left the impression on the vessel base could have been used as a working surface. The results obtained are in favour of the hypothesis that the basketry elements functioned as a base or as a working surface for building the vessels. The impressions of the basketry element on the base of the ceramic vessels seem to be conditioned by the procedure followed during this process, i.e., the pressure exerted on the base of the ceramic vessel is different if the clay base is produced in the potter's hands or directly on the basketry element.

Other factors can cause a more or less deep impression of basketry on the ceramic. One is wear of the turntable itself due to its repeated use. Use causes the fibres, especially the exterior ones, to become increasingly worn. In addition, the nature of the clay may influence the possibility of the vegetable fibres being imprinted on the ceramic. In any case, the fact that the prints are visible or not is due to a decision of the ceramist, who can smooth them, partially or totally, or not at all. In this sense, the impressions on Potsherd number 25 are not clearly visible probably because of the intentional action of the potter in order to make the surface of the base smooth and to erase the imprint of the basket.

It should be noted that the visual aspect of the bases of Potsherds 13,736 and 13,950 is different, even though they were placed on baskets made with the same technique. While in Potsherd 13,736 the impression of the basketry base is more evidently marked, in Potsherd 13,950 the impression seems to have been blurred. This distinction also occurs in Potsherds 25, 28, 13,718 and 13,951, where, unlike pieces 13,717 and 13,949, the impressions are quite less well marked. These variations in the appearance of the impressions are not related to the basket-making technique used, but to different treatments of the bases prior to firing. Basketry impressions will be clearly marked, unless the surface has been previously blurred with the help of moistened fingers or a surface smoothing tool. Therefore, it is conceivable that the ceramic assemblage recovered from Cova Fonda was left to dry on the basketry elements without smoothing or blurring the vessel bases.

6. Conclusions

The study of basketry impressions on vessel bases from Cova Fonda has been carried out by describing the most characteristic technical parameters directly from the negatives -the impressions-, and making comparisons with the 3D models of the original potsherds. The development of an experimental protocol has made it possible to test technological hypotheses about the production of basketry elements and about the plant types used, through the study of the impressions found on the archaeological material. In the present research, the development of an experimental program to complete the information obtained from the archaeological remains has been proved highly effective, as it has filled possible information gaps that arose from the archaeological remains themselves. Thanks to the comparison with the experimental replicas, it has been possible to determine up to two different types of stitches used in making the basketry and to suggest hypotheses of the plant types according to the impressions left on the clay.

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.

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Author statement

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Appendix A. Supplementary data

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