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Manufacturing traces and pot-forming processes during the Early Neolithic at Cueva de El Toro (Málaga, Spain, 5280–4780 BCE)

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ABSTRACT

This paper reports the results of forming processes used in pottery manufacture at La Cueva de El Toro (Málaga, Spain) during the Early Neolithic (5280–4780 cal. BCE). La Cueva de El Toro is one of the most important sites of reference on the southern Iberian Peninsula for providing extensive and systematised data on early farming practices. The identification of manufacturing traces on pottery has enabled the assessment of the variability of forming techniques used by the communities of herders that seasonally inhabited the cave during the Early Neolithic. Forming processes were also compared with characteristic features of pottery products (typology, decorations) that are representative of the first pottery production in this area. Furthermore, this study provides new insights into the distribution of the first pot-forming processes in the south of the Iberian Peninsula, which suggest the use of similar techniques to the forming-sequences documented at other Early Neolithic sites (the use of coils and circular patches) and other forming processes (moulding process and the use of discs) which are still unknown in the Western Mediterranean.

1. Introduction

The onset of the manufacture and use of ceramic vessels in the Western Mediterranean occurred with the spread of farming practices during the 6th millennium cal. BCE. Ceramic vessels started to be used in each area in accordance with the different temporal, spatial and social dynamics of the Neolithisation process, which recent studies have coincided in defining as non-linear and possibly multidirectional (Bernabeu and Martí Oliver, 2014; Binder et al., 2017; Guilaine, 2013; Manen et al., 2019a).

In this context, the first pottery productions have been investigated on the basis of their formal and decorative attributes – grouped into the so-called *Impressa*, *Cardial* and *Epicardial* decorative styles – in order to define the spread and sequence of the Neolithisation process as well as to shed light on the connections and contacts between several regions of the Western Mediterranean (e.g., Bernabeu et al., 2017; Rigaud et al., 2018). Meanwhile, studies focused on their technological features have provided data on different issues, such as the supply areas of raw materials, the circulation of ceramic products and mobility patterns during the Early Neolithic based on these parameters (e.g., Angeli and Fabbri, 2017; Binder et al., 2010; Capelli et al., 2017; Clop, 2011, 2012; Gabriele et al., 2019; Manen and Convertini, 2012; Stempfle et al., 2018). One of the latest research lines to have been included in discussions of the Neolithisation process is the identification of pot-forming sequences used in the first pottery production in Western Europe and the Mediterranean basin (Gomart et al., 2017, 2020).

Current technological studies have revealed the existence of several traditions and technical practices that spread with the Neolithisation process in Western Europe. The coiling techniques documented since the beginning of the Early Neolithic in the Balkans (end of the VII millennium cal. BCE) (Gomart et al., 2020), are linked to the introduction of farming and Linear Pottery (LBK) in several areas of Central and Western Europe, such as Hungary (Gomart et al., 2020; Kreiter et al., 2017), the Czech Republic (Neumannová et al., 2017; Thér et al., 2019), Belgium and north-east France (c. 5500–4950 cal. BCE) (Bosquet et al., 2005; Gomart, 2014; Van Doosselaere et al., 2013). Indeed, these technical

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practices prevailed between Hungary and the Paris basin practically without change (Gomart et al., 2017) and were also linked to the diffusion of others such as the construction of vessels with slabs or the beating technique (Gomart et al., 2020; Thér et al., 2019). In contrast, recent research conducted at the first farming sites from the Western Mediterranean underscore a technical duality in the ceramic manufacture, characterised by both the coiling forming sequences and the juxtaposition of circular patches. The use of coiling techniques is also identified in the first *Impressa* vessels in southeast Italy (5900–5600 cal. BCE) (Angeli and Fabbri, 2017; Colombo, 2017). Conversely, in the Ligurian-Provencal Arc and southeast France (5800–5600 cal. BCE), ceramic vessels, also linked to *Impressa* decors, were entirely manufactured using juxtaposed patches, each formed by a spiral coil (Gomart et al., 2017).

Unfortunately, the distribution of the first pottery forming processes during the Early Neolithic is still unknown in several areas and chronologies, including the Iberian Peninsula. The first pottery production on this area dates to around 5650 cal. BCE (Bernabeu et al., 2011; García Borja et al., 2014; Oms et al., 2014), although no specific pottery studies based on the identification of manufacturing traces have been reported to date.

This paper focuses on the examination of ceramic vessels from the Early Neolithic occupation of Cueva de El Toro, located in the south of the Iberian Peninsula (Martín-Socas et al., 2004). Since the introduction of farming to this region (c. 5500–4700 cal. BCE, Martín-Socas et al., 2018), a wide variety of decorative techniques were used in the production of vessels, with the application of *almagra* being especially prominent throughout the region, as well as *cardial* decorations, concentrated mainly around Granada and Málaga. Cueva de El Toro represents one of many examples of this morphological and decorative variety (Camalich Massieu and Martín-Socas, 2013), but one that is singular due to the absence of vessels with *cardial* decorations.

The aim of this paper is to reveal the pot-forming processes used by the communities that periodically inhabited Cueva de El Toro during the Early Neolithic (5280–4780 cal. BCE). First, in order to recognise which forming processes were used in pottery manufacture, the ceramic assemblage was examined considering the diagnostic traces preserved in the ceramic vessels. Second, the identified techniques were compared with the shape and decorative attributes. Finally, results were contextualised and compared with the available data on forming-sequences documented in other Early Neolithic sites from the Mediterranean basin and Western Europe.

2. Site: Cueva de El Toro

Cueva de El Toro is located in the Sierra de El Torcal (Málaga, Spain) at 1190 m above sea level (Fig. 1). The inside of the cave was formed by large limestone blocks detached from the roof. The original space is articulated on two platforms (Sector 1 and Sector 2) at different heights (Martín-Socas et al., 2004).

Archaeological fieldwork identified a 2.40 m deep stratigraphic sequence, with four chrono-cultural phases. The two lower layers correspond to the Neolithic occupations: Phase IV (Early Neolithic, 5280–4780 cal. BCE) and Phase III (Late Neolithic, 4250–3950 cal. BCE) (Martín-Socas et al., 2018), with a period of site abandonment of 500 years between the two phases.

The first occupation (Early Neolithic) suggests a domestic context characterised by domestic species, mainly ovicaprids and cereal plants, as well as a wide range of representative artefacts of the Early Neolithic: carved and polished stone tools, animal hard matter tools (bone, shell

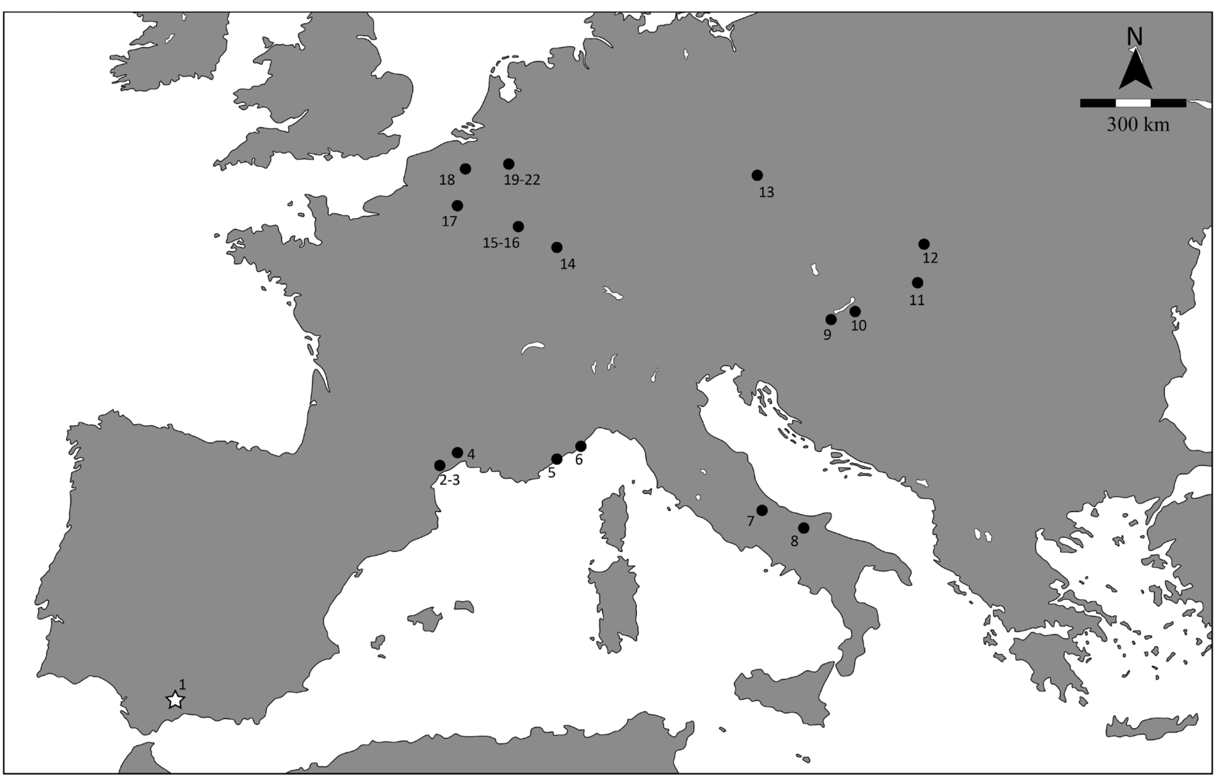

Fig. 1. Location of Cueva de El Toro (Málaga, Spain) and the other Early Neolithic sites with research on forming processes based on the observation of manufacturing traces (VI millennium cal. BCE): 1. Cueva de El Toro (Spain), 2, Peiro Signado, 3. Pont de Roque-Haute, 4. La Farigoule 2, 5. Abri Pendimoun (southeastern France) (Gomart et al., 2017; Manen et al., 2019b), 6. Arene Candide, 7. Colle Santo Stefano, 8. Ripa Tetta (Italy) (Angeli and Fabbri, 2017; Colombo, 2017; Gomart et al., 2017), 9, Vörs-Máriaasszo-ny-sziget, 10. Balatonszárzó-Kis-erdei-dulo, 11. Nagykörű-Tsz. Gyümölcsös, 12. Polgár-Ferenci-hát (Hungary) (Gomart et al., 2020; Kreiter et al., 2017), 13. Bylany (Check Republic) (Neumannová et al., 2017; Thér et al., 2019), 14. Rosheim, 15. Ennery, 16. Metz-Nord, 17. Cury-lès-Chaudardes (northwestern France) (Gomart, 2014), 18. Aubechies, 19. Rosmeer, 20. Verlaine, 21. Fexhe-le-Haut-Clocher, 21. Remicourt, 22. Vaux-et-Borset (Belgium) (Bosquet et al., 2005; Gomart, 2014; Van Doosselaere et al., 2013).

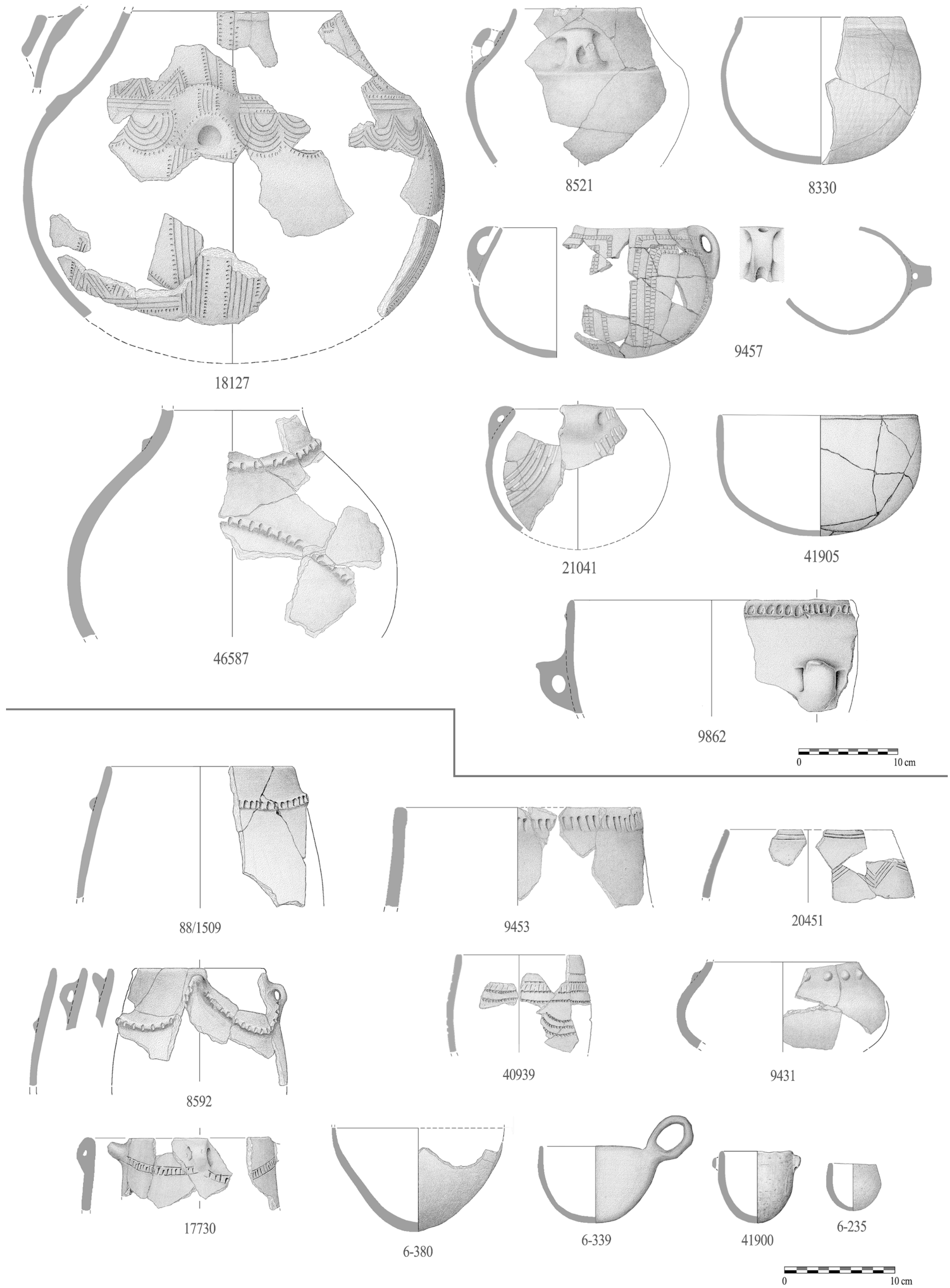

Fig. 2. Examples of pottery shapes and decoration from Cueva de El Toro (Phase IV).

and antler), vegetal fibres, jewellery and ceramic vessels.

Phase IV is therefore interpreted as a periodical or seasonal occupation with a predominantly pastoral orientation. The cave interior was used for consumption and craft activities, as well as activities associated with the rituality and symbolism of these communities (Camalich Massieu and Martín-Socas, 2013; Égüez et al., 2016; Martín-Socas et al., 2004, 2018; Santana et al., 2019).

Pottery production is characterised by its extraordinary quality, predominantly fine-ware with major attention to surface treatments and decorations (Fig. 2). Overall, the most predominant shapes are hemispherical, ellipsoidal and ovoid profiles, although the repertoire is very wide, including vessels with converging walls, spherical and conical bases and, in some cases, compound shapes with collars. These shapes are normally associated with ribbon handles, solid protrusions and, exceptionally, spouts.

In general, two volumetric groups of vessels can be identified. One, with a capacity ranging from one to three litres, would have been used for domestic activities. The other, which is quantitatively less frequent and has a greater capacity and attached grip elements, would be related to the transport and storage of food products (Martín-Socas et al., 2004; Tarifa et al., 2019).

The pottery is also characterised by the outstanding presence of decorated vessels, either with the exclusive application of *almagra*, or with a technical variety that encompasses impressions, incisions, stab-and-dragging (*boquique*) and applied decorations. In addition, red paste is also used to fill the negatives of the aforesaid decorations.

3. Material and methods

3.1. Technological approach

Amongst research on pottery manufacture, forming processes are considered a suitable indicator to assess the variability of ways of doing, the work processes used in ceramic production as well as the transmission of technical know-how (García Rosselló and Calvo Trias, 2013). Ethnoarchaeological studies reveal how these techniques are learnt by observation and, more importantly, by practice through a close interaction between apprentices and tutors (Bril, 2002; Gosselain, 2011; Calvo Trias and García Rosselló, 2014). This means that technical gestures are thus 'incorporated' and cannot be easily modified or changed once they have been learnt (Gosselain, 2011; Roux, 2011). As a result, their reproduction and transmission across several generations of producers may entail major stability over time and space, especially when compared to other features of ceramic vessels (Gosselain, 2000; Roux et al., 2017).

The technological study focuses on the identification of forming techniques and methods. Forming techniques include those modalities whereby paste is transformed into a volume (forming and auxiliary techniques, building phases of vessels and added elements) and those whereby ceramic products are regularised and the final shape is obtained (García Rosselló and Calvo Trias, 2013). Forming methods were defined according to the sequence of forming techniques used for building each part of ceramic vessels (Roux, 2011, 2019).

3.2. Pottery analysed

The ceramic assemblage from Phase IV of Cueva de El Toro consists of around 128 ceramic vessels. The analysis focused on ceramic sherds with diagnostic macro-traces which preserve part of the profile (base, belly, upper parts/rim) and which can be individualised from its formal and decorative traits. In total, forming processes were identified in 95 vessels and 47 ceramic elements with diagnostic macro-traces (5 rims, 6 parts of bellies, 6 bases and 30 handles not assigned to specific vessels), which include 396 potsherds (Table 1). This sample presents several degrees of preservation, with a majority of vessels for which only the upper part and rim are preserved. The ceramic assemblage comes from the central area of the cave (domestic context) (Martín-Socas et al., 2004) with the exception of four vessels that were recovered from a specific context related to symbolic or ideological practices (Santana et al., 2019). Additionally, the sample of analysed vessels comprises the variety of shapes and decors that characterise the ceramic assemblage of Phase IV.

Table 1
Vessels and ceramic elements analysed from Phase IV of Cueva de El Toro with diagnostic macro-traces examined with macroscopic observations and optical microscope. *Bases included in the analysis. **Handle elements preserved within the sample of vessels.

Preservation	Number of vessels	Number of ceramic elements
Large part of the profile preserved	7	-
Profile of the belly, the upper part and rim	28	6
Upper parts / rim	60	5
Lower part of vessels (bases)	-	6*
Handles / grip elements	29**	30
Total	95/29**	47

3.3. Examination of manufacturing traces with macroscopic observations and optical microscope

The identification of forming processes was based on the recognition of manufacturing traces preserved in the ceramic vessels. Manufacturing traces encompass all those features produced directly during the production process of vessels that were not obliterated by other techniques or subsequent processes (surface treatments, decorations, use-wear traces and taphonomic processes), and those macro-traces produced indirectly as a consequence of their use, rupture or abandonment, which also inform about their manufacture (García Rosselló and Calvo Trias, 2013, 2019).

The examination of manufacturing traces was conducted by macroscopic observations of the topography and texture of surfaces, formal variations in vessel profile and wall-thickness, the fracturing patterns of vessels (linear fractures, laminar fractures, cracks formed on the surfaces and cross-sections) and the internal structure of vessels in the radial plane (discontinuities and distribution of pores and particles) (Cámara, 2019; García Rosselló and Calvo Trias, 2013; Livingstone Smith, 2007).

Ceramic macro-traces were recognised by combining observations with the naked eye and angular lights and observations with an optical microscope (5x to 16x magnifications). In parallel, manufacturing traces were photographically recorded using a digital camera and alternating between two lenses (18–55 mm intermediate lens and 90 mm macro lens). Photographs were taken with a static tripod and auxiliary LED lights, preventing the entry of artificial or natural light during the shooting process. Photographs at 8x magnification were obtained with a Leica Microscope. Photographs obtained at different depths of field were processed with Helicom Focus v.4.62 software.

3.4. Recording and interpretation of manufacturing traces

Two methodologies were used to record and systematically describe macro-traces (García Rosselló and Calvo Trias, 2013) and the internal structure of vessels in the radial plane (Livingstone Smith, 2007; Martineau, 2000).

The interpretation of forming processes in each ceramic vessel was based on the correlation of manufacturing traces and their comparison with a series of experimental and ethnoarchaeological collections (García Rosselló and Calvo Trias, 2013, 2019; Gelbert, 2005; Lepère, 2014; Livingstone Smith, 2007; Martineau, 2000, 2010; Roux, 2016, 2019; Rye, 1981). During examination of the ceramic assemblage of Cueva de El Toro, a set of manufacturing traces with no current ethnoarchaeological or experimental referential was detected. Their technological origin was inferred by comparing these features with a series of macro-traces identified in archaeological contexts (Gomart et al., 2017; Manen et al., 2019b), which led to the proposal of several hypotheses regarding their forming sequence.

The manufacturing traces and forming techniques inferred in each ceramic vessel were entered in a relational database that separates the empirical data (manufacturing traces) from their technical interpretation (forming techniques). The number of macro-traces identified in those vessels and handles included in the study amounted to 516. The forming sequence of vessels was established afterwards in consideration of the degree of vessel preservation.

3.5. Quantitative analysis of assembled elements

Several statistical tests were conducted to assess the degree of deformation and variability of those vessels formed by assembled elements, such as the use of coils. First, the coil height and wall-thickness of the vessels were measured for each part of the profile. The measurements correspond to the largest coil height whilst the thickness of the walls is related to the part of the profile where the coil measures were obtained. The distribution of the measurements in the box plot diagram was used to visualise the similarities and differences between the location of measures in the belly and upper parts of the vessels, bearing in mind that the interquartile range and median is represented in the box. In order to assess the variability of coil heights, the coefficient of variation (CV) was used and compared between each part of ceramic vessels. Second, a scatter plot and the Pearson coefficient correlation were used to assess the correlation between coil height and wall-thickness, with a correlation probability threshold of $a = 0.05$ (Hammer et al., 2001). Finally, the standard deviation of the diameter of circular elements detected in several vessels was estimated.

4. Results

The study of the ceramic assemblage of Phase IV from Cueva de El Toro enabled the identification of several forming processes based on the diagnostic macro-traces preserved on ceramic vessels. At least five forming methods (TCT1 to TCT5) were reconstructed on the basis of vessels that preserve a large part of their profiles (Table 2). Moreover, a series of partial forming sequences were defined according to the preservation of vessels which do not preserve their profile completely and bases that hence could not be assigned to any specific ceramic vessel (Table 3).

4.1. Forming process with several assembled elements (lower parts) and coils with alternate overlapping (upper parts)

The reconstruction of the TCT1 forming method is based on several vessels that present a similar morphology of macro-traces. First, this forming sequence encompasses 2 vessels whose whole profile is preserved, both of which display a similar morphology of traces in the lower part with 4 of the bases analysed. Second, there are 22 vessels with a preserved part of the belly, 50 vessels with a preserved upper part and rim and 10 elements not assigned to specific individuals (5 rims and 5 parts of bellies) that also present a similar morphology of traces. These vessels, however, cannot be strictly associated with a forming method as their profiles are not completely preserved.

The bases present sub-circular and horizontal fractures at the bottom and at the beginning of the belly. The topography preserves wavy depressions on the inner surface of the base and individual variations both on the inner and the outer topography (Fig. 3a2-a3). In the radial plane, transversal fractures present a heterogeneous internal structure with oblique discontinuities (Fig. 3a1). The correlation of these macro-traces suggests that the bases were formed at least by several assembled elements with possible oval shapes. The forming of horizontal preferential fractures also suggests the fashioning of vessels with several building phases.

The belly, upper part and rim of the vessels present horizontal and diagonal fractures as well as staggered vertical fractures (Figs. 4, 5). The internal and external topography of the walls preserves horizontal undulations that can be associated with horizontal burrs on the inner surface (Fig. 4a1). The correlation of these traces suggests that the belly and upper parts of the vessels were formed by horizontal or diagonal coils. In the radial plane, the internal structure is heterogeneous, with a regular distribution of particles and voids forming S/Z-shaped configurations (Fig. 4b1). This type of configuration is generally linked with superimposed coils that are subsequently thinned and stretched (Livingstone Smith, 2007) or coils that are successively alternate overlapped, both externally and internally (Martineau, 2000). In the analysed ceramic vessels, the presence of undulations and burrs on the topography creating horizontal bands (Fig. 4a1) and the oblique configurations of coils in the radial sections suggest that they may correspond to alternate gestures. The internal structure of the upper parts and rims also suggests the forming with oblique assembled coils (Fig. 4a2,

Table 2
Reconstructed forming methods identified in the ceramic assemblage of Phase IV in Cueva de El Toro. *Bases included in the analysis.

Forming Methods	Number of vessels / bases	Base Forming	Belly Forming	Upper Part/Rim Forming	Shaping Techniques
TCT1	2	Several assembled elements (oval depressions and fractures, with oblique discontinuities in the radial plane)	Coils with alternate overlapping (S/Z-shaped configurations in the radial plane)	Coils with alternate overlapping, internally and externally overlapped (S/Z-shaped configurations in the radial plane)	Traces of scraping on the inner surface of the belly
TCT2	2*	Shaped disc with an oval shape (oval fracture with an oblique edge)	Coils with alternate overlapping (S/Z-shaped configurations)	–	–
TCT3	2	Circular juxtaposed elements (curvilinear macro-traces, laminar fractures and long oblique discontinuities in the radial plane)		Circular juxtaposed elements (laminar fractures and vertical discontinuities in the radial plane)	–
TCT4	1	Moulding over a convex support (regular profile and topography, compression of the internal structure in the radial plane and development of fissures parallel to the surfaces)		Coil externally overlapped (horizontal variations in the external topography of the rim)	Traces of scraping on the inner surface of the rim
TCT5	1	Pinching technique (finger-print in the inner part of the base, uneven variations of wall-thickness and vertical cracks)			
Total	6 / 2*				

Table 3
Partial forming sequences identified in the ceramic assemblage of Phase IV in Cueva de El Toro. *Bases included in the analysis.

Forming Methods	Number of vessels / ceramic elements	Base Forming	Belly Forming	Upper Part/Rim Forming	Shaping Techniques
–	4*	Several assembled elements (oval depressions and fractures, with oblique discontinuities in the radial plane)	–	–	
–	22 / 5	Preserved in one small-size vessel, not determined	Coils with alternate overlapping (S/Z-shaped configurations). Not determined in 2 cases	Coils with alternate overlapping, with the last coil internally and externally overlapped (S/Z-shaped configurations). Without the preservation of the rim in 8 cases	Traces of scraping on the inner surface of the belly (n = 4)
–	50 / 5	–	–	Coils with alternate overlapping, with the last coil internally and externally overlapped (S/Z-shaped configurations). Without the preservation of the rim in 3 cases	
–	4 / 1	–	Circular juxtaposed elements (curvilinear macro-traces, laminar fractures and long oblique discontinuities in the radial plane)	–	
–	13	–	Sub-circular fractures and macro-traces partially preserved, not determined	Coils with alternate overlapping, with the last coil internally and externally overlapped (S/Z-shaped configurations). Without the preservation of the rim in 3 cases	
Total	89 / 15				

5b2), with the last coil internally or externally overlapped (internal or external oblique discontinuity in the radial plane).

In addition, several vessels display regular surfaces with grooves that were not removed with surface treatments. These traces suggest that the surfaces were scraped, which modified the wall-thickness and also removed the previous manufacturing traces produced by the initial forming techniques.

4.2. Shaped disc and assembled coils

The TCT2 forming method has been reconstructed on the basis of two conical profiles with preserved bottoms and bellies (Fig. 6). The two conical profiles show a different topography for the base and the belly. In the bases, the topography is uniform both inside and outside, whereas the topography of the belly preserves several horizontal undulations (Fig. 6a2). Only one of the vessels has a fractured base that enables recognition of its forming process. This base has an oval-shaped fracture with an oblique margin at the edges (length 7.6 mm and 5.8 mm wide fractured part) (Fig. 6b). On the internal surface, the oblique edge is associated with a laminar fracture that corresponds to the beginning of the belly (Fig. 6b1). This fracture suggests that the base was formed with an oval disc, dragging of the margins to form an oblique edge. This oval disc is identified in one of the conical bases while in the other case, as the base is not fractured, the use of this element cannot be confirmed. Nonetheless, the regularity of the topography and density of the bottom in comparison to the belly (Fig. 6a2) may suggest that in this case the base was also formed by a disc.

In the belly, the topography displays undulations on the surfaces (Fig. 6a2). In the radial plane, the internal structure is heterogeneous, forming S-shaped configurations (Fig. 6a1). Together, these traces suggest the use of the same forming sequence as the TCT1 method with the assemblage of coils with alternate overlapping.

4.3. Forming process with juxtaposed circular elements

The reconstruction of the TCT3 forming method was based on several vessels displaying a series of macro-traces that morphologically differ from the other forming processes identified. These traces are identified in 2 vessels with practically entirely preserved profiles, in 4 vessels with only partially preserved bellies and 1 pottery sherd from a belly not individualised.

The lower parts of the vessels display sub-circular and circular-shaped fractures in the frontal view (Fig. 7c). These sub-circular fractures can be associated with laminar fractures with wavy edges (Fig. 7b1) that form layers parallel to the surface in the radial plane (Fig. 7b2). Sub-circularities can also be identified on the internal surfaces where curvilinear burrs and sub-circular fractures merge together in circular juxtaposed shapes (Fig. 7f; Fig. 8b2). In a particular case, laminar fractures coincide with sherds detached from the belly, which also present a sub-circular shape and an uneven topography that do not correspond to the internal surface of the vessel (Fig. 7g1-g3).

In the radial plane, the internal structure is heterogeneous and forms long discontinuities parallel to the surfaces associated with sub-circular configurations (Fig. 8b1). These long discontinuities can correspond to vertical fissures formed in the cross-sections and associated with several layers that form laminar fractures parallel to the surfaces (Fig. 7a). The forming of these layers can also be observed on the internal and external surfaces (Fig. 7e). Similarly, in the horizontal cross-section of a vessel, long sub-circular configurations appear juxtaposed over a horizontal layer facing the inner wall (Fig. 7d).

These macro-traces that delimit the edge of circular elements are not identified in the current series of ethnographic and experimental collections. In contrast, this evidence does bear similarities to several features documented in the first pottery productions from Abri Pendimoun, Arene Candide (Gomart et al., 2017) and La Farigoule 2 (Manen et al., 2019b). At these sites, ceramic vessels present networks of curvilinear fractures and circular convexities on the topography, detached sherds from the body and sub-circular configurations associated with long oblique discontinuities in the radial plane. According to Gomart et al. (2017), these traces suggest that the vessels were built by means of circular juxtaposed and fused patches, each formed by a spiral coil, with a patch diameter of around 44 ± 2.3 mm (standard deviation). The interpretations of this forming process using spiralled patches are also based on other traces, such as the circular organization of pores and

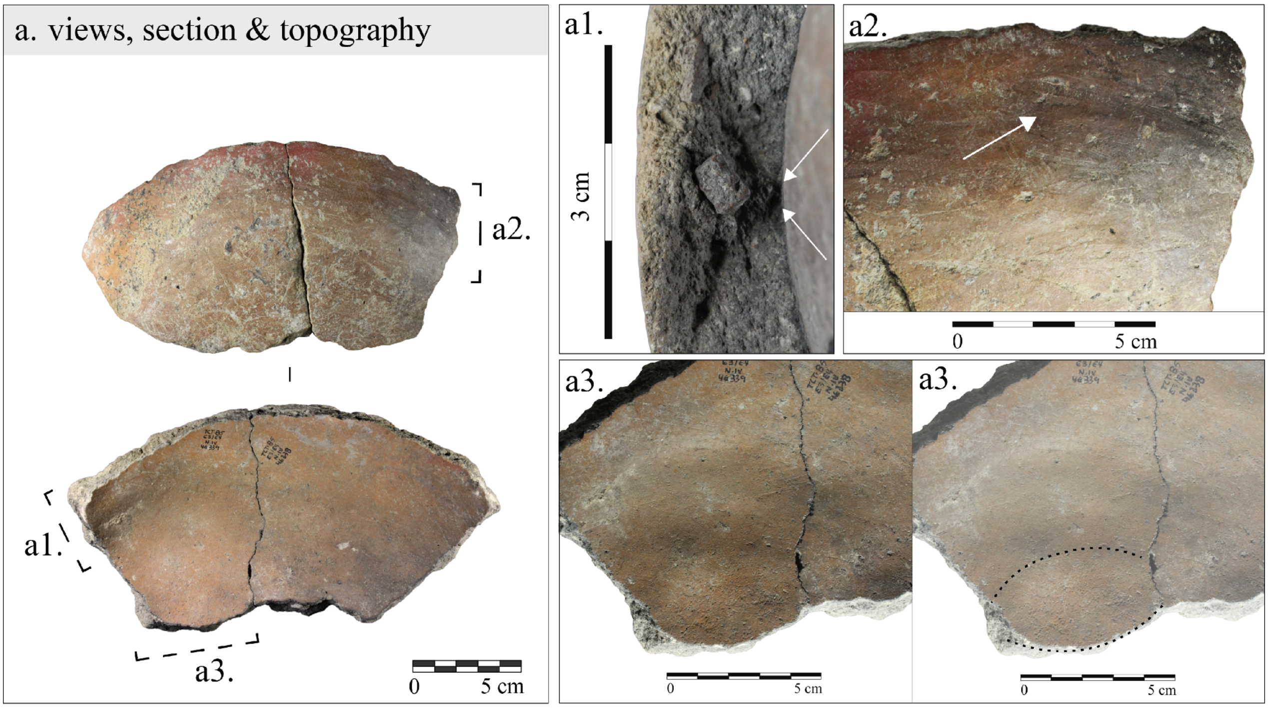

Fig. 3. Macro-traces of TCT1 forming method associated with the bases. a1: Transversal fracture with oblique discontinuities in the radial plane (white arrows). a2: Horizontal preferential fracture and individual horizontal variation on the external topography. a3: Wavy depressions and convexities on the inner surface and sub-circular fractures, forming together an oval shape. These macro-traces suggest that bases were formed by several assembled with a possible oval shape. Edition & photography: J. Cámara.

particles in the tangential plane visible at macroscopic scale or determined by micro-computed tomography analyses (μCT) (Gomart et al., 2017). In the case of Cueva de El Toro, these circular elements can also be interpreted as partially juxtaposed patches, with diameters of around 52 ± 8.4 mm (n°. of measured patches = 6). Nonetheless, sub-circularities inside these circular elements can only be observed in some specific cases (Fig. 8b1), which do not enable us to confirm whether all these circular elements were formed by a spiral coil.

4.4. Moulding over a convex support and assembled coils

The reconstruction of the TCT4 forming method is based on one vessel with an entirely preserved profile (Fig. 9). The external topography of the base and the belly is completely regular and the surface was vertically polished. The profile is also regular, despite a progressive decrease in wall-thickness from the base to the belly (Fig. 9b). Only one horizontal variation in the external topography of the rim is preserved, which coincides with a thickening of the profile (Fig. 9a1).

The internal surface presents an uneven smoothing treatment, with bands at the base (Fig. 9c3) and a grainy texture with linear striations and protruded grains on the belly (Fig. 9c2). Additionally, the inner surface of the rim preserves a concentration of several grooves with marked edges (Fig. 9c1).

In the radial plane, the internal structure of the base and the belly is compressed, with a vertical distribution of a-plastic particles and voids and the formation of cracks parallel to the surfaces (Fig. 9b1-b2). The internal structure of the rim is heterogeneous, although it is so eroded that it is not possible to discern the orientation of pores and particles.

Altogether, these macro-traces suggest that the lower part was moulded over a convex support whilst the rim was formed by horizontal coils. The bottom and belly were built over a convex support, regularising the external surface and obtaining a regular profile and topography. Precisely, as a consequence of the intensive regularization of surfaces and compression of the paste it is not possible to confirm whether this vessel was moulded by a mass of paste or by assembled elements. The support practically covered the piece as far the upper part of the belly and once extracted the internal surface was smoothed, leaving striations in the belly and grooves in the base, the latter caused by a major displacement of clay (Lepère, 2014). The rim was then formed by coils, thickening its profile. The inner surface of the rim was subsequently scraped, forming several grooves that removed the leftover paste in order to regularize this part of the vessel. Additionally, the morphology of the grooves also indicate that the scraping was performed when the paste of the vessel was at its initial hard-leather stage.

4.5. Vessel built by pinching

The TCT5 forming process comprises a single, fully-preserved vessel. The external surface is polished, leaving a regular topography, whilst the internal surface is smoothed. A hemispherical hollow is identified on the inside of the base, which is vertically oriented from the bottom towards the belly (Fig. 10a2). This vessel also presents uneven variations in the thickness of the walls, decreasing in the base and partially increasing in the belly. The only observed fractures correspond to vertical and irregular cracks formed from the rim to the belly (Fig. 10a1).

The morphology of these traces and the small size of the vessel suggest that this vessel was formed by pinching. The hollow located in the inner part of the vessel corresponds to a finger-print produced when pinching and subsequently stretching the vessel from the bottom to the belly. In turn, the uneven variations and the cracks may have been formed by stretching the walls vertically up to the rim. The size of the vessel also suggests that it was fashioned in only one forming sequence.

4.6. Variability of coil heights

Coil height was measured in a large number of vessels, most of which only preserve the upper part and rim. The distribution of values in the box plot shows that coil height measurements are similar both in the belly and in the upper part of the vessels (Fig. 11a). Considering the percentage of the Coefficient of Variation (CV), coil heights are quite

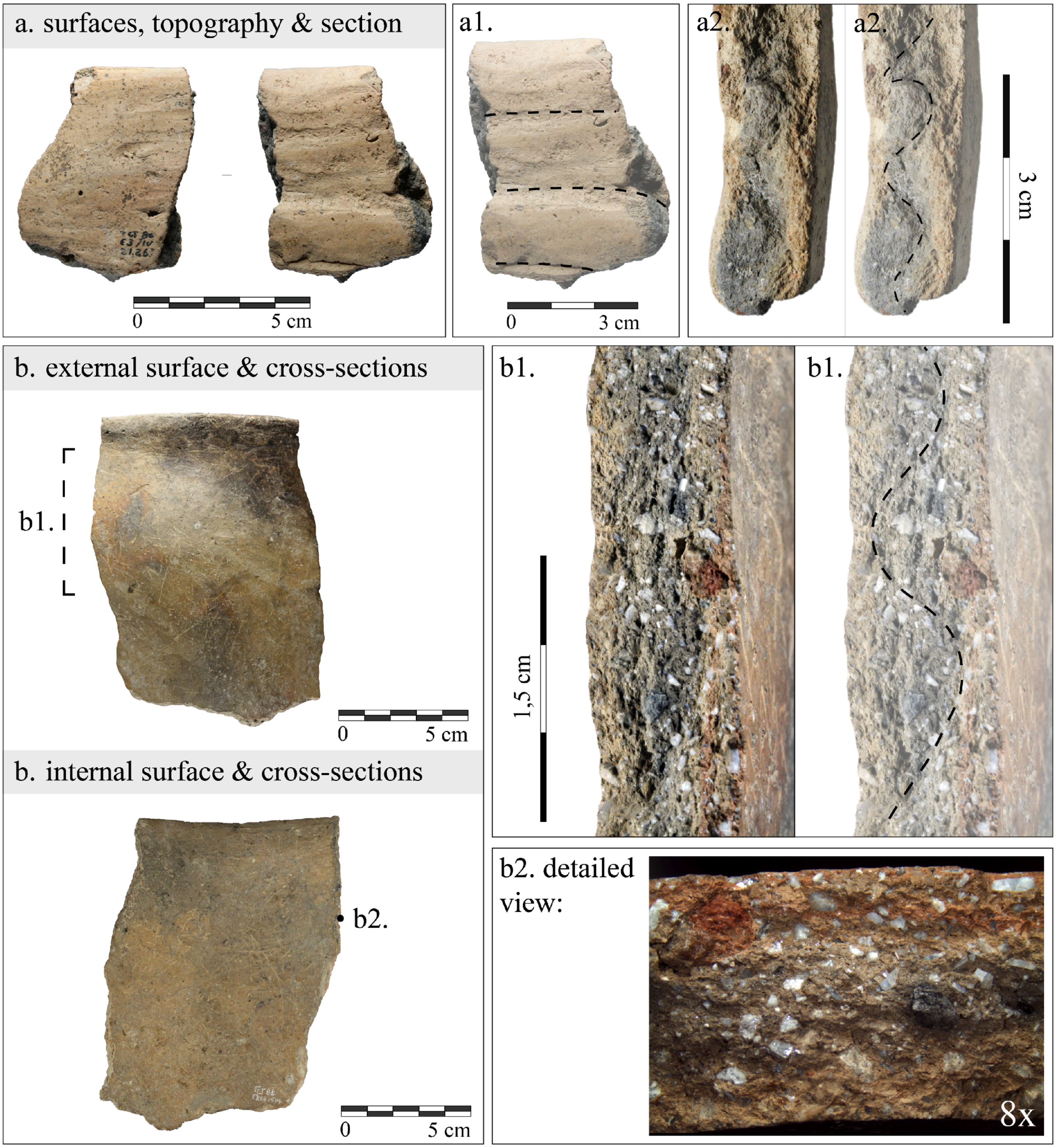

Fig. 4. Macro-traces associated with the TCT1 forming method. a2: Horizontal undulations and burrs on the internal surface (black discontinuous dashes). a2 & b1: S/Z-shaped configurations on the cross-section of the belly and the rim. The distribution of porosity and a-plastic particles is oblique to vertical. b2: Detailed view of distribution of pores and particles. These macro-traces suggest the forming process of the belly and the rim with oblique alternate coils. Edition & photography: J. Cámara.

variable when all measures are tested together. Nonetheless, the CV value from the measurements of the belly is slightly higher compared to the CV value from the upper parts (Table 1, supplementary material). This may suggest that coils were of similar height, although several coils from the upper parts and the rim were less variable and probably less deformed in comparison to the ones used to form the belly.

The scatter plot shows a linear correlation between wall-thickness and coil height in the belly and upper parts of the vessels (Fig. 11b). Non-correlation *p* values of the Pearson test also reveal that these variables are both correlated for the belly and the upper part of the vessels (Table 2, supplementary material). The large number of measurements oscillates between 10.1 and 16.4 mm, while there are lower height values of between 7.9 and 9.7 mm and others that are higher than 17.6 mm. This variability may indicate that the coils were slightly or not deformed, while the highest measures may correspond to higher assembled elements that were more elongated or deformed during the forming process.

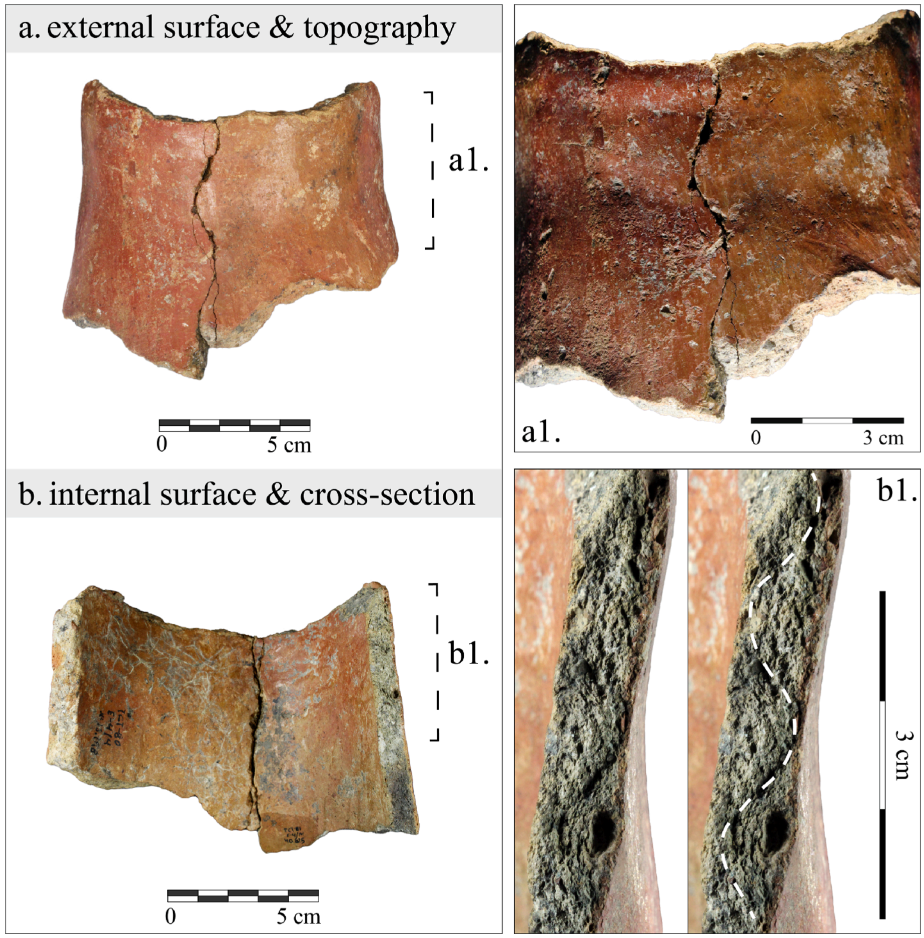

Fig. 5. Macro-traces associated with the TCT1 forming method. a1: Horizontal undulations on the external topography of the collar. b1: S/Z-shaped configurations on the cross-section of the collar. The orientation of particles and voids is oblique to vertical. These macro-traces suggest the forming process of the collar with oblique alternate coils. Edition & photography: J. Cámara.

4.7. Attachment systems of handles and grip elements

Grip and hanging elements from the ceramic assemblage of Cueva de El Toro present different ways to attach these elements on the walls. The sample analysed with diagnostic traces comprises 30 sherds of handles and lugs that are not assigned to any specific vessel as well as 29 elements that are preserved on individualised vessels (Table 1).

The forming varies according to the morphology of handles (ribbon, annular, tunnelled and bilobed shapes), spouts and impressed cordons. In the case of spouts and some handles, the sections and edges of holes indicate that both these elements were drilled (Fig. 12a2).

The systems used to add handles and lugs have been identified by a series of manufacturing traces, such as laminar fractures, cracks in the cross-sections and burrs preserved in the internal and external surfaces. First, there is a predominance of superimposed elements on the edge of the rims (lenticular appendix and one over-lifted handle, n = 12) and elements attached by a simple hook (handles and cordons, n = 12) (Fig. 12a1). Second, handles can also be attached by partial insertions creating a concavity on the walls (n = 13) or by pinching the surfaces (n = 6). The latter system is identified by the presence of hemispherical hollows in the laminar fractures of the surfaces or at the ends of handles (Fig. 12a2 & 12b1). Finally, some handles can be attached by complete insertions, using a pivot or a protuberance formed on their edges (Fig. 12c1-c2). This system is the least frequent (n = 4), although this may be a consequence of the non-formation of fractures and the lack of handles undetached from the walls.

5. Discussion

5.1. Variability of pottery forming processes identified in Cueva de El Toro

The results obtained from the examination of manufacturing traces enabled reconstruction of the forming processes that were used in ceramic production at Cueva de El Toro during the Early Neolithic occupation (Phase IV, 5280–4780 cal. BCE 2σ). Within the degree of fragmentation of ceramic vessels, the recognition of techniques was more feasible in those vessels for which a high number of diagnostic traces were preserved. In some vessels, however, the technical interpretation was conditioned by the degradation and obliteration of manufacturing traces, for reasons such as intensive surface treatments and decorations, the deterioration of fractures and the reuse of potsherds as tools (García Rosselló and Calvo Trias 2013).

The coiling forming process was recognised by examining traces preserved in the topography and surfaces, the way in which vessels are fractured and the analysis of cross-sections in the radial plane. This forming process is identified in several vessels which preserve the belly, although it is predominant in the forming of the upper parts and rims. Overall, the use of coils is similar in terms of technical gestures (S/Z-shaped configurations) and coil height. This may indicate that these gestures correspond to a similar dynamic in the forming process of the belly and upper parts of the vessels, with coils that were slightly or not deformed and, in some cases, more elongated.

The examination of macro-traces also made it possible to distinguish

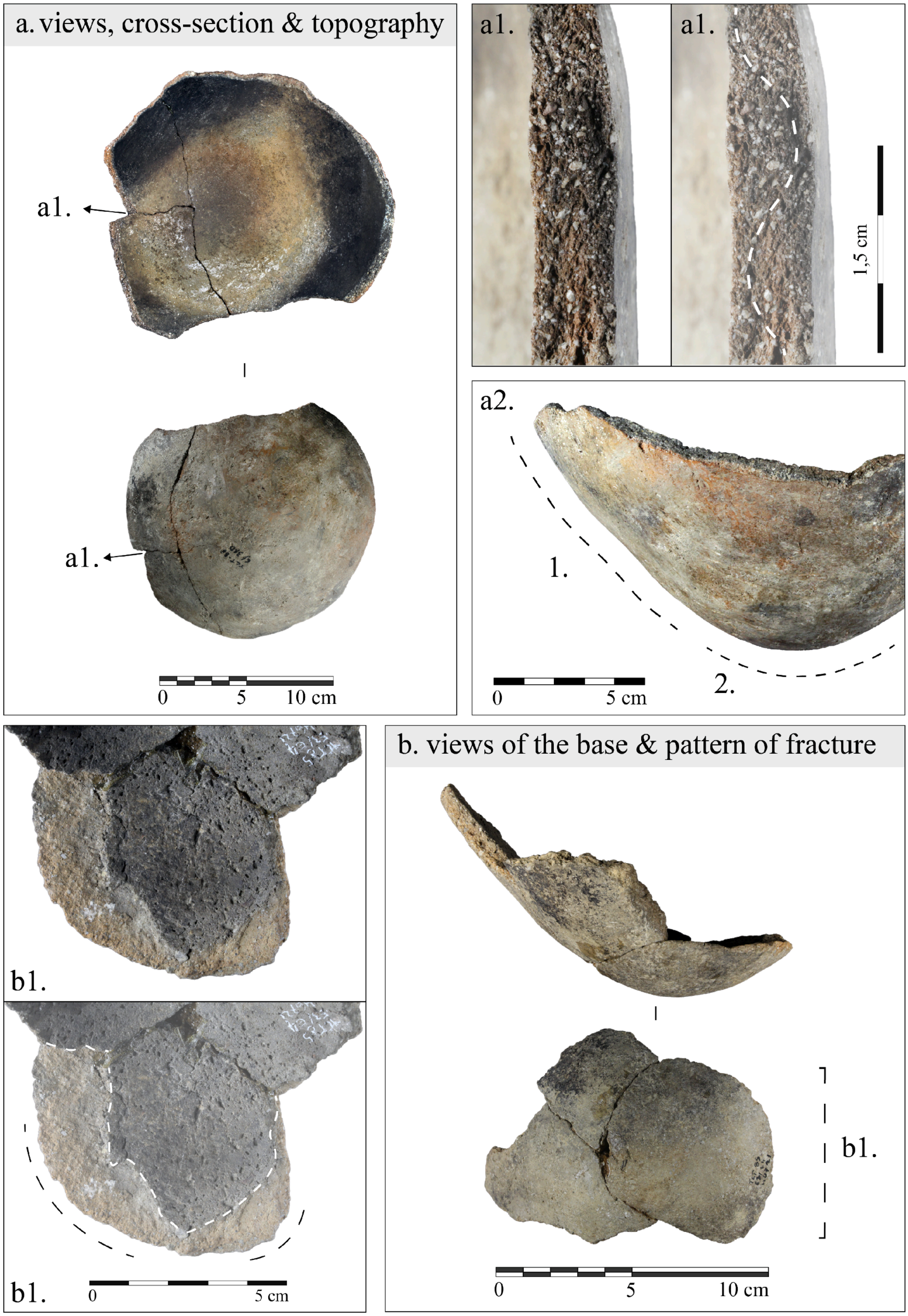

Fig. 6. Macro-traces of the TCT2 forming method. a1. S/Z-shaped configurations on the cross-section at the end of the base and the belly. The orientation of particles and voids is oblique to vertical. a2. Undulations in the external topography of the belly (1) and regular topography with a large thickness at the base (2). b1. Oval-shaped fracture of the base. The internal surface of the base presents a laminar fracture (white discontinuous dashes) with an oblique edge (black discontinuous dashes). The correlation of these macro-traces suggests that bases were formed by an oval disc and the bellies were formed by oblique coils. Edition & photography: J. Cámara.

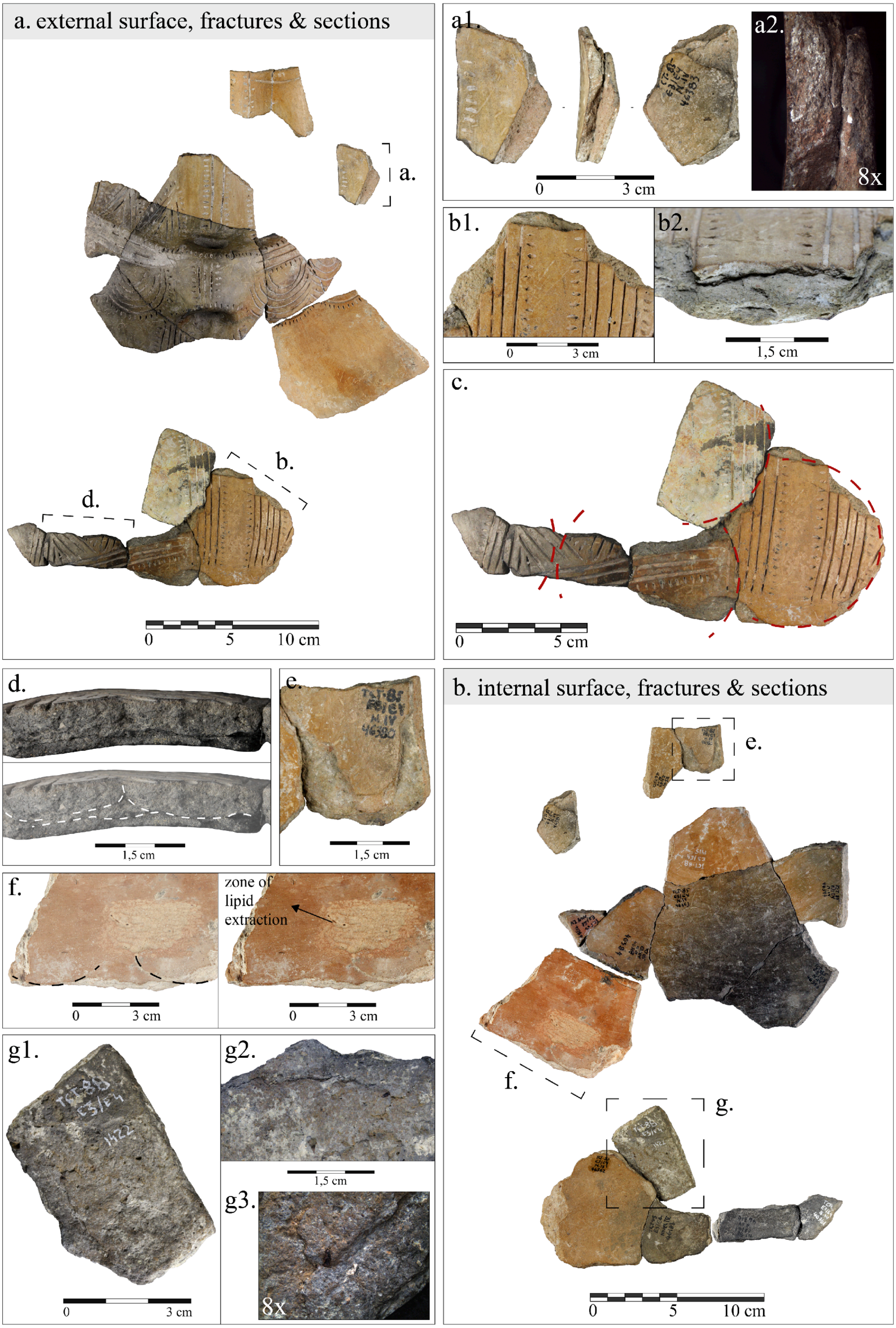

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Fig. 7. Macro-traces associated with the TCT3 forming method. a1. Vertical fissure formed in the cross-section of the collar. This fissure forms a long intermediate discontinuity in the cross-section parallel to the surfaces. Surfaces also present internal and external laminations. a2. Detailed view of fissures parallels to the surfaces. b1. Laminar fractures on the external surface of the belly with wavy edges. b2. Horizontal cross-section of the belly with a layer parallel to the external surface. c. Sub-circular and circular-shaped fractures on the belly. This fracturing pattern is correlated with the laminar fractures and the horizontal cross-sections. d. Horizontal cross-section of the belly: horizontal layer placed towards the inner wall and sub-circular configurations placed towards the outer wall. Sub-circular configurations appear juxtaposed over the horizontal layer. e. Internal laminations on the collar with several layers. f. Burrs and fractures which merge together in subcircular shapes. Both sub-circular shapes appear juxtaposed on the internal surface of the belly. g1. Sub-circular sherd detached from the belly. The external surface of the sherd preserves decor motives whilst the internal surface presents an irregular texture with leveled areas and wavy burrs. g2. Horizontal burrs parallel to the wavy edges of the detached sherd. g3. Detailed view of burrs preserved on the internal surface. Together, these macro-traces suggest that the lower parts, the belly and the collar of this vessel were formed by circular juxtaposed elements. Edition & photography: J. Cámara.

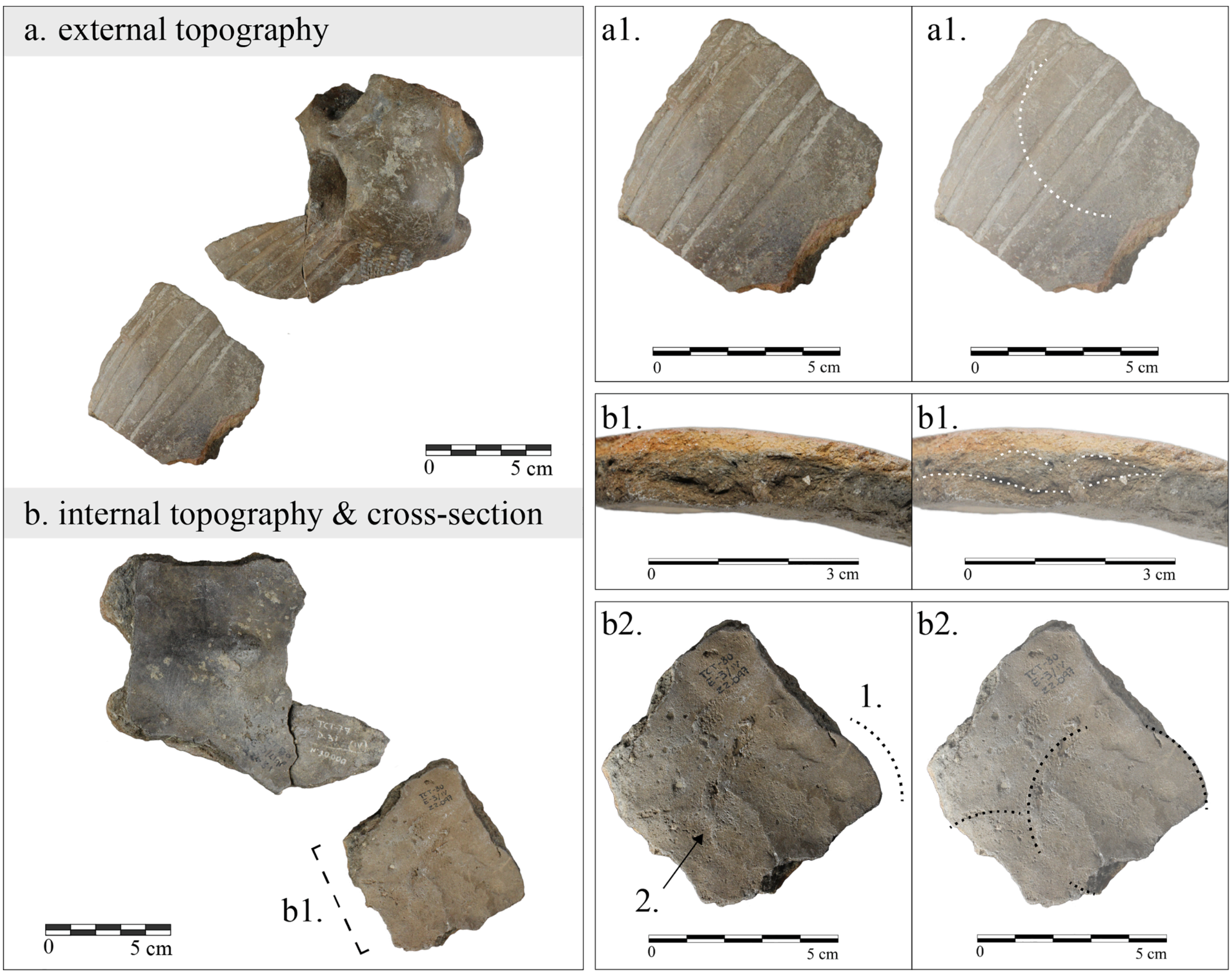

Fig. 8. Macro-traces associated with the TCT3 forming method. a1. Subcircular flat areas on the external topography. b1. Long oblique discontinuity associated with subcircular configurations in the radial plane. b2. Curvilinear fractures (1) and burrs (2) that merge together in circular elements. These macro-traces suggest the forming process of the belly with circular elements, probably each formed by a spiral coil (patches), partially juxtaposed among them. Edition & photography: J. Cámara.

the forming technique of bases from the ones that uses several assembled elements (TCT1) or an oval-shaped disc (TCT2). The interpretation of the assembled elements used in the TCT1 method may correspond to several oval elements similar to the one that is used in the TCT2 forming method, although this hypothesis needs to be proven by other analytical methods.

The forming process with juxtaposed circular elements (TCT3) was interpreted by comparing macro-traces with a series of recognisable traces – curvilinear fractures, burrs, an uneven topography and circular flat areas (Fig. 8a1) – documented in the ceramic assemblages from several Early Neolithic sites from the Western Mediterranean (Gomart et al., 2017; Manen et al., 2019b). In Cueva de El Toro, these series of traces suggest that these elements may also correspond to similar patches that were partially juxtaposed to form entire ceramic vessels (Fig. 7). However, in those vessels with only partially preserved profiles, the juxtaposition of patches is only recognised in the belly. This may be because the vessels were entirely formed by juxtaposed patches or, contrarily, because the forming sequence combined the use of juxtaposed patches and the use of coils to build the upper parts and rim.

Precisely, in several vessels in which the upper part and the rim are formed by coils, the forming process of the belly cannot be recognised. This is because of the low degree of preservation of the belly (n = 2) or a consequence of degradation and partial preservation of macro-traces (n = 13) (Table 3). In fact, these vessels also have partial macro-traces – e.g., sub-circularities and laminar fractures with wavy edges – preserved in the belly, for which insufficient referential ceramic series have been

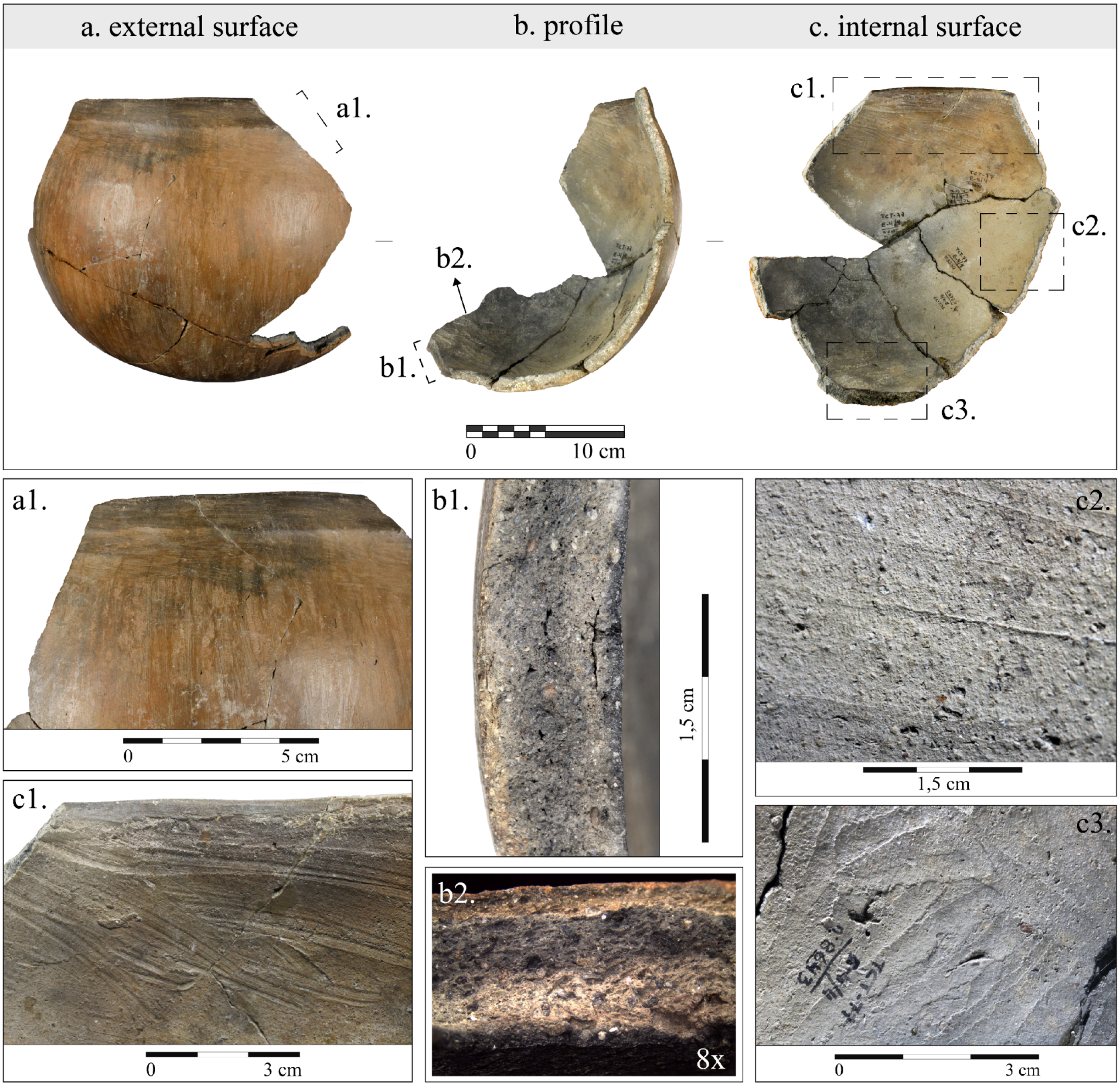

Fig. 9. Macro-traces observed in TCT4 forming method. a1. Horizontal variation on the external surface of the rim. The edge presents a ridge which allows its distinction on the external topography. b1. Cross-section of the base with parallel fissures to the surface. The orientation of particles and voids is vertical. b2. Detailed view of a cross-section of the belly: the paste is compressed and the distribution of porosity and particles is parallel to the surfaces. c1. Horizontal and diagonal grooves on the internal surface of the rim with internal striations, marked edges and flat sections. c2. Internal surface of the belly with linear striations, protruding grains (grainy texture) and particle extractions. c3. Bidirectional grooves on the internal surface of the base. Together, these macro-traces suggest that the base and the belly were moulded over a convex support whereas the rim was formed by horizontal coils and an external overlapped coil. The internal surface was subsequently smoothed (base and belly) and scraped (rim). Edition & photography: J. Cámara.

reported to identify their forming process. In these cases, the technical origin of macro-traces must be verified by the application of other methodologies.

The moulding process (TCT4) of the base and the belly was only recognised by examining macro-traces in a globular vessel that does not present decorations. This forming process reflects a set of traces related to the use of an internal support, although it cannot be confirmed whether it was moulded by a mass or by assembled elements since the internal structure is compressed and the topography regularised. In this regard, the hypothesis that the moulding process was performed by using circular elements detected on this site cannot be ruled out.

Finally, the last forming process concerns the pinching technique (TCT5) which is associated to a small-size vessel without decors.

5.2. Comparison between pot-forming sequences and morpho-decorative features

A first comparison between ceramic forming processes and morpho-decorative traits has been conducted, which enables to propose several initial hypotheses regarding the correlation of these ceramic features during the Early Neolithic occupation of Cueva de El Toro.

The use of coils is linked with ceramic products of different shapes and sizes. In those vessels with preserved belly profiles, this forming sequence is recognised in vessels with ovoid shapes, with collar and globular shapes, the latter being predominant in the ceramic assemblage (Fig. 2: 9862, 9431, 88/1509, 41900). The forming process with circular elements also comprises vessels with a globular shape and collar (Fig. 2:

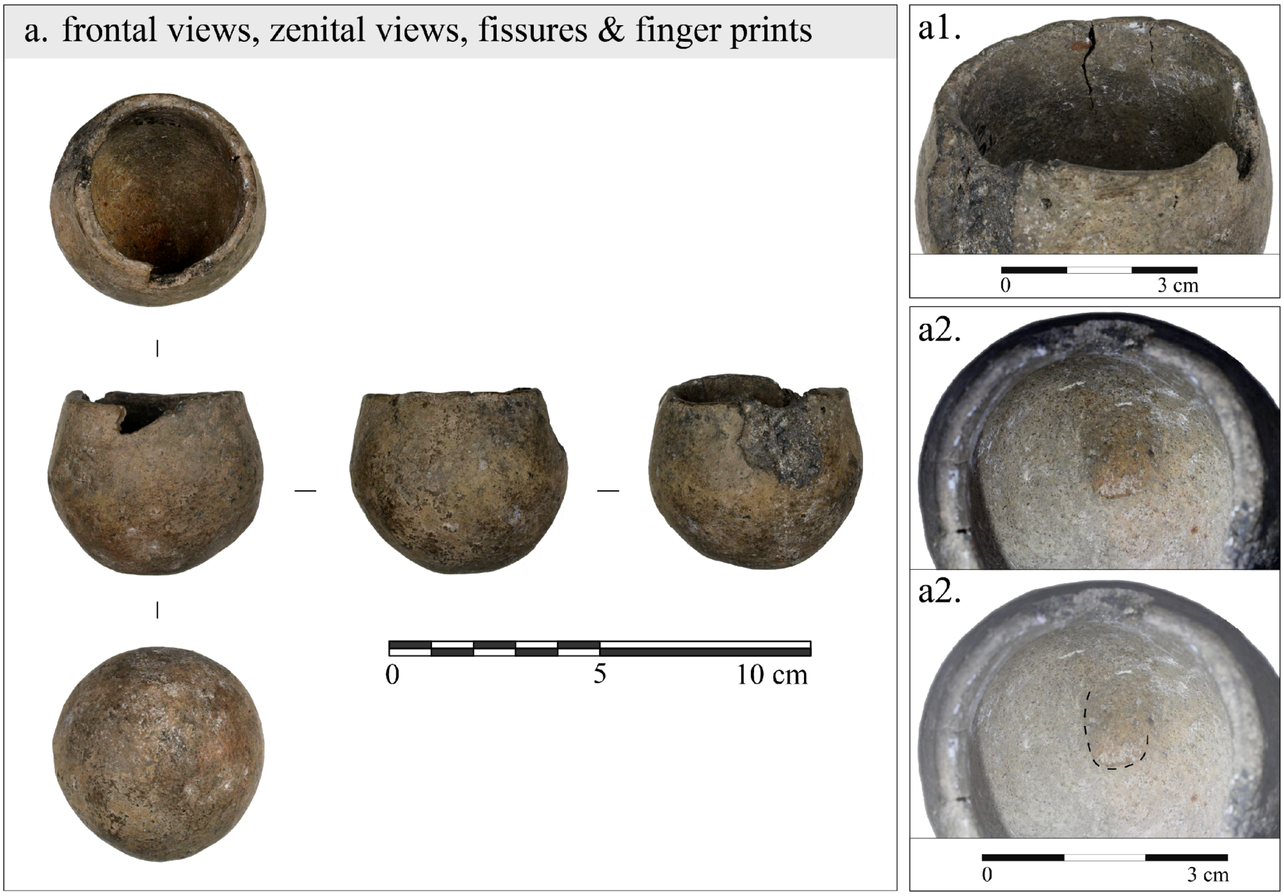

Fig. 10. Macro-traces observed in the TCT5 forming method. a1: Irregular and vertical cracks located at the external and internal surface of the rim. a2: Individual hollow placed at the bottom of the base. Its shape is quadrangular and prompts vertically towards the inner surface of the belly. These macro-traces suggest the forming of the vessel by pinching from the base to the rim. Edition and photography: J. Cámara.

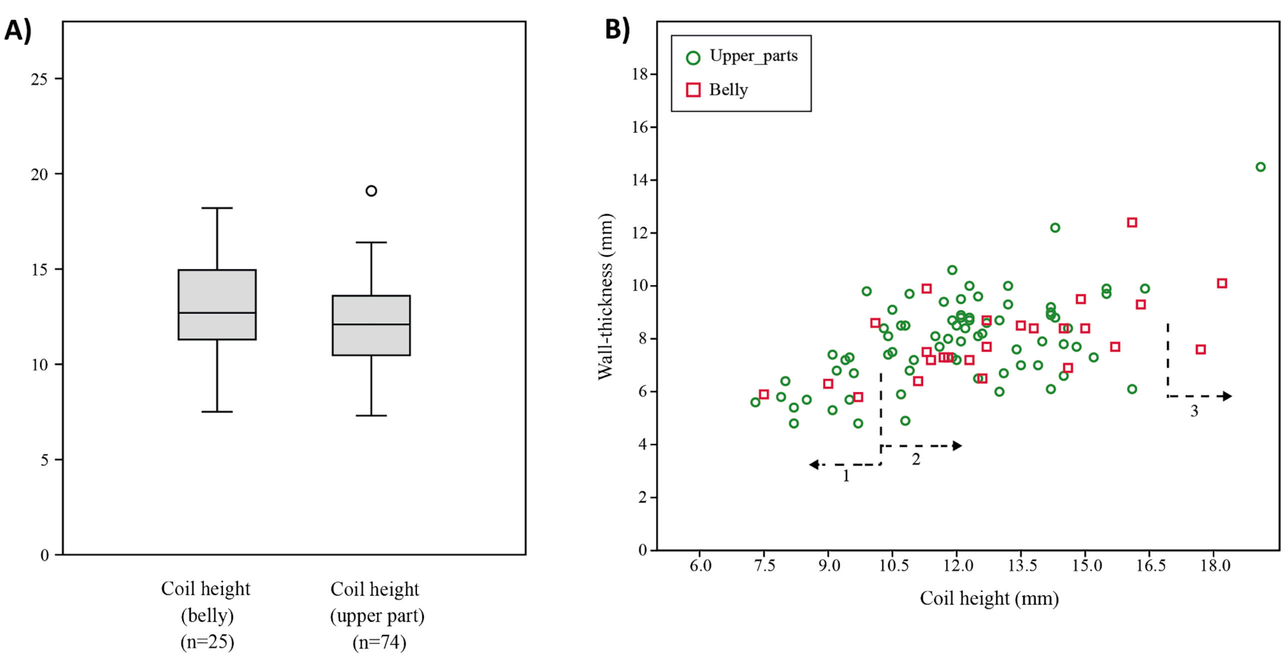

Fig. 11. Box plot diagram with the distribution of coil height measures of the belly and the upper part from each ceramic individual (A) and scatter plot comparing coil height and wall-thickness measures of the belly (red squares) and the upper parts (green circles) from each ceramic vessel (B). Coil heights between 7.9 and 9.7 mm (1), 10.1–16.4 mm (2) and 17.6–19.1 mm (3). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

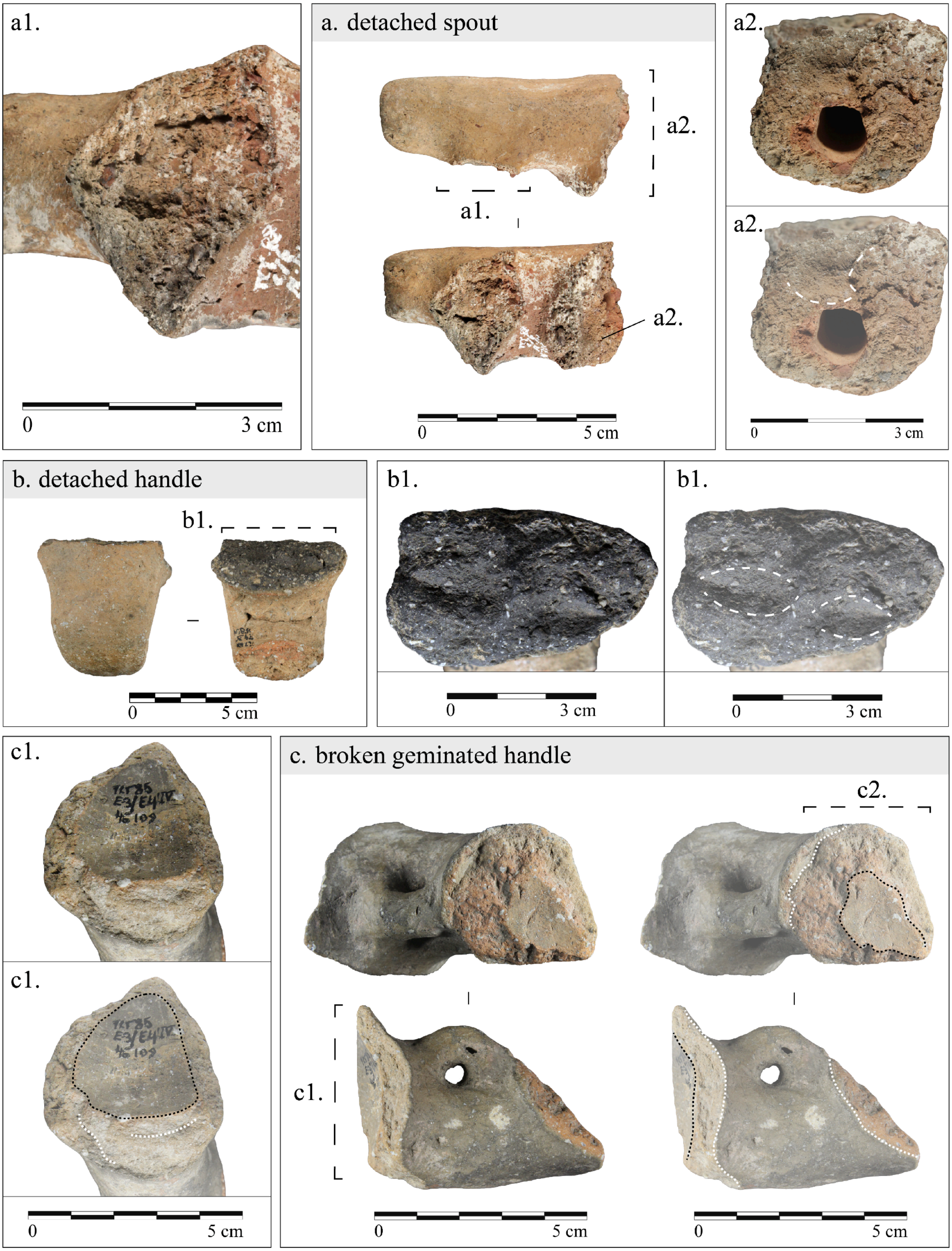

Fig. 12. Macro-traces associated with the attachment systems with grip elements. a1: External laminar fracture in the midpoint of the spout. a2: Laminar fracture and section of the broken edge of the spout with a hemispherical depression. These traces suggest that the spout was attached both by a simple hook (a1) and pinched (a2). b1: Detached handle with a laminar fracture which preserve two hemispherical depressions. These traces suggest that handles were added by partial insertions, pinching the edge of the handles. c1 & c2: Both broken ends of a geminated handle, which preserve the inner surface of the geminated vessel (black dashes). The edges show the protuberance used to insert completely the handle (white dashes).

18127), while the vessel moulded over a convex support is only related to a globular shape (Fig. 2: 8330). Hence, these forming processes seem to be used in the production of several vessel shapes (TCT1) or the same typology of vessels (TCT3 & TCT4).

Conversely, some forming methods were only identified in particular shapes and sizes of vessels. The use of the pinching technique (TCT5) is restricted to a small-size vessel, which is also particularly located in a specific context inside the cave (Santana et al., 2019), isolated from the rest of the ceramic production in the domestic area (Fig. 2: 6–235). The forming of conical bases with a shaped disc (TCT2) have only been identified in the two conical profiles preserved within the ceramic assemblage of Phase IV (Fig. 2: 6–339). This type of shape is widely documented in the ceramic production from the southeast Iberian Peninsula (Carvalho, 2011; Manen et al., 2007) and northwest Africa (El Idrissi, 2012; Martínez Sánchez et al., 2018). Thus, the hypothesis that the production of such vessels may be linked to the forming of the lower parts with an oval disc cannot be ruled out.

Concerning grip elements, it is interesting to note that no joining system can be strictly associated with any specific type of handle. For instance, spouts and handles are attached with partial insertions by pinching the walls or with complete insertions by drilling the walls. This suggests that these variations might correspond to distinct ways of doing in the ceramic production methods or that the use of these systems was conditioned by functional factors in order to ensure the stability of handles and lugs on the walls.

When comparing forming processes and decorations, no clear relation can be established between these two pottery features. As with shapes, vessels formed by coils comprise distinct decorations, including those vessels with only the upper part and rim preserved. Together, these vessels include the majority of the decorations documented in Phase IV: the use of incisions, impressions, applied cordons, *boquique* (stab-and-drag) and the application of *almagra* (Camalich Massieu and Martín-Socas, 2013). Vessels formed by circular elements are also associated with decorations that combine incisions and impressions, the *almagra* or the *boquique*.

The surface decoration with *almagra* represents one of the most widespread decorations during the Early Neolithic in Andalusia (García Borja et al., 2014; Martín-Socas et al., 2018), while the *boquique* is mainly concentrated in inland regions of the Iberian Peninsula (Alday and Moral del Hoyo, 2011). In contrast, decorations with incisions and impressions are documented across the Iberian Peninsula and southern France in the late 6th millennium cal. BCE (García Martínez et al., 2011; Guilaine and Manen, 2012; Oms et al., 2016). Results from Cueva de El Toro show that these decorations appear to be related to the forming processes of coils and the use of juxtaposed circular elements. This possibility, along with the hypotheses formulated for the shapes, needs to be further investigated through the development of new research and contrasted with other ceramic assemblages from Early Neolithic contexts with similar morpho-decorative features located in this area of the Iberian Peninsula.

5.3. *Context and chronological framework of the first pottery forming processes during the Early Neolithic*

Current technological studies on the first pottery forming processes have revealed several trajectories regarding the technical practices used in pottery manufacture that spread with the Neolithisation process. Overall, pottery forming processes identified in Cueva de El Toro fit with the forming-sequences documented in several Early Neolithic sites from the Mediterranean basin and Western Europe (Fig. 1). At Colle Santo Stefano and Ripa Tetta (southeast Italy, 5800–5600 cal. BCE), the vessels are built with thin or elongated, obliquely assembled (S-shaped configurations) or superimposed (O-shaped configurations) coils (Angeli and Fabbri, 2017; Colombo, 2017; Gomart et al., 2017). In Central Europe, coiling techniques are also widely documented in the ceramic production of several LBK sites, such as Cuiry-lès-Chaudardes (northwest France) (Gomart, 2014), Balatonszárszó-Kis-erdei-dűlő (Hungary) (Kreiter et al., 2017) and Bylany (Czech Republic) (Neumannová et al., 2017; Thér et al., 2019), where forming sequences vary according to the gestures with which coils are assembled and deformed. Hence, the assembly gestures of coils documented at these sites – S/Z-shaped configurations with slightly or not deformed coils - display similarities with the coiling technique with alternate overlapping documented at Cueva de El Toro.

In the context of the Western Mediterranean, there are also remarkable similarities between several vessels formed by circular elements documented at Cueva de El Toro and the spiralled patchwork technology located at the first farming sites of Abri Pendimoun and Arene Candide (Ligurian-Provencal Arc) (Gomart et al., 2017), as well as la Farigoule 2, Peiro Signado and Pont de Roque-Haute (southeast France, 5800–5600 cal. BCE) (Manen et al., 2019b). The *Impressa* pottery from these sites show several traces that reflect the use of spiralled patches to uniformly build ceramic vessels. In the case of Cueva de El Toro, the morphology of macro-traces preserved in the ceramic assemblage do not enable us to completely verify whether all these circular elements were also formed by a spiral coil. If so, the evidence of this technology at Cueva de El Toro would reflect the continuity of this technique in more recent chronologies and its distribution in more remote areas from the Western Mediterranean, such as the southern Iberian Peninsula.

On the contrary, there are no currently available data on the forming of the first ceramic productions from the Western Mediterranean using oval discs, the pinching technique or the moulding process. In particular, the use of internal supports to shape the lower parts and belly of vessels is not currently documented for the Early Neolithic in Europe. The latest technological data reported suggests the use of concave supports in LBK contexts to shape bases that were previously made by spiralled coils (Gomart, 2014) or remarkably at Polgár-Ferenci-hát (Hungary) where the base and the belly of vessels are formed by coils and shaped by moulding against concave supports (Gomart et al., 2020). In contrast, in more recent chronologies the moulding technique over convex supports is well-documented at Mines de Gavà (northwest Iberian Peninsula) (Calvo Peña, 2019) and in the Aisne valley (northeast France) (Colas et al., 2015).

6. Conclusions

The technological study of the ceramic assemblage of Cueva de El Toro provides the first empirical evidence of the techniques that were used in pottery-manufacturing processes during the Early Neolithic in the south of the Iberian Peninsula. The results obtained based on the examination of manufacturing traces reveal that several ways of doing coexisted during the occupations of Phase IV at Cueva de El Toro. These ways of doing are represented by the use of coils – with alternate overlapping and slightly or not deformed -, which predominate in the forming of the upper part and rim of vessels; the juxtaposition of circular elements and, in particular, the moulding process with convex supports. Precisely, the coil forming sequence and the use of patches identified on this site also bear similarities with the pot-forming processes documented to date for the Early Neolithic in Western Europe. Furthermore, this study reveals the use of other forming techniques – elements with oval shapes and the pinching technique – that are practically unknown in Early Neolithic contexts from the Western Mediterranean. Altogether, these ways of doing may indicate that the communities who periodically inhabited the cave during the Early Neolithic (5280–4780 cal. BCE 2σ) possessed and used different techniques to produce ceramic vessels. This interpretation is also supported by comparing forming processes with the typology of vessels, which reflect that different forming techniques can be used in the production of several pottery shapes. Moreover, no clear relationship can be established when comparing these forming sequences with decorations, which may therefore suggest that decorations were possibly not related to these technical features of ceramic manufacturing processes.

This investigation has also been compared and contextualised with the distribution of the first pottery forming processes discovered around Western Europe during the Early Neolithic. The coiling technique and the patchwork technology, which appear in southeast Italy and southeast France and the Ligurian-Provencal Arch respectively (Gomart et al., 2017; Gomart et al., forthcoming), is documented in Cueva de El Toro during the Early Neolithic occupation. This data, which must be further investigated in new studies, may confirm the distribution of similar techniques in more recent chronologies in the south of the Iberian Peninsula. Hence, these forming processes could be an indicator of the connections between the southern Iberian Peninsula and the Neolithisation process of the Central and Western Mediterranean, in line with the results of other investigations, such as DNA analyses, among which Cueva de El Toro is included (Fregel et al., 2018). However, there are forming processes such as the use of oval discs and the use of internal supports for which no references have been currently reported in the context of the Early Neolithic in the Western Mediterranean. These cases, which must be compared with other archaeological contexts, may reflect a more complex panorama of the technical practices that were used in the manufacture of the first pottery productions during the Early Neolithic in this area.

Ultimately, the hypotheses formulated from this site must be properly contrasted with new analyses (X-ray imaging, µCT, thin sections) and the examination of a greater number of sites in order to increase our knowledge on the distribution of the first ceramic forming processes during the Early Neolithic in the Iberian Peninsula.

CRediT authorship contribution statement

Javier Cámara Manzaneda: Conceptualization, Methodology, Formal analysis, Investigation, Visualization, Writing - original draft, Writing - review & editing. **Xavier Clop García:** Conceptualization, Supervision, Project administration, Funding acquisition, Writing - original draft, Writing - review & editing. **Jaume García Rosselló:** Conceptualization, Methodology, Supervision, Writing - original draft, Writing - review & editing. **Maria Dolores Camalich Massieu:** Conceptualization, Visualization, Project administration, Funding acquisition, Writing - original draft, Writing - review & editing. **Dimas Martín-Socas:** Conceptualization, Project administration, Funding acquisition, Writing - original draft, Writing - review & editing.

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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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jasrep.2021.102936.

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