This is an Accepted Manuscript of an article published by Taylor & Francis in ENVIRONMENTAL ARCHAEOLOGY. The Journal of Human Palaeoecology on 28 February 2021, available at:

http://wwww.tandfonline.com/10.1080/14614103.2021.1891813

Environmental implications and chalcolithic ornamental use of marine barnacle shells present in the tholos of "La Pastora" (Valencina de la Concepción, Sevilla, Spain)

Fernando Muñiz Guinea[a], Luis Miguel Cáceres Puro[b,e*], Marta Díaz-Zorita Bonilla[c], Juan Manuel Vargas Jiménez[d], Hervé Bocherens[c], James H. Nebelsick[c], Teodosio Donaire Romero[b] and Joaquín Rodríguez Vidal[b,e].

[a]Department of Crystallography, Mineralogy and Agricultural Chemistry, University of Seville, Seville, Spain; [b]Department of Earth Sciences, University of Huelva, Huelva, Spain; [c]Institut für Geowissenschaften, Eberhardt Karls Universität, Tübingen, Germany; [d]Archaeological Service, Municipality of Valencina de la Concepción, Seville, Spain; [e]Centro de Investigación en Patrimonio Histórico, Cultural y Natural (CIPHCN), Facultad de Humanidades, Universidad de Huelva

*Corresponding author. e-mail: mcaceres@uhu.es Address: Department of Earth Sciences, University of Huelva, Avda. Tres de Marzo, s/n, 21071 Huelva, Spain.

ABSTRACT

The study of a set of marine arthropod shells from an archaeological excavation carried out in 1991-1992 in the tholos of La Pastora (Cooper Age Mega-site of Valencina-Castilleja, S Spain), has highlighted the environmental implications and ornamental use as beads not cited so far for this purpose. It is the barnacle species *Chthamalus montagui* Southward, 1976, of which are preserved 71 complete specimens. In this study a taxonomic analysis of these organisms is carried out, determining their classification and their physical and ecological characteristics, which make them especially suitable for this use. The interpretation is made regarding the environment in which these organisms were collected during the 3rd millennium BCE. Thus, it points towards a protected coastal area, but with a predominant marine influence, such as the wide marine bay that formed the mouth of the Guadalquivir River in those times. Finally, a radiocarbon analysis of one of these beads and two specimens of another species of barnacle collected in the rocks of the monument, provide a time range of 2760–2200 yr BCE. This range is consistent with the period of activity in the monument estimated by other authors.

Key words: Valencina de la Concepción, tholos of La Pastora, barnacle shells, beads, Copper Age, Radiocarbon.

Introduction

Ornaments made of marine shells are among the most common materials found in the archaeological record (Álvarez-Fernández & Carvajal-Contreras, 2010). Although their identification and description is often difficult due to intensive reworking, it is known that during the Late Neolithic and the Copper Age in southern Iberia, most beads are characteristically constructed of locally derived raw materials (Thomas, 2011). There are, however, some types of beads that are scarce and limited in their use, requiring special attention with respect to their symbolic and social value, such as the specific examples introduced in this study.

The marine shell beads presented in this paper are part of a limited amount of material that can be directly associated with the construction process and the period of use of the tholos of La Pastora, which is the best-known megalith of the Copper Age mega-site of Valencina-Castilleja, Spain (Fig. 1). This construction is located to the east of the current village of Valencina de la Concepción and forms part of one of the main areas of the site, where the most important monuments of the prehistoric necropolis such as Matarrubilla (Obermaier, 1919; Collantes de Terán, 1969; Gómez de Terreros Guardiola, 2005), Ontiveros, Montelirio (Fernández Flores et al., 2016) and Structure 10.042-10.049 at the PP4 sector (García Sanjuán et al., 2019) can be found. Excavated constructions are mostly identified as tholoi. These megalithic monuments are characterized by longs and narrows corridors that ends in a circular chamber. Its walls can be made of rock slabs (orthostats) or masonry and the roof of rocky slabs (capstones). The whole complex would be covered by an earthen or rocky fragments tumulus. The tholoi of Valencina featuring circulars chambers between 1 and 4.4 m diameter, and corridors which range from a few metres in minor tombs to several tens of metres in monumental examples. Structural variations include: 1) spectacular constructions featuring masonry walls, large capstones and burial mounds, 2) middle-sized corridors lacking burial mounds, 3) tombs featuring both chambers and corridors occasionally constructed of slabs, and finally 4) examples where the walls were left bare (Cruz-Auñón et al., 2010; Mora Molina et al., 2013). In addition, there is evidence in the western edge of the site pointing to an area of specialised production (Nocete Calvo et al., 2008). Moreover, amongst the funerary constructions, domestic constructions have also been identified (Mora Molina et al., 2013) which highlight the degree of complexity found in this area of the Valencina-Castilleja mega-site (García Sanjuán et al., 2018).

Figure 1

The tholos of La Pastora was discovered by chance during the planting of a vineyard in 1860 (Tubino, 1868). From a constructive point of view, it features a long corridor and a circular chamber, which together exceed 45 m in length. The chamber is circular with a maximum diameter of 2.6 m and is constructed of stone masonry walls closed by a false vault supporting a large closing capstone. The stone masonry corridor has a trapezoidal section and is articulated into three areas, separated from one another by protruding slabs acting as doors. In the second and third areas, the door jamb and lintel were preserved, while the area giving access to the chamber still had a threshold. The roofing was constructed of Neogene calcareous sandstone slabs and some granite capstones. The floor, the jambs and lintels of the doors and the upper rows of the chamber walls are also consist of Neogene sandstone slabs and blocks.

The first area is in a poor state of preservation and lacks roofing and floor slabs, with the level of wall destruction reaching to the ground in some areas. This first area was not discovered until the 1963 excavation, for which only fragmentary references are preserved, as well as an unpublished documentary collection belonging to Professor Collantes de Terán, particularly with respect to the photographs therein. During this excavation, the overall floorplan and dimensions were established. The excavation removed all the infilling of the uncovered stretch of the corridor, and unveiled the so-called first door, as well as the façade and the pile of stones which blocked the entrance to the rest of the architectural ensemble.

Some Neogene sandstones slabs (11 capstones, lintels and jambs of the doors) have an intense marine bioerosion, with the tracemaker (*Petricola lithophaga* Retzius, 1788) preserved in their borings, as well as encrusting epibenthic organisms on the rock surfaces including the barnacle *Balanus crenatus* Bruguière, 1789 and the oyster *Ostrea edulis* Linnaeus, 1758 (Cáceres et al., 2014). This bioerosive and encrusting activity was developed during the 3rd millennium BCE, prior to the extraction of rocks for the monument. The presence of these organisms allows for the establishment of a direct connection between building elements of the monument and the shell beads described here found within the infilling sediment. The fact that both the building stones and the beads were derived from the same environment is of key importance for the interpretations of the La Pastora site.

In this work we present the first record of marine shells of the barnacle *Chthamalus montagui* Southward, 1976 used as ornamental beads. Its main objectives are (1) a taxonomic classification and description of these shells, (2) provide a geochronological framework for the shells via radiocarbon dating as possibility to obtain insights about the construction of the tholos of La Pastora, and (3) determine the palaeoenvironmental significance of the presence of *Chthamalus montagui* during the 3rd millennium BCE near the Valencina-Castilleja mega-site.

Materials and methods

Three inventory references in the Valencina Museum (numbers 5/1, 5/2 y 5/3) refer to material assemblages derived from the excavation of the tholos of La Pastora undertaken from the middle of 1991 to the beginning of 1992. This excavation took place immediately before the Universal Exposition of Seville (Expo 1992) and since the local authorities made an effort to invest in the heritage of areas surrounding Seville, an architectural adaptation of the monument was proposed. Although this planned restoration project was never realized, excavations were carried out in order to modify the access of visits to the monument. The aim was to change the access area into the prehistoric construction, a task that involved exposing the original corridor which still contained a small amount of archaeological fill.

Figure 2

This work took place in two well-differentiated sectors, on both ends of the first section of the corridor. In the eastern sector, the imprint of a former doorjamb was uncovered, as well as the continuation of the corridor's side walls into an area which had been excavated to ground level in 1963, as can be seen in the archive images that have been consulted (Fig. 2A). At the other end, representing the beginning of the tholos, the excavation revealed an intact layer (Fig. 2). The depositional fill represented by this layer was removed, along with part of the structures that occupied the initial part of the corridor and the immediate outer area. These were the imprints of the vertical slabs which would have formed the first section of the corridor, the so-called first door. In the small space between it and the beginning of the monument, the walls open slightly outwards. The interior is occupied by a structure composed of stones and clay, which was interpreted as a seal (Ruiz Moreno, 2013). Finally, on the outer side of the façade, the presence of an assemblage consisting of randomly arranged pieces of slate was recorded (Ruiz Moreno, 2013).

Following the archaeologists' description, a set of beads (Fig. 3) were retrieved during the sieving of the infill material (Fig. 2) (Ruiz Moreno & Martín Espinosa, 1993). There is thus an absence of primary archaeological context which could allow for precise spatial referencing. In any case, the beads were recovered from some sediment that formed part of the lower area of the preserved sedimentary record, and most probably originated from the beginning of the corridor area where the sedimentary record was unaltered (Fig. 2B).

Figure 3

With respect to the sediment fill in which the beads were found, this can be linked to the aforementioned fill deposit inside the corridor which was mostly excavated in 1963; a record which, unfortunately, was never published. Through the revision of the graphic documentation, it is possible to notice that the initial section of the monument was covered by sediment without the presence of a covering slab (Fig. 2A). During the preparation work within the monument from 1991 and 1992, the façade and the side walls of the corridor were uncovered. The rich interior fill was excavated, and included besides sediment, also rock fragments, some of which belonged to the displaced stone masonry. Furthermore, abundant malacological and various human remains were also recovered from the sediment (Ruiz Moreno, 2013).

As mentioned above, from the excavation of 1991-1992 a set of beads was extracted and deposited in the Valencina Museum. The set adds a total of 98 beads divided into three groups or references in the Museum: 5/1, 5/2 and 5/3. Of these, those corresponding to references 5/1 and 5/3 are specimens of *Chthamalus montagui* (Fig. 3A), which can appear isolated or paired. The rest, corresponding to reference 5/2, are a set of 30 circular beads mainly of bone and some of lithic material (currently under study), with diameters between 3 and 11 mm (Fig. 3B). All of them probably belonged to the same ornamental object. The shell and bone beads were the only pieces found, other than the odd human tooth (Ruiz Moreno, 2013). This distribution of elements represents a typical funerary record, which serves as a link between this material record and the monument itself. It can thus be asserted, that the described beads must have formed part of the original funerary depositional context from within the tholos and were later, but still within Prehistoric times, redeposited within the initial part of the corridor.

This above described situation is that which is reflected in the earliest photographic images and, to a great extent, the current state of conservation, showing the initial part of the monument. The lack of any preservation of remains inside the monument (Tubino, 1868), especially when compared with the uniqueness of monumentality of the construction might be associated to an episode of destruction or other intrusive events which cannot be ruled out. Furthermore, the association of the shell beads with the records of marine fauna preserved within and on the sandstone slabs represent a clear conformity with respect to the environmental context from which these resources were derived. This thus highlights the great significance of the marine environment with respect to both the monument itself and the burial context.

The shells of barnacle Chthamalus

71 specimens of balanomorph barnacles belonging to the species *Chthamalus montagui* Southward were studied (Fig. 3). Of those, 65 are isolated specimens (including one fragmented) and three are pairs of united individuals and are also complete. All specimens are deposited in the Valencina Museum and are stored under the inventory numbers 5/1, which include units 1 to 53, and with number 5/3, which refers to units 54 to 68. The terminology used in the description of samples follows that of Southward (1976, 2008), Crisp et al. (1981), Anderson (1992), Burrows et al. (1999). Photographs were taken with Canon Power Shot SX50HS and Nikon D50 cameras. For detailed studies, an Ultralyt 20x-40x stereoscopic microscope and a digital camera for DCM130 binocular were used. This methodology would aim to identify the non-artificial origin of the central "hole". Barnacles have a natural "hole" (opercular opening) and implies any trace of use (erosion, cut, cracks, for example).

Laboratory: Radiocarbon dating

For the present study, two samples of the barnacle *Balanus* sp. (VA1101 and VA1118) preserved in their original position, were collected. The dating of these two samples were compared with the AMS calibrated date of a specimen of *Chthamalus montagui* (VA1304) belonging to the set studied in this research (García Sanjuán et al., 2019) (Tab. 1). The radiocarbon analysis by AMS was performed in the "Centro Nacional de Aceleradores" (CNA) in Seville (Spain). Conventional radiocarbon ages have been converted to calibrated ages (cal yr BP) with the CALIB 5.0.1 program (Stuiver & Reimer, 1993), using the Marine13 calibration dataset (Reimer et al., 2013) for marine samples (Tab. 1). An additional regional marine reservoir correction (ΔR) of -108±31 yr^{14}C (Martins & Soares, 2013) was also applied for marine samples, which will be explained in more detail in section 4.1.

Table 1

A stable isotope analysis δ^{18}O and δ^{13}C (Koch et al., 1994; Koch, 1998) was performed of a barnacle specimen. Approximately 0.5-0.8 mg of carbonate powder was treated for analysis, according to the method of Bocherens et al. (1994). The isotopes were analyzed in the Department of Geosciences facilities within the University of Tübingen (Germany), being calibrated (using NBS-18 y NBS-19), expressed relative to the V-PDB (Vienna Pee-Dee belemnite) and converted to V-SMOW (Standard Mean Ocean Water) (Coplen et al., 1983; Iacumin et al., 1996).

The barnacle *Chthamalus*

Taxonomy

Phylum Arthropoda von Siebold 1848
Subphylum Crustacea Brünnich 1772
Class Maxillopoda Dahl 1956
Subclass Cirripedia Burmeister 1834
Superorder Thoracica Darwin 1854
Order Sessilia Lamarck 1818
Suborder Balanomorpha Pilsbry 1916
Family Chthamalidae Darwin 1854
Genus *Chthamalus* Ranzani 1817
Type species: *Chthamalus stellatus* (Poli, 1791) original designation.

Diagnosis of Chthamalus montagui (only referring to the shell)

Shell usually conical to low conical, but often elongated or columnar. Opercular opening nearly always kite-shaped or sub-quadrangular. Wall with six plates, rostrum and carina provided with radii, rostrolaterals without radii, carinolateral lacking, parietes and radii not permeated by pores, basis membranous (from Southward, 1976; Chan et al., 2016).

Figure 4

Description of the material studied

For the *Chthamalus montagui* samples studied, only the six parietal plates are preserved (rostrum, pair of rostrolaterals, carina and pair of carinolaterals) (Fig. 4A), connected with each other and with a low-profile conical morphology (Fig. 4C). The sutures between the plates are closed; in some samples they can be observed (Fig. 5AI, B and CI) while in others they are hidden (Fig. 5C II and III). The rostrum and carina are elongated and narrow, the rostrolateral plates are semitrapezoidal and the carinolateral irregular and larger in size than the rest of the plates. In apical view, the opercular opening presents the typical kite-shape (Figs. 4 and 5) that defines this species. Three of the studied samples correspond to individuals attached to one another (Fig. 5B). The opercular plates, which consist of two terga and two scuta are missing. These were most likely removed during the application of the articulated wall plates to a necklace. Besides, the opercular plates are only attached by soft tissue to the rest of the shell, which readily decays after death of the individual barnacles. Furthermore, the membranous basal plates are missing, which were either removed upon collection or during the handling of these objects.

The height (h) (Fig. 4C) of the specimen ranges between a minimum of 1 mm and a maximum of 4 mm. In apical view, the average mean obtained for the lateral width (LW) (Fig. 4B) is 5.4 mm and the rostrum-carina length (RCL) is 5.7 mm. The maximum LW y RCL values are 7 mm y 7.5 mm, respectively, minimum values are 4 mm and 3 mm, respectively.

Figure 5

Results and discussion

Environmental implications of the presence of Chthamalus montagui

The Cirripedia are marine crustaceans (Order Sessilia) which are permanently attached to the substrate (post-larvae stage) and are surrounded by a calcified, multi-plated skeleton. They affix themselves to a substrate through the formation of a basal plate (Bourguet, 1987; Southward, 1976; Walker, 1992), which can be calcareous or membranous depending on the species. This basal plate, when this is calcareous, can sometimes create bioerosion structures on specific substrates such shells (Santos et al., 2005) or rocks. In the case of the basal membranous plaque, such as *Chthamalus montagui*, this does not produce any type of erosive structure or "scar" (Southward,1976) over the rock where it is fixed, in addition of being a weaker and perishable fixation.

In general, sessile cirripedes are key species in ecological communities of rocky coasts (O'Riordan et al., 2004). Within this Order, the genus *Chthamalus* Ranzani is widely known from rocky intertidal zones (Southward, 1976; Crisp et al., 1981; Burrows et al., 1999; Pitombo & Burton, 2007; Wares et al., 2009; Chan & Cheang, 2015; Chan et al., 2016 amongst others). This genus contains around 23 accepted species (Chan & Cheang, 2015; Chan et al., 2016; Wares et al., 2009) including *Ch. montagui* Southward, which is the species object of this study, and *Ch. Stellatus* Poli, 1791. Both species are sympatric in their geographic distribution and are found along the Atlantic coasts of the British Isles, France, Spain, Portugal, Morocco and Mauritania, as well as in the Mediterranean coasts of Spain (Iberian Peninsula and Balearic Islands), France, Italy, Croatia, Algeria, Tunisia and Israel (Southward, 1976; Crisp et al., 1981; O'Riordan et al., 2004).

Ecological aspects of both *Ch. montagui* and *Ch. stellatus* have been studied in detail (e.g. Delany et al., 2003; O'Riordan et al., 2004). They both occur in the intertidal rocky zones with overlapping horizontal and vertical distributions (Southward, 1976; Crisp et al., 1981; Burrows et al., 1992 Pannacciulli & Relini, 2000; Ross et al., 2003). According to Burrows et al. (1999)

and Pannacciulli & Relini (2000), these two species have separate habitats, with *Ch. montagui* being more abundant in sheltered areas such as bays or estuaries, while *Ch. stellatus* prevails in high energy, openly exposed coasts. With respect to vertical distributions, *Ch. montagui* prevails in the upper area of the "barnacle zone" encompassing the mean high water of spring and neap tides. Burrows (1988) suggests that in juvenile stages, *Ch. montagui* possesses a certain tolerance to being exposed to aerial conditions. The tight closure of the opercular plates is known to counter stress by desiccation allowing this species to colonise the upper intertidal zone, which is exposed during low tide and high wave movement.

With respect to reproduction and life cycles, balanomorph barnacles are, in general, hermaphroditic and usually reproduce through cross fertilization (Klepal, 1990). It is estimated that *Ch. montagui* attains sexual maturity when the rostrum-carina diameter reaches 4.5 mm (O'Riordan et al., 2004). *Ch. montagui* starts reproducing nine to ten months after fixation to the substrate (Crisp et al., 1981). The growth of balanid barnacles is directly influenced by both abiotic (including temperature, currents, light, swells, tidal levels, etc) and biotic factors (such as food availability, population density, size, etc.) (Chan et al., 2016). Growth rates of *Ch. montagui* are influenced both by the tidal gradient and by the exposure to swell (Burrows 1988). Pannacciulli & Relini (2000) mentions that *Ch. montagui* can reach an age of ten years in protected coasts

The specific characteristics of *Chthamalus montagui* regarding their membranous basal plaque makes it easier for its extraction and gathering from the rock surface. The separation of this element from the rest of the shell is also readily possible once the specimen is no longer attached to the substrate surface. In addition, the fact that the terga and scuta are attached by soft tissues to the rest of the shell means that they can also be easily removed exposing the internal organs of the animal through the opercular aperture. This results in a continuous ring of wall plates consisting of the rostrum, rostrolaterals, carina and carinolaterals after removal of the basal plate and opercular membrane with terga and scuta.

The presence of *Chamalus montagui* suggests that the barnacles were collected in more sheltered areas such as bays or estuaries than an exposed high energy coastline in which the species *Ch. stellatus* should be predominate. The stable isotope data ($\delta^{18}$and δ^{13}C) correspond to a marine environment rather than a mixed environment, so that the barnacles specimens could come from a protected area but with a predominant marine influence. In this sense, Cáceres *et al*. (2014) concluded that, with a level of the sea similar to the current one, corresponding to the 3rd millennium BCE, the bioeroded Neogene sandstones of La Pastora could come from the surrounding of current town of Coria del Río (Fig. 1), about 15 km south of Valencina. This sector was part of a wide marine bay, currently occupied by marshes that constitute the mouth of the Guadalquivir River (Fig. 1). In this environment, Neogene sandstones would have cropped out on a coastal wave-cut platform subject to tides, waves and biological coastal activity. This described situation coincides with the data provided in this study. Thus, the multi-proxy methods used here suggest that the shells used as ornaments were collected during the same time period and possibly from the same coastal source as the Neogene sandstone used as building material of the tholos itself.

Use of barnacle shells

The use of elaborate (or not) marine shells as artefactual elements during the Chalcolithic Age in the Valencina area is poorly documented, despite the obvious proximity of the site to the sea (Cáceres et al., 2014; Díaz-Guardamino Uribe et al., 2016; Pajuelo Pando, 2016). Marine shells registered to date are exclusively bivalve mollusc belonging to the following species: *Petricola lithophaga* Linnaeus, 1758 and *Ostrea edulis* (Cáceres et al., 2014), *Ruditapes decussatus* Linnaeus, 1758 (Pajuelo Pando, 2016) and *Pecten maximus* Linnaeus, 1758 (López Aldana, 2001). As for the use, Cáceres et al. (2019) propose that the presence of *Petricola lithophaga* and *Ostrea edulis* attached on the capstones and floor slabs of the La Pastora monuments, denote highly aesthetic qualities and an intentional arrangement to highlight as specific decorative or symbolic elements; complete valves of *Pecten maximus* were recognized as ajuar in several burial structures of the PP4-Montelírio sector (López Aldana, 2001); Pajuelo Pando (2016) considers that the presence of *Ruditapes decussatus* may have some symbolic meaning and not exclusively of consumption and, finally, Díaz-Guardamino Uribe et al. (2016) cite the manufacture of bivalve shells (taxonomic classification under study) for the creation of perforated beads that characterized the exceptional garments documented in the tholos of Montelírio. In this sense, the unusual finding of barnacles used as ornaments is exceptional and unique in the archaeological record and provides insights into the age, habitat exploitation as well as the symbolism of the Copper Age communities in Iberia. This is the first evidence that barnacles were gathered within the vicinity of the Valencina-Castilleja mega-site by the 3rd millennium BCE. Taking advantage of the specific anatomical characteristics of *Chthamalus montagui*, the membranous basal plate that facilitates extraction and the opercular opening as a central hole, made it possible to deliberately collect these shells and were given special symbolism due to their use as personal ornaments.

Concerning the age of the shells, there is a conformity of some dates which are key to understand the function of the monument within the Valencina-Castilleja mega-site. Cáceres et al. (2014) dated three samples of bivalves (*Petricola lithophaga*) preserved within the bore holes. The radiocarbon dates obtained from these bivalve shells provided a time range between 4780 and 4400 cal yr BP (2830−2450 yr BCE) as the highest probability for rock extraction and the subsequent construction of the tholos ("Terminus Post Quem"). In addition, the two samples of barnacles (*Balanus* sp.) preserved in their original position on the sandstone slabs, one attached to a rock in the floor (VA1101) and the other on a chamber jamb (VA1118) are comparable to the AMS calibrated date of a specimen of *Chthamalus montagui* (VA1304) showing a time range of 2760−2200 yr BCE (Tab. 1). This range is also comparable to that obtained for the lithophagous bivalves mentioned above.

In García Sanjuán et al. (2018), using a Bayesian model in which these radiocarbon dating with others of human bone are combined, it is determined that the activity in La Pastora began in 2755–2465 yr BCE (95% probability), probably in 2615–2480 yr BCE (68% probability), and ended in 2485–1360 yr BCE (95% probability), probably in 2435–2035 yr BCE (68% probability).

Analytical results

Radiocarbon dates on marine samples have not been used as extensively as terrestrial biosphere dates for establishing absolute chronologies, as interpreting these dates is complicated due to oceanographic factors. In order to set up chronologies for a particular coastal area using marine samples, previous research concerning the oceanographic conditions and the marine reservoir effect for that coastal area is needed if accurate and reliable results are to be obtained (Stuiver & Braziunas, 1993).

Stuiver et al. (1986) modelled the response of the world's oceans to atmospheric ^{14}C variations. Regional differences in radiocarbon content between the sea surface water of a specific region and the average world sea surface water are linked to several factors and anomalies, such as the upwelling of deep water. ΔR is the parameter that has to be known when a marine radiocarbon date is calibrated, i.e. converted into calendar years, and can be defined as the difference between the reservoir age of the mixed layer of the regional ocean and the reservoir age of the mixed layer of the average world ocean in AD 1950. Marine13 is the last calibration curve published (Reimer et al., 2013) for the mixed layer, the most widely used and its use internationally recommended.

Soares (2005) was the first to determine an accurate marine radiocarbon reservoir effect ΔR for the eastern coast of the Gulf of Cádiz. For the last 3000 years on the Andalusian Atlantic coast, ΔR has been calculated as ′−108±31 BP′, which is in accordance with the oceanographic conditions present in the area. For ^{14}C dates between 4600–4000 yr BP, two sets of ΔR values were considered in the calculation of the weighted mean value (Martins & Soares, 2013). These ΔR values must be used together with the Marine13 calibration curve (Reimer et al., 2013) in order to convert the conventional radiocarbon dates of marine shells collected at La Pastora into calendar dates (Tab. 1).

Three samples of barnacles were taken for radiocarbon dating (Tab. 1). Of them, two (*Balanus* sp.) of the sandstone slabs and one (*Chthamalus montagui)* bead belonging to the set studied here. The ages obtained showed a maximum relative time range of 2760 and a minimum of 2200 yr BCE. Two samples were very similar in age and a third one was younger. The three samples are graphically represented in Fig. 6, which shows the time period in which the marine bioerosive episodes would have been most likely to occur (Cáceres et al., 2014).

Figure 6

On the other hand, the results of δ^{18}O and δ^{13}C analysis in *Ch. montagui* are: $\delta^{18}_{\text{V-OSMOW}}$ of 30.67‰, $\delta^{18}O_{\text{V-PDB}}$ of -0.18‰ and $\delta^{13}C_{\text{V-PDB}}$ 0.20‰. These values can help discriminate among ecosystems terrestrial vs. marine or mixed environments such as restricted estuaries. In this case, although the results correspond to a marine environment, the analysis of a single sample is considered insufficient and the values obtained here are needed to increase the dataset concerning the geochemistry of marine shells.

Conclusions

The identification of the barnacle species *Chthamalus montagui* and the application of multiple methods of analysis point towards a protected coast area but with a predominant marine influence environment.

This unique find of the use of barnacles as ornaments represents an exception in the archaeological record of the Iberian Chalcolithic and has far reaching implications with respect to the environment, habitat exploitation and use of building materials as well as burial rites of the La Pastora tholos from the Valencina-Castilleja Copper Age mega-site.

The radiocarbon dating of one of the beads and two *balanus* attached to the rocks of La Pastora shows a time range of 2760-2200 yr BCE, which is consistent with the period of activity in the monument published in García Sanjuán et al. (2018).

This finding, along with the previous publications, allows us to redefine the indirect date of the construction of the monument as well as giving some hints about the use of this monument by the Copper Age communities who inhabited the site of Valencina-Castilleja. Furthermore, the link between the shells used as ornaments and the Neogene sandstones from the tholos directly relates the builders of the monument to the occupants of the tomb emphasizing the significance that the marine environment and their resources had for them.

Acknowledgements

We would like to thank our colleagues Dorothée Drucker, Christoph Wissing and Martin Cotte for their help with the laboratory work for isotopic analysis. Thanks also to Michael Burrows (Scottish Marine Institute) and Christoph Wissing (Tübingen University) for his comments and the references provided.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the Town Council of Valencina de la Concepción under Grant "The Project of Geoarchaeological Investigations in the area of the tholos of La Pastora" and EPIT-2020 of the University of Huelva (Poyectos IP Noveles 636). This study is part of the activities of the Research Group RNM 293 "Geomorfología Ambiental y Recursos Hídricos", University of Huelva.

Notes on contributors

Fernando Muñiz Guinea, Department of Crystallography, Mineralogy and Agricultural Chemistry, University of Seville, Seville, Spain. fmuniz@us.es https://orcid.org/0000-0002-5727-3646

Luis Miguel Cáceres Puro, Department of Earth Sciences, University of Huelva, Huelva, Spain. mcaceres@uhu.es https://orcid.org/0000-0002-1381-2476

Marta Díaz-Zorita Bonilla, Institut für Geowissenschaften, Eberhardt Karls Universität, Tübingen, Germany. marta.diaz-zorita-bonilla@uni-tuebingen.de https://orcid.org/0000-0002-1697-0111

Juan Manuel Vargas Jiménez, [d]Archaeological Service, Municipality of Valencina de la Concepción, Seville, Spain. jmvargas66@gmail.com https://orcid.org/0000-0002-5772-1226

Hervé Bocherens, Institut für Geowissenschaften, Eberhardt Karls Universität, Tübingen, Germany. herve.bocherens@uni-tuebingen.de https://orcid.org/0000-0002-0494-0126

James H. Nebelsick, Institut für Geowissenschaften, Eberhardt Karls Universität, Tübingen, Germany. nebelsick@uni-tuebingen.de https://orcid.org/0000-0001-5381-0267

Teodosio Donaire Romero, Department of Earth Sciences, University of Huelva, Huelva, Spain. donaire@dgeo.uhu.es https://orcid.org/0000-0001-5582-2253
Joaquín Rodríguez Vidal, Department of Earth Sciences, University of Huelva, Huelva, Spain. jrvidal@dgeo.uhu.es https://orcid.org/0000-0002-9475-3307

References

Álvarez-Fernández, E. and D. Rocio Carvajal-Contreras. 2010. *Not only Food. Marine, Terrestrial and Freshwater Molluscs in Archaeological Sites*. Munibe. Suplemento 31. San Sebastian, Spain: S.C. Aranzadi.

Anderson, D. T. 1992. *Barnacles: structure, function, development and evolution*. Connecticut, U.S.A.: Chapman y Hall.

Bocherens, H., M. Fizet, A. Mariotti, G. Bellon, and J. P. Borel. 1994. "Les gisements de mammiféres du Miocene supérieur de Kemiklitepe, Turquie: 10. Biogéochimie isotopique". *Bulletin du Muséum National d´Histoire Naturelle Paris*16: 211–223.

Brünnich, M. T. 1772. *Zoologiae fundamenta praelectionibus academicis accommodate*. Copenhagen, Denmark: Fridericus Christianus Pelt.

Burmeister, H. 1834. *Beiträge zur Naturgeschichte der Rankenfüsser (Cirripedia)*. Berlin, Germany: G. Reimer.

Burrows, M. T. 1988. *The comparative biology of "Chthamalus stellatus" (Poll) and "Chthamalus montagui" Southward*. PhD Thesis, University of Manchester, United Kingdom.

Burrows, M. T., S. J. Hawkins, and J. A. Southward 1992. "A comparison of reproduction in co-occurring chthamalid barnacles, *Chthamalus stellatus* (Poli) and *Chthamalus montagui* Southward". *Journal of Experimental Marine Biology and Ecology* 160: 229–249. doi: 10.1016/0022-0981(92)90240-B

Burrows, M. T., S. J. Hawkins, and J. A. Southward 1999. "Larval development of the intertidal barnacles *Chthamalus stellatus* and *Chthamalus montagui*". *Journal of the Marine Biological Association of the United Kingdom* 79: 93–101. doi: 10.1017/S0025315498000101

Cáceres, L. M., F. Muñiz, J. Rodríguez-Vidal, J. M. Vargas, and T. Donaire. 2014. "Marine bioerosion in rocks of the prehistoric tholos of La Pastora (Valencina de la Concepción, Seville, Spain): archaeological and palaeoenvironmental implications". *Journal of Archaeological Science* 41: 435−446. doi: 10.1016/j.jas.2013.09.001

Cáceres, L. M., J. M. Vargas, F. Muñiz, T. Donaire, L. García-Sanjuán, C. Odriozola, and J. Rodríguez-Vidal. 2019. "Natural Megalithic Art at Valencina (Seville): a geoarchaeological approach to stone, architecture, and cultural choice in Copper Age Iberia". *Archaeological and Anthropological Sciences* 11(9): 4621–4641. doi.org/10.1007/s12520-019-00870-z

Chan, B. K. K., and C. C. Cheang. 2015. "A new *Chthamalus* (Crustacea: Cirripedia) from the challengeri subgroup on Taiwan rocky intertidal shores". *Zootaxa* 4000: 547–558. doi: 10.11646/zootaxa.4000.5.4

Chan, B. K., H. N. Chen, P. R. Dando, J.A. Southward, and E. C. Southward. 2016. "Biodiversity and Biogeography of Chthamalid Barnacles from the North-Eastern Pacific (Crustacea Cirripedia) ". *PloS one* 11 (3): e0149556. doi: 10.1371/journal.pone.0149556

Collantes de Terán, F. 1969. "El dolmen de Matarrubilla". *Actas del V Symposium internacional de prehistoria peninsular. Tartessos y sus problemas (Jerez, 1968)*. 47–61. Barcelona, Universidad de Barcelona, Spain.

Coplen, T. B., C. Kendall, and J. Hopple. 1983. "Comparison of stable isotope reference samples". *Nature* 302: 236–238. doi: 10.1038/302236a0

Crisp, D. J., J. A. Southward, and E. C. Southward. 1981. "On the distribution of the intertidal barnacles *Chthamalus stellatus*, *Chthamalus montagui* and *Euraphia depressa*". *Journal of the Marine Biological Association of the United Kingdom* 61: 359–380. doi: 10.1017/S0025315400047007

Cruz-Auñón, R., F. Nocete Calvo, and J. C. Mejías García. 2010. "Ciertos aspectos funerarios en la necrópolis del III milenio de Valencina-Castilleja (Sevilla)". In *Monumental Questions: Prehistoric Megaliths, Mounds, and Enclosures, Proceedings of the XV world congress (Lisbon 2006)*, edited by D. Calado, M. Baldia, y M. Boulanger, 51–56. Lisbon, Portugal.

Dahl, E. 1956: Some crustacean relationships. In *Bertil Hanström, Zoological papers in honour of his sixty-fifth birthday* Stockholm, edited by K. G. Wingstrand, 138–147, Sweden, Zoological Institute.

Darwin, C. R. 1854: *A monograph of the sub-class Cirripedia, with Fig.s of all the species. The Balanidae, (or sessile cirripedes); the Verrucidae, etc., etc., etc.* London, England: Ray Society.

Delany, J., A. A. Myers, D. McGrath, R. M. O'Riordan, and A. M. Power. 2003. "Role of post-settlement mortality and supply-side ecology in setting patterns of intertidal distribution in the chthamalid barnacles *Chthamalus montagui* and *C. stellatus*”. *Marine Ecology Progress Series* 249: 207–214. doi: 10.3354/meps249207

Diaz-Guardamino Uribe, M., D. W. Wheatley, E. Williams, and J. Garrido Cordero. 2016. Los textiles elaborados con cuentas perforadas de Montelirio. In *Montelirio: Un gran monumento megalítico de la Edad del Cobre*, edited by A. Fernández Flores, L. García Sanjuan, y M. Díaz-Zorita Bonilla, 345-364, Seville, Junta de Andalucía, Spain.

Fernández Flores, A., L. García Sanjuán, and M. Díaz-Zorita Bonilla. 2016. *Montelirio: Un gran monumento megalítico de la Edad del Cobre*. Seville, Spain, Junta de Andalucía.

García Sanjuán, L., J. M. Vargas Jiménez, L. M. Cáceres Puro, M. E. Costa Caramé, M. Díaz-Guardamino, M. Díaz-Zorita Bonilla, … A. Whittle. 2018. “Assembling the dead, gathering the living: radiocarbon dating and Bayesian modeling for Copper Age Valencina de la Concepción (Sevilla, Spain)”. *Journal of World Prehis*tory 31: 179–313. doi: 10.1007/s10963-018-9114-2

García Sanjuán, L., M. Cintas-Peña, M. Díaz-Zorita Bonilla, J. Escudero Carrillo, M. Luciañez Triviño, C. Mora Molina, and S. Robles Carrasco. 2019. “Burial practices and social hierarchisation in Copper Age Southern Spain: Analysing tomb 10.042-10.049 of Valencina de la Concepción (Seville, Spain)”. In *Megaliths, societies, landscapes: Early monumentality and social differentiation in Neolithic Europe*, edited by J. Müller, M. Hinz and M. Wunderlich,1005–1038, Bonn, Germany.

Gómez de Terreros Guardiola, M. G. 2005. Intervenciones en dólmenes, 1953–1964. Proyectos y obras de Félix Hernández Giménez. Dólmenes de Matarrubilla y Cueva de La Pastora (Valencina de la Concepción, Sevilla), Dolmen de Zancarrón de Soto (Trigueros, Huelva). Seville, Spain, Universidad de Sevilla.

Iacumin, P., H. Bocherens, A. Mariotti, and A. Longinelli. 1996. “Oxygen Isotope Analyses of Co-Existing Carbonate and Phosphate in Biogenic Apatite: A Way to Monitor Diagenetic Alteration of Bone Phosphate? ”. *Earth and Planetary Science Letters* 142: 1–6. doi: 10.1016/0012-821X(96)00093-3

Klepal, W. 1990. “The fundamentals of insemination in Cirripedes”. *Oceanography and Marine Biology: An Annual Review* 28: 353–379.

Koch, P.L. 1998. “Isotopic reconstruction of past continental environments”. *Annual Review of Earth and Planetary Sciences* 26 : 573–613. doi : 10.1146/annurev.earth.26.1.573

Koch, P. L., M. L. Fogel, and N. Tuross. 1994. “Tracing the diets of fossil animals using stable isotopes”. In *Stable Isoptopes in Ecology and Environmental Science*, edited by K. Lajtha y B. Michener, 63-92, Oxford, England, Blackwell Scientific Publications.

Lamarck, J. D. M. 1818. *Histoire Naturelle des Animaux sans Vertèbres, Présentant les Caractères Généraux et Particuliers de ces Animaux, leur Distribution, leurs Classes, leurs Familles, leurs Genres, et la Citation des Principales Espèces qui s'y Rapportent.* Volume, 5. Paris, France: Verdiére Libraire.

Nocete Calvo, F., G. Queipo de Llano Martínez, R. Sáez Ramos, J. M. Nieto Liñán, N. Inácio, M. R. Rodríguez Bayona, … J. F. Santos Zalduegui. 2008. "The smelting quarter of Valencina de la Concepción (Seville, Spain): the specialized copper industry in a political centre of the Guadalquivir Valley during the Third millennium BC (2750-2500 BC)". *Journal of Archaeological Science* 35: 717–732. doi: 10.1016/j.jas.2007.05.019

Martins, J. M. M., and A. M. M. Soares. 2013. "Marine radiocarbon reservoir effect in Southern Atlantic Iberian coast". *Radiocarbon* 55: 1123–1134. doi: 10.1017/S0033822200048037

Mora Molina, C., L. García-Sanjuan, J. Peinado Cucarella, and D. Wheatley. 2013. "Las estructuras de la Edad del Cobre del sector PP4-Montelirio del sitio arqueológico de Valencina de la Concepción - Castilleja de Guzmán (Sevilla)". In *El Asentamiento Prehistórico de Valencina de la Concepción (Sevilla): Investigación y Tutela en el 150 Aniversario del Descubrimiento de La Pastora*, edited by L. García-Sanjuan, J. M. Vargas Jiménez, V. Hurtado Pérez, M. T. Ruiz Moreno and R. Cruz-Auñon Briones, 261-279, Seville, Spain, Universidad de Sevilla.

Obermaier, H. 1919. El Dolmen de Matarrubilla (Sevilla). *Memorias de la Comisión de Investigaciones Paleontológicas y Prehistóricas*, 26. Madrid, Spain: Museo de las Ciencias Naturales.

O'Riordan, R. M., F. Arenas, J. Arrontes, J. J. Castro, T. Cruz, J. Delany, … T. Silva. 2004. "Spatial variation in the recruitment of the intertidal barnacles *Chthamalus montagui* Southward and *Chthamalus stellatus* (Poli) (Crustacea: Cirripedia) over an European scale". *Journal of Experimental Marine Biology and Ecology* 304: 243–264. doi: 10.1016/j.jembe.2003.12.005

Pannacciulli, F. G., and G. Relini. 2000. "The vertical distribution of *Chthamalus montagui* and *Chthamalus stellatus* (Crustacea, Cirripedia) in two areas of the NW Mediterranean Sea". In *Life at Interfaces and Under Extreme Conditions*, 105–112, Heidelberg, Germany, Springer Netherlands.

Pajuelo Pando, A. 2016. "Los restos de animals de Montelírio". In *Montelirio: Un gran monumento megalítico de la Edad del Cobre*, edited by A. Fernández Flores, L. García Sanjuan, and M. Díaz-Zorita Bonilla, 455-467, Seville, Junta de Andalucía, Spain.

Pilsbry, H.A. 1916. *The sessile barnacles (Cirripedia) contained in the collections of the U.S. National Museum; including a monograph of the American species. United States National Museum Bull*etin, 93. Washington, U.S.A.: Washington Government Printing Office.

Pitombo, F. B., and R. O. N. Burton. 2007. "Systematics and biogeography of Tropical Eastern Pacific *Chthamalus* with descriptions of two new species (Cirripedia, Thoracica)". *Zootaxa* 1574: 1–30.

Poli, G. S. 1791-1795. *Testacea utrusque Siciliae, eorumque historia et anatomie tabulis aeneis illustrata*, Tomus primus. Parma, Italy: Regio Typographia.

Ranzani, C. 1817. "Osservazioni sui Balanidi". *Opuscoli Scientifici*, I, 195–202, II, 269–276.

Reimer, P. J., E. Bard, A. Bayliss, J. W. Beck, P. Blackwell, C. Bronk Ramsey, … J. Van der Plicht. 2013. "IntCal13 and Marine13 Radiocarbon Age Calibration Curves, 0-50,000 Years cal BP". *Radiocarbon* 5: 1869–1887. doi: 10.2458/azu_js_rc.55.16947

Ross, P. M., M. T. Burrows, S. J. Hawkins, A. J. Southward, and K. P. Ryan. 2003. "A key for the identification of the nauplii of common barnacles of the British Isles, with emphasis on Chthamalus". *Journal of Crustacean Biology* 23: 328–340. doi: 10.1163/20021975-99990343

Ruiz Moreno, M. T. 2013. "La Pastora (Valencina de la Concepción, Sevilla): una historia desconocida". In *El Asentamiento Prehistórico de Valencina de la Concepción (Sevilla): Investigación y Tutela en el 150 Aniversario del Descubrimiento de La Pastora*, edited by L. García-Sanjuan, J. M. Vargas Jiménez, V. Hurtado Pérez, M. T. Ruiz Moreno, and R. Cruz-Auñon Briones, 201-217, Seville, Spain, Universidad de Sevilla.

Ruiz Moreno, M. T., and A. Martín Espinosa. 1993. "Excavación de urgencia en el dolmen de La Pastora, Valencina de la Concepción, Sevilla". *Anuario Arqueologico de Andalucía*, 1991, T. III Cadiz, Spain, Junta de Andalucía. 554–558.

Santos, A., E. Mayoral, and F. Muñiz. 2005. "Bioerosion scars of acorn barnacles from the southwestern Iberian Peninsula, upper Neogene". *Rivista Italiana di Paleontologia e Stratigrafia* 111: 181–189. doi: 10.13130/2039-4942/6289

Siebold, C. T. 1848. „Lehrbuch der vergleichenden Anatomie der Wirbellosen Thiere. Erster Theil". In C. T. von Siebold and H. Stannius (eds.:, *Lehrbuch der vergleichenden Anatomie*. Berlin, Germany: Verlag von Veit & Comp.

Soares, A. M. M. 2005. *Variabilidade do "Upwelling" Costeiro durante o Holocéniconas Margens Atlânticas Ocidental e Meridional da Península Ibérica*. PhD Thesis, Universidade do Algarve, Portugal.

Southward, A. J. 1976. "On the taxonomic status and distribution of *Chthamalus stellatus* (Cirripedia) in the north-east Atlantic region: with a key to the common intertidal barnacles of Britain". *Journal of the Marine Biological Association of the United Kingdom* 56: 1007–1028. doi: 10.1017/S0025315400021044

Southward, A.J. 2008. *Barnacles: Keys and Notes of the identification of British Species*. Field Study Council Publications Synopses of British Fauna, New Series, Vol. 57. Telford, United Kingdom: Field Studies Council.

Stuiver, M., and T. F. Braziunas. 1993. "Modeling atmospheric 14C influences and 14C ages of marine samples to 10,000 BC". *Radiocarbon* 35: 137–189. doi: 10.1017/S0033822200013874

Stuiver, M., and P. J. Reimer. 1993. "Extended 14C data base and revised CALIB 3.0 14C age calibration". *Radiocarbon* 35: 215−230. doi: 10.1017/S0033822200013904

Stuiver, M., G. W. Pearson, and T. F. Braziunas. 1986. "Radiocarbon age calibration of marine samples back to 9000 cal yr BP". *Radiocarbon* 28: 980–1021. doi: 10.1017/S0033822200060264

Thomas, J. T. 201. "Fashioning Identities, Forging Inequalities: Late Neolithic/Copper Age Personal Ornaments of the Portuguese Estremadura". *European Journal of Archaeology* 14: 29–59. doi: 10.1179/146195711798369373

Tubino y Oliva, F. M. 1868. "Monumento Prehistórico de Castilleja de Guzmán". *Estudios prehistóricos*. Oficina de la Revista de Bellas Artes. Madrid. 49–59.

Wares, J. P., M. S. Pankey, F. Pitombo, L. G. Daglio, and Y. Achituv. 2009. "A "Shallow Phylogeny" of Shallow Barnacles (*Chthamalus*)". *PLoS One* 4: e5567. doi: 10.1371/journal.pone.0005567

Walker, G., 1992. Cirripedia. In *Microscopy Anatomy of Invertebrates* (pp. 249–311). New York, U.S.A. Wiley-Liss, INC.

Data Availability Statement : The data that support the findings of this study are available from the corresponding author upon reasonable request.

Field code	Laboratory code	Material	^{14}C yr BP	δ^{13}C‰	Age cal BP/BCE 1σ	Age cal BP/BCE 2σ
VA1101	CNA-1485	cirriped	4245±30	-9.1	4540–4420 2590−2470	4640–4380 2690−2430
VA1118	CNA-1495	cirriped	4095±30	-4.0	4370–4230 2420−2280	4410–4150 2460−2200
VA1304†	CNA-2504	cirriped	4280±35	-1.5	4600−4450 2650−2500	4710−4400 2760−2450

Note: †García Sanjuán, et al., 2018

Table 1. AMS Radiocarbon dating (BP: Before Present) and calendar dates (BCE: Before Common Era) of barnacle shell samples collected in the tholos of La Pastora.

Figure captions

Fig. 1. (A) Map of Iberia with location of Valencina de la Concepción. (B) Extensión of the Copper Age mega-site of Valencina-Castilleja and location of La Pastora.

Fig. 2. (A) Excavations from 1963 at the first part of tholos of La Pastora (from Collantes de Terán archive, Departament of Archaeology and Prehistory, University of Seville). (B) Plan of La Pastora with indication of the place where the shell beads were found.

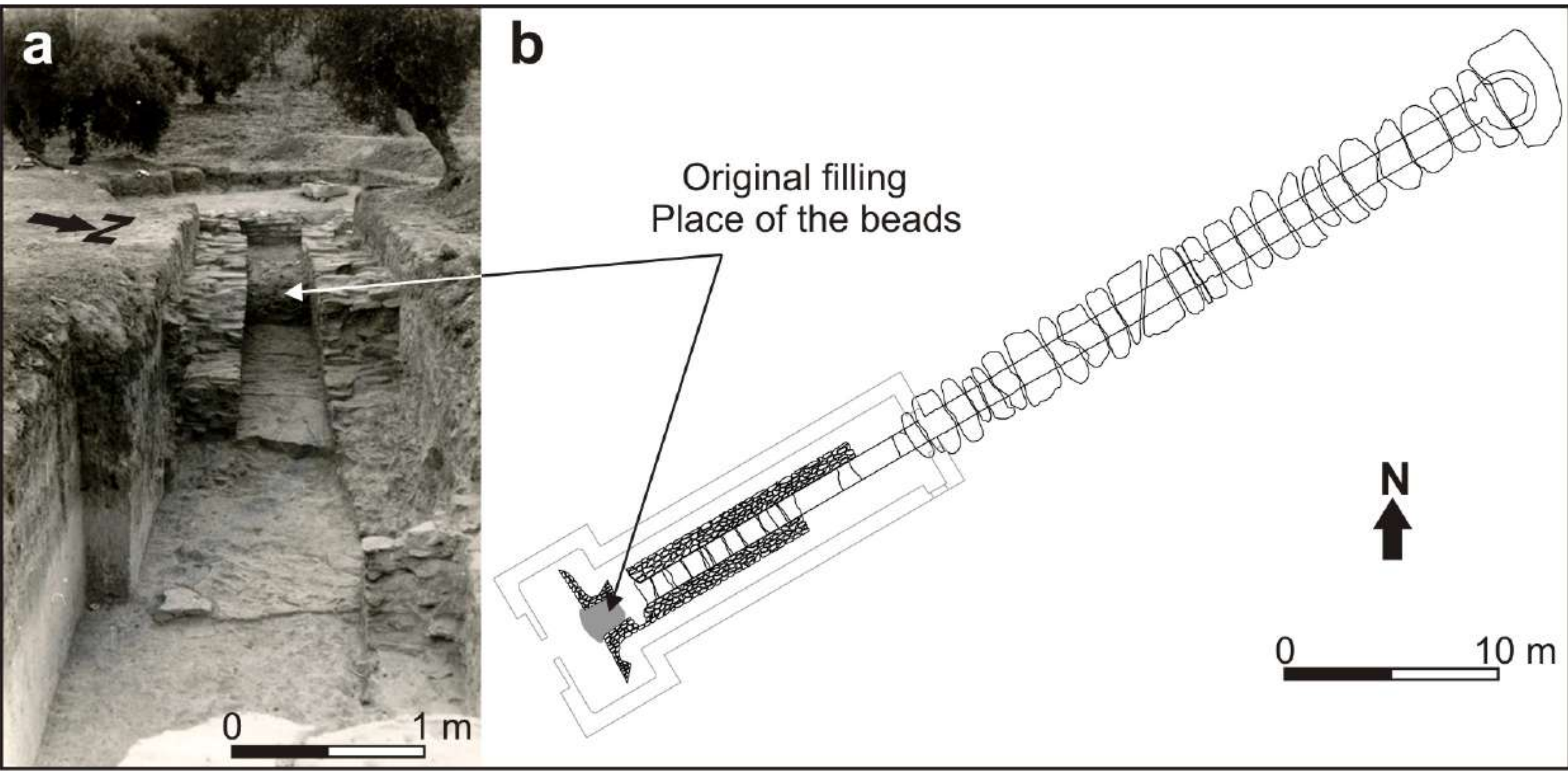
Fig. 3. Set of beads from the 1991-92 excavation of tholos de la Pastora (Museum of Valencina de La Concepción). (A) 71 specimens of *Chthamalus montagui* (three of them double). (B) 30 bone and rock beads.

Fig. 4. *Chthamalus montagui* shell morphology. (A) External morphology and outline sketches of external plates, dorsal view. (B) External morphology with indication of LW (lateral width) and RCL (rostrum-carina length), dorsal view. (C) External morphology, lateral view, h (height).

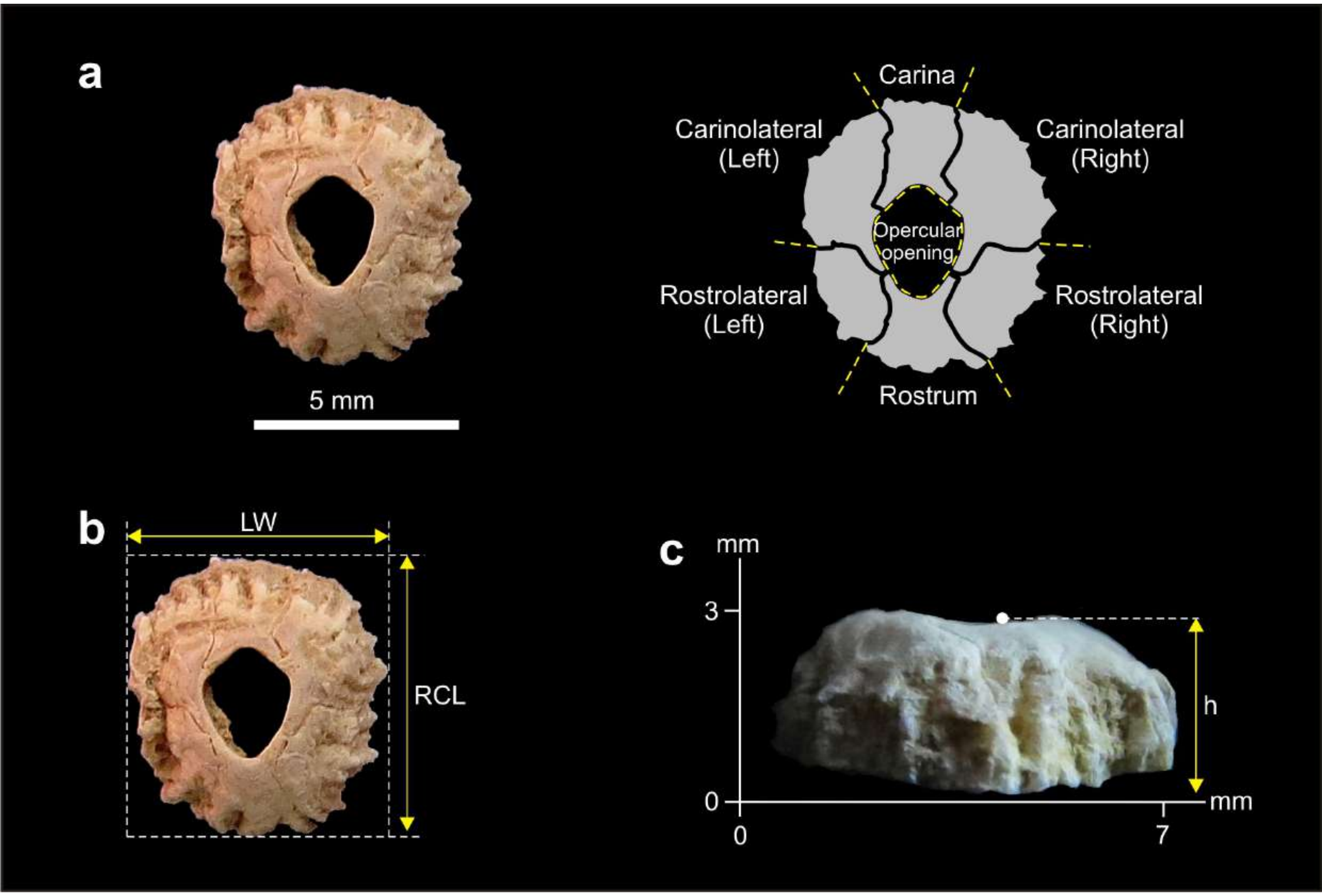
Fig. 5. *Chthamalus montagui* shell morphology. (A) Specimen in dorsal (I) and ventral (II) view, it is possible to observe the typical Kite-shape of the natural opercular opening. (B) Two specimens attached, dorsal view. (C) Specimens where the sutures between the plates can be observed (I) or they are hidden (II and III), dorsal view.

Fig. 6. Graphic representation of three calibrated AMS dates (2σ) from barnacle samples into the tholos of La Pastora and the time range published by Cáceres et al. (2014). (*) archaeological sample.

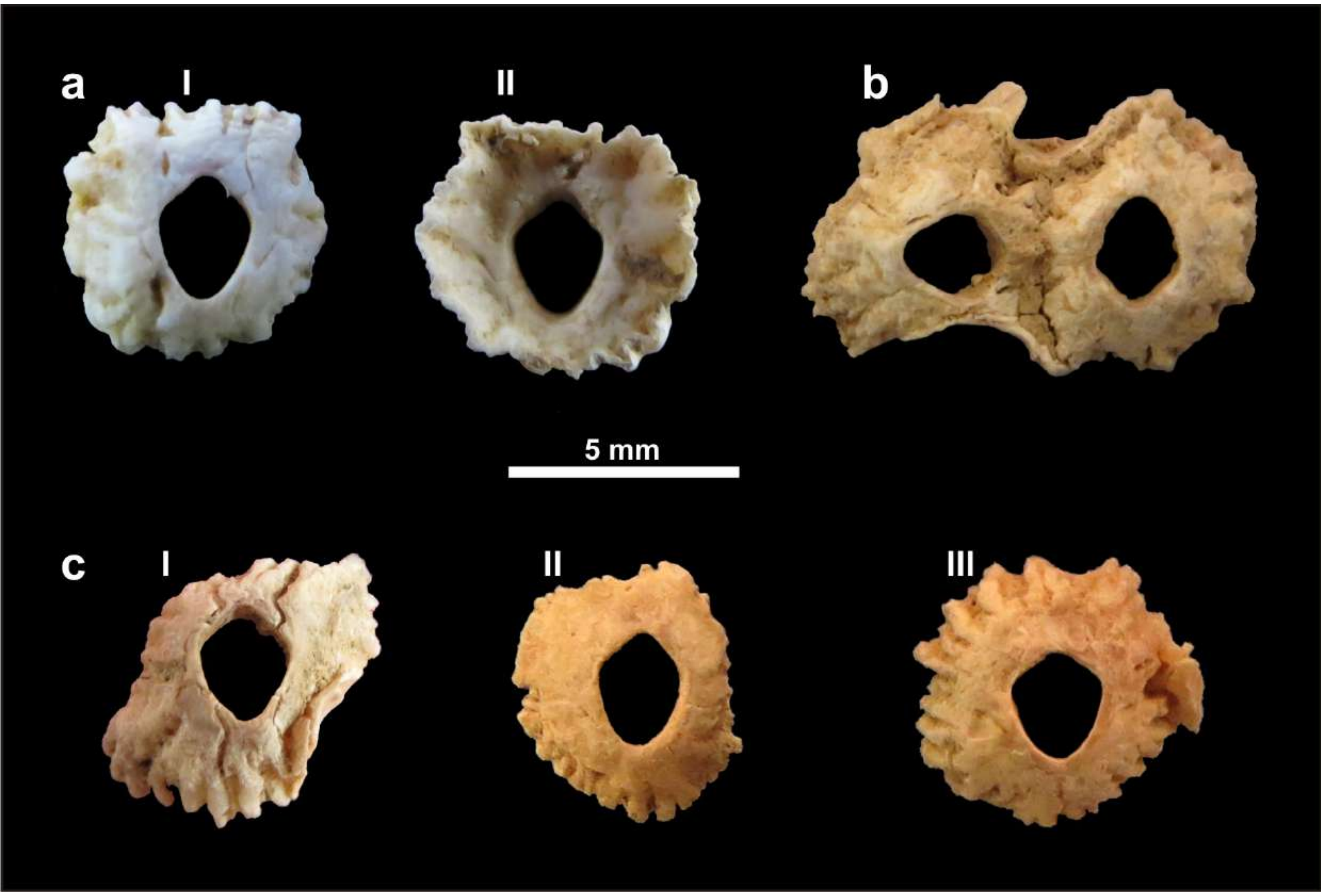

a
Iberian Peninsula
Valencina de la Concepción
SEVILLA
Coria del Río
Guadalquivir Marshes
Google Earth
50 km
N
b
Mega-site Valencina-Castilleja
La Pastora
Guadalquivir River
SEVILLA
Google Earth
3 km
N


a
b
Original filling
Place of the beads
N
0
1 m
0
10 m

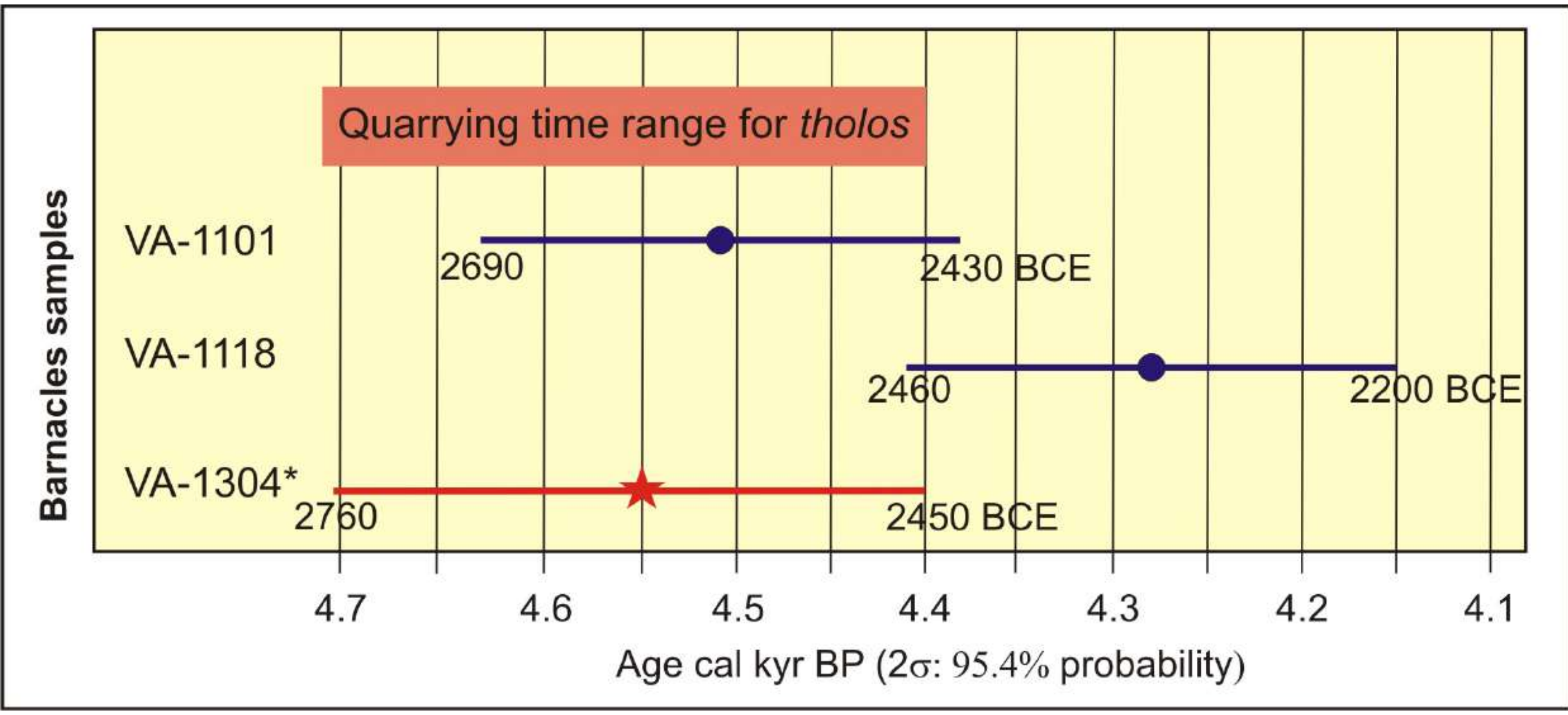

a
20 mm
b



a
Carina
Carinolateral
(Left)
Carinolateral
(Right)
Opercular
opening
Rostrolateral
(Left)
Rostrolateral
(Right)
Rostrum
5 mm
b
LW
RCL
c
mm
3
0
h
0
7
mm



a
I
II
b
5 mm
c
I
II
III



Quarrying time range for *tholos*
Barnacles samples
VA-1101
2690
2430 BCE
VA-1118
2460
2200 BCE
VA-1304*
2760
2450 BCE
4.7
4.6
4.5
4.4
4.3
4.2
4.1
Age cal kyr BP (2σ: 95.4% probability)