



Surviving on the isle of Formentera (Balearic Islands): Adaptation of economic behaviour by Bronze Age first settlers to an extreme insular environment

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ABSTRACT

The isle of Formentera (Balearic Archipelago, Spain) was one of the latest insular contexts to be colonized in the Mediterranean. The first settlement occurred during the second millennium cal BCE, and this late human occupation is associated with insularity factors, including an extreme environment. Cap de Barbaria II is one of the biggest open-air *naviform* villages occupied during the first prehistoric settlement and for an extended period (ca. 1600–850 cal BCE). Multidisciplinary archaeological research conducted within the site reveals adaptation of the economic behaviour of these first settlers to an environment poor in resources. In this sense, aspects such as innovation, diversification, and intensification in the use of resources characterized the subsistence and technological patterns developed by the prehistoric inhabitants of Formentera. New data from different archaeological and paleoenvironmental studies, such as archaeobotanical, archaeozoological, or technological and functional, have been analyzed. In this sense, the assessed subsistence patterns, reveal adaptive strategies that encompass different local and exogenous resources and differ from those observed in the rest of the Balearic Islands.

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1. Introduction

From an archaeological perspective, insular contexts are the perfect laboratory for understanding prehistoric human societies (Evans, 1973). First, islands are good contexts to identify and scientifically control the influx of foreign elements, both human and raw material, or specific objects (Knapp and van Dommelen, 2014; Cherry and Leppard, 2014). Islands are also the perfect context for approaching the anthropic impact on non-colonized ecosystems and human-environment interactions. In this sense, the Mediterranean Sea has played an important

role in insular archaeology for examining all these issues (e.g. Cherry, 1990; Patton, 1996; Rainbird, 1999; Broodbank, 2000; Boomert and Bright, 2007; Fitzpatrick et al., 2007; Fitzpatrick and Anderson, 2008; Dawson, 2014). The case of the Balearic Islands, in the Western Mediterranean, provides particularly outstanding evidence for understanding colonization processes in relation to insular ecosystems.

The first human settlement of the Balearic Islands is widely accepted to have occurred during the end of the mid-third millennium cal BCE (Costa and Guerrero, 2002; Guerrero et al., 2007), although some studies suggest previous sporadic exploration during the Mesolithic, based on non-dated lithic assemblages (see Guerrero and Calvo, 2008; Fullola et al., 2005). Nevertheless, reliable direct radiocarbon dating located the first human settlement between 2350 and 2150 cal BCE

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(Alcover, 2008) or 2400 and 2300 cal BCE (Lull et al., 2008; colonization process summarized in Guerrero and Gornés, 2000; Ramis, 2014). Therefore, the islands in the Balearic Archipelago—the Gymnesic Islands (Majorca and Menorca) and the Pithyusic Islands (Ibiza and Formentera) (see Fig. 1)—were the latest Mediterranean islands to be colonized by humans, and they remained almost isolated during most of the Bronze Age (Ramis, 2014). Among all the islands, Majorca is the one with the earliest evidence of human occupation (Alcover, 2008).

For the small isle of Formentera, reliable archaeological evidence for the earliest prehistoric occupation is scarce and restricted to a few sites such as Cova des Riuets (Marlasca, 2008; 2010), Cova des Fum (Topp, 1988; Marlasca and López Garí, 2015), and to the funerary megalith of Ca na Costa (Fernández et al., 1976; Topp et al., 1979; van Strydonck et al., 2005) (Fig. 1); all of these have been dated to the early second millennium cal BCE (Costa and Guerrero, 2002). This late occupation, compared with the rest of the islands in the Mediterranean, is probably due to its environment, poor in resources and biodiversity for sustaining a permanent settlement (Alcover et al., 1994; Costa and Benito, 2000; Bofill and Sureda, 2008). Nevertheless, archaeological evidence of a stable population during the Bronze Age is represented by more than 30 sites, most of them located in Cape Barbaria (Fig. 1), being one of them the site discussed in this paper. Many of these sites have not yet been excavated and are habitation structures with imprecise chronology (Costa and Fernández, 1992). Archaeological research conducted on the isle and focusing on the prehistoric period is scarce, with a few

exceptions (summarized in Costa and Benito, 2000; Ramis, 2014); therefore, no information is available related to the social and economic characteristics of the first human occupation.

For these reasons, the aim of this paper is to contribute to the understanding of the economic behaviour developed by the first prehistoric settlers of Formentera. We tackle this by presenting the results of our systematic multidisciplinary archaeological research conducted at Cap de Barbaria II since 2012 (Sureda et al., 2013a, 2013b, Sureda et al., 2014, Sureda et al., 2015).

Our results indicate that human settlement on Formentera during the Bronze Age was possible due to the adaptation of economic behaviour to the environment, based on innovation, diversification, and intensification of resources management. This differed from the economic behaviour developed in the rest of the Balearic Islands during the same chronology.

2. Geographical, geological and environmental settings of the Formentera isle

Formentera is a 83.24 km² island and possesses a very specific environment with some conditions that difficult the development of a subsistence model based on the agriculture-livestock tandem, as we know for other Bronze Age societies. In general, the environment is quite similar to other Mediterranean isles, rainfall is scarce and xeric taxa are the dominant flora. In addition, a particular poor sedimentation and the absence of superficial water sources, affects the development of crops and

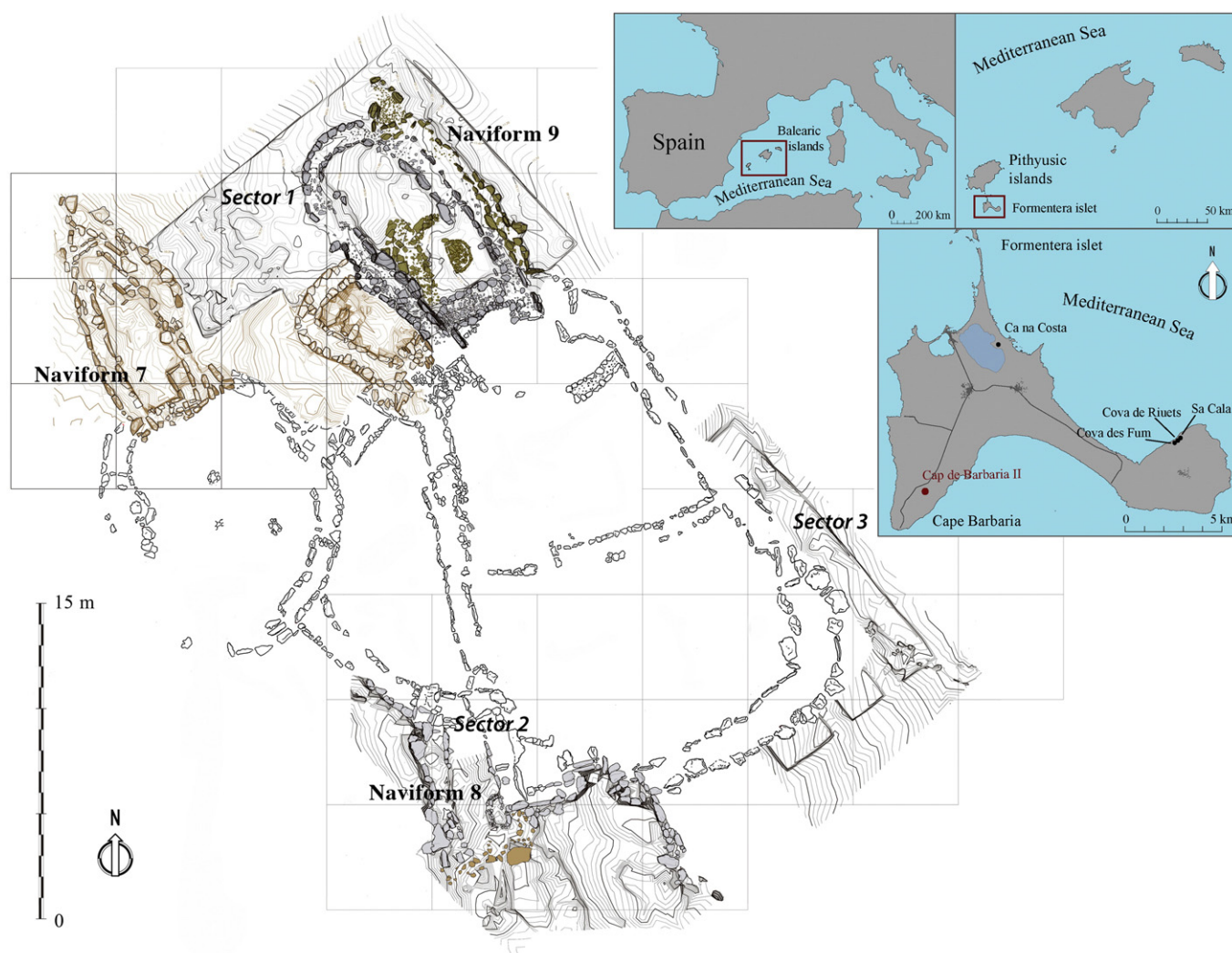


Fig. 1. Geographical location of CBII in the Isle of Formentera (Balearic Archipelago, Spain) and plan of the site highlighting the excavated sectors since 2012.

pastures. Indeed, common raw materials on other Bronze Age societies are scarce or non-existent (i.e., flint, copper, tin) due to mainly calcareous geology of the island. For this reasons we consider that Formentera represents an extreme environment case for prehistoric human settlement that required a specific subsistence model. Also CBII represents a unique case with these characteristics in the Balearic Archipelago, and it is the perfect archaeological context to understand how the first settlers interacted with an insular ecological niche and how this affected their subsequent economic behaviour.

3. The site of Cap de Barbaria II (Formentera isle)

Cap de Barbaria II (CBII), an open-air village composed of up at least nine habitations and collective structures, is located in the Southwestern cape of the isle of Formentera (Fig. 1). CBII is the largest prehistoric village in the isle (Costa and Fernández, 1992; Costa and Benito, 2000; Sureda et al., 2013a), covering an area of ca. 1500 m², with prehistoric houses similar to those present in Majorca and Menorca. The houses, called *naviforms*, are boat-shaped structures constructed with a cyclopean technique (i.e., Juan and Plantalamor, 1997; Pons, 1999; Fornés and Salvà, 2001; Salvà and Hernández-Gasch, 2009; Anglada et al., 2013; Ramis and Salas, 2014). The *naviforms* at CBII do not differ from each other from a material point of view (size, construction technique and material), and they were the places where domestic activities were centered during Balearic Bronze Age.

CBII was first excavated between 1979 and 1987 (Fernández, 1984; Costa and Fernández, 1992). Since 2012, a new archaeological project was designed to reanalyze the previously excavated material, as well as to excavate *Naviform* 8 (Fig. 3c) and 9 (Fig. 3b) with modern methodology, together with some exterior zones (Sectors 1, 2 and 3) (Fig. 1) (Sureda et al., 2014).

New radiocarbon dating (Table 1) attributes a first occupation of the site dated from ca. 1600 cal BCE, with two different construction phases [i.e., Phase 1 (ca. 1662–1490 cal BCE) is highlighted for *Naviform* 9 in the plan shown in Fig. 1]. Occupation continued for almost 800 years, until peaceful abandonment of the village, probably related to the Phoenician colonization of Formentera and Ibiza. In this sense, other *naviform* sites from Majorca and Menorca (i.e. Closos de Can Gaià site) have dated this abandonment phase from 850 cal BCE (Micó, 2005). For this reasons we have suggested that CBII probably responds to the same chronological occupation scheme: ca. 1.600–850 cal BCE (Sureda et al., 2013a, 2013b).

4. Materials and methods

4.1. Archaeological and raw material analysis

4.1.1. Present paragraph

A multidisciplinary approach has been applied to the materials and samples analyzed from CBII; these were recovered during three archaeological fieldwork seasons (2012–2014) from *Naviforms* 8 and 9 and exterior zones (Sectors 1, 2 and 3) (see Figs. 1 and 2). The present paper describes and integrates the lithic, archaeozoological, archaeobotanical (including pollen, anthracological, starch grain, and plant macro remains analysis), archaeometallurgical, and petrological analysis of the pottery. The aim is to provide a general view of the economic strategies developed by the first settlers in Formentera, as well as a precise environmental context, in order to elucidate socioeconomical adaptations to the insular environment. Poor sedimentation processes in Formentera isle have produced a simple stratigraphy in CBII (Fig. 2).

According to this, normally three, or four at the most, overlapping levels, can be differentiated at the site, to a maximum depth of 30 to 50 cm above the natural bedrock. This stratigraphic sequence consists on a top natural level overlaying a collapse stratum and a floor occupation level. This occupation floor generally sits on top of the natural, but sometimes it overlies a preparation stratum to pave it. All studied materials and samples were recovered in the occupational layers from both interior and exterior zones of the structures. Standard archaeological recovery methods have been applied and all stratigraphic units have been individualized and geometrically defined by topographic and photogrammetric techniques. Total stations [Leica TCRM1205], topographic and photogrammetric software [n4ce/Applications in Cadd; Photomodeler Scanner 2016] and CAD environments [MicroStation/Bentley] were used for this purpose.

4.1.2. Geochemical analyses

In relation to lithic materials, the study of macrolithic (or ground stone) artefacts followed the methodological approach for their functional analysis (Adams et al., 2009; Bofill, 2015). Factors such as raw material, manufacture, maintenance and use of macrolithics were examined in order to explore the role of food processing and craft activities related to these tools at the site. For use-wear analysis of flaked lithic surfaces, a metallographic microscope (Leica DM2500M) and a stereomicroscope (Leica MZ16) were used. The examination was carried out at 100×, 200× and 400× magnifications. During the analysis, the IMF-CSIC's (Instución Milà i Fontanals-Consejo Superior de Investigaciones Científicas) Laboratory of Prehistoric Technology (Barcelona) flint reference collection was used. As a methodological support the standards proposed by Gonzalez Urquijo and Ibáñez (1994) and Vaughan (1985) were selected.

With reference to archaeometallurgical studies, chemical composition of all items have been analyzed with Energy Dispersive X-ray Fluorescence (EDXRF). EDXRF analyses were developed with an Innov-X Alpha spectrometer, acquisition times were set at 40 s and the quantitative values were calculated from a calibration validated with certified standards. Values are expressed as weight percent (%) of each of the elements detected (ND = not detected). Metallographic analyses were performed using optical and scanning electron microscopy (SEM-EDX). All samples have been prepared and polished following standard laboratory procedures (Scott, 1991; Rovira and Gómez Ramos, 2003). Structural examination of metal sections was performed working between ×50 and ×500 magnifications.

Finally, for the petrological analysis, pottery vessels were sampled and polished for petrographic and textural characterization by optical microscopy. The optical examination of thin sections was performed using a petrographic microscope Leica DM2500P, working between ×16 and ×400 magnifications. Photomicrographs of the samples were taken with a Leica DFC295 digital camera.

4.2. Paleoecological and palaeoenvironmental analysis

4.2.1. Archaeozoological

Regarding archaeozoological studies, the faunal analysis (vertebrates and invertebrates) was carried out following standard archaeozoological methods (Lyman, 2008; Moreno, 1994; Reitz and Wing, 2008). Anatomical and taxonomic identification was based on reference material. Additionally, bone and shell surfaces modifications details were recorded.

Table 1

14C age determinations for Cap de Barbaria II (*Naviform* 9). Calibrated dates are obtained using INTCAL13 (Reimer et al., 2013) and OxCal 4.2 software (Bronk Ramsey, 2009).

Sample code	Structure and Unit	Sample Description	Conventional Age (BP)	Calibrated age at 1 sigma ranges (BCE)	Calibrated age at 2 sigma ranges (BCE)	C:N
MAMS-22,644	Naviform 9 US 1.9.2.4	Bone (Caprinae)	3308 ± 23	1616–1533	1662–1518	2.2
RICH-20,967	Naviform 9 US 1.9.1.4	Bone (Caprinae)	3287 ± 33	1610–1525	1650–1490	3.3

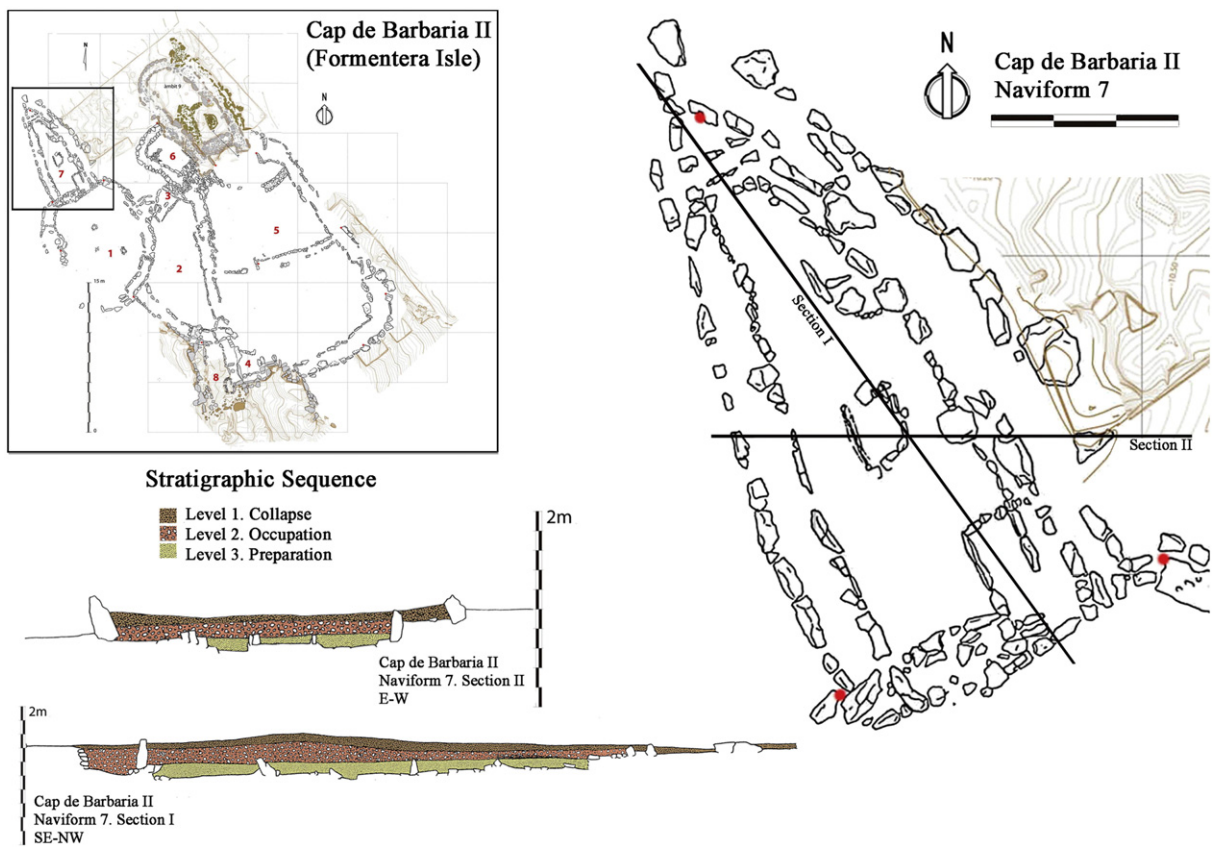


Fig. 2. General stratigraphic sequence of CBII site.

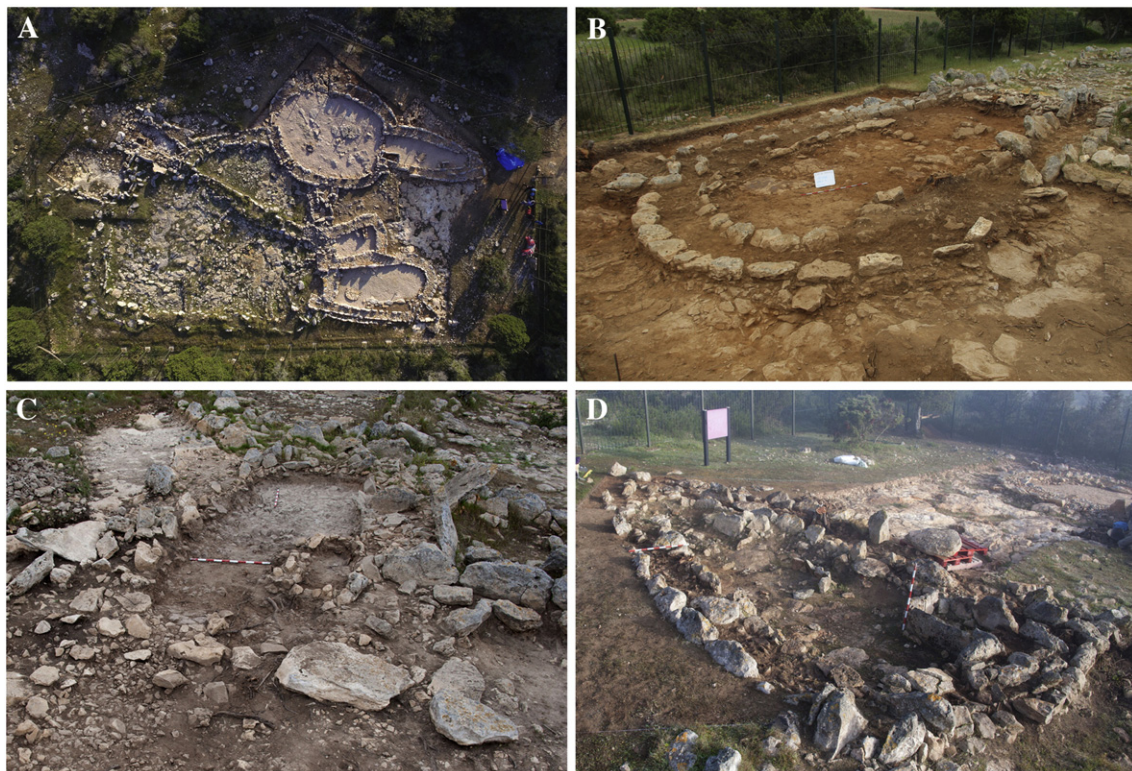


Fig. 3. Cap de Barbaria II: A) Aerial view of CBII with restored areas; B) Naviform 9; C) Naviform 8 and D) Naviform 7.

4.2.2. Archaeobotanical

Concerning archaeobotanical studies, we have to consider different strategies. The sampling program for the recovery of plant macroremains consisted in a random sampling of 20% of the sediment from the outside of the *naviforms* structures and 100% of the sediment from the interior zones, and processing by flotation. Soil samples were of around 10 l and flotation was carried out by hand in a tank with the heavy residue being retained in a 2 mm mesh and flots retrieved in a 0.25 mm mesh. Dried flots were divided into fractions with a column of sieves of 2, 1 and 0.5 mm. and scanned under a microscope under low magnification (between 10× and 80×). In addition, casts have been obtained from plant imprints in pottery fragments by application of a high-resolution silicone (Camarós et al., 2016). Non-woody plant macroremains (or their silicone casts) have been taxonomically identified by comparison of anatomical and morphological characteristics with atlases (e.g., Neef et al., 2012) and a modern seed reference collection at the IIIIPC (Cantabria).

Charcoal analysis has been conducted following the standard methodology (Chabal et al. 1999, Asouti and Austin, 2005, Théry-Parisot et al. 2010). Charcoal fragments have been hand-broken to obtain fresh cuts of the three anatomical planes of wood (transversal, longitudinal tangential and longitudinal radial). Wood anatomy has been observed in a reflected light microscope (Olympus BX-40) for taxonomical identification. Wood anatomy atlases (Greguss, 1955, 1959; Jacquot, 1955; Jacquot et al., 1973; Schweingruber, 1990; Vernet et al. 2001) and the charcoal reference collection of the University of the Balearic Islands have been used as reference materials for identification. Quantification is based in fragment count per taxon/sample.

Pollen analysis, as the limited stratigraphy prevented a diachronic analysis, sampling consisted of collecting sediment from different archaeological layers and structures from the 1st phase of occupation (2nd phase layers did not ensure proper preservation conditions and lack of modern contamination). The preparation of the samples followed standard methods (Burjachs et al., 2003) using treatment with HCl, NaOH, flotation in dense Thoullet liquor (2.1 cm³/g), HF (70%) and final mounting in glycerine. 300 pollen grains of terrestrial taxa were counted using an Olympus Bx43 microscope fitted with ×10 oculars and ×40/60 objectives. In samples where pollen was poorly preserved, pollen sum was under 300 pollen grain and results are expressed in absence/presence (Fig. 10). All pollen types are defined according to Reille (1992, 1995, 1998) and Cerealia-type was defined according to the morphometric criteria of Faegri and Iversen (1989). Pollen concentration is expressed in pollen grains/g of sediment following the volumetric method (Loublier, 1978).

Starch grain analysis was carried out in order to identify processed plants, through comparison of archaeological starch grains with reference collections. For the recovery of the starch grains we applied a separation protocol based on the difference of density between the starch grains and a solution prepared with cesium chloride (CsCl) (Dickau, 2005; Piperno, 2006:60).

5. Results

5.1. Lithic studies

This study of the lithic material differentiates between macrolithic and microlithic remains. The macrolithic tools and ornaments included a total of 35 remains recovered from both inner and exterior zones in CBII. Local raw materials were used by prehistoric societies on Formentera, and can be described as a sedimentary type, using mostly organogenic and microcrystalline limestone available as pebbles in coastal natural deposits. Especially relevant for grinding purposes were some layers of local organogenic limestone (*Lumaquela*), extremely abrasive, which are formed through the high accumulation of organic remains (shell, coral, etc.) (Fig. 4c). Finally, foreign raw materials were

used for a few types of artefacts, such as a schist palette, a quartzite hammerstone, and a *Bundsandstein* sandstone abrader.

Typologically, the macrolithic remains are tools used in different activities, such as cereal grinding (27%) (i.e., Fig. 4b–c), smoothing (9%), percussion (15%), and a combined smoothing-percussion function (9%) (i.e., Fig. 4a). A further 33% of the tools display a non-defined functionality, although they display of use-wear traces.

The functional studies among macrolithic remains were supplemented by starch analysis conducted over grinding tools to infer the types of substances processed on them. Preliminary results show that in CBII those tools were used to grind cereals such as millets (see the starch grain analysis section), although other species such as barley could have been also processed. Nevertheless, other type of function of the macrolithic tools is currently being analyzed, such as pigment production.

Knapped lithic tools have been also recovered in CBII, indicating the use of two types of raw materials from different origins. On the one hand, the identification of a core (Fig. 5e) and three knapped flakes made on limestone (Fig. 5d), one of them used for scrapping hide, confirms the expeditious anthropic use of local resources (Fig. 6). On the other hand, we identified the presence of three lithic tools knapped on flint (Fig. 5a–c), which had to have been imported from outside the island of Formentera, as this type of abiotic resource has not been identified in the Pithyusic islands (Ibiza and Formentera). Flint resources can be found in the other islands of the Balearic archipelago, especially in Majorca and Menorca (Arche et al., 2002). Specifically, it is found inside the Triassic geological levels (Muschelkalk formation) in the form of little nodules embedded into the limestone. However, more detailed studies have to be done in order to determine the flint raw materials origin. These flint tools were used extensively and for a long time (probably for decades). We highlight a flint core (Fig. 5e), knapped until it achieved its maximum potential for blade and microblade procurement. Use-wear analysis in CBII allows us to infer activities such as cereal stem cutting at high (Fig. 5b) and low (Fig. 5c) heights and woodworking and hide processing (Fig. 5a).

The identification of a pyramidal limestone perforated button (Fig. 11c), and several stone beads (NR = 5) (Fig. 11d) among microlithic remains indicates activities beyond subsistence, such as ornament production.

5.2. Archaeozoological studies

Faunal remains have been recovered from all stratigraphic units (Fig. 2), with significant numbers from the interiors of *Naviforms* 8 and 9. However, the poor preservation of the mammalian and avian faunal spectrum precluded any socioeconomic inference regarding animal processing as resources based on fractures, cutmarks and other anthropic signatures. Post-depositional modification is characterized by differential anatomical preservation and almost the 50% of the recovered faunal remains were dental.

Despite the impossibility of reconstructing animal processing for CBII due to post-depositional factors, several inferences can be made based on the species representation, which included goats (*Capra* sp.) and sheep (*Ovis aries*) as the most well represented taxa, followed by cattle (*Bos taurus*) and pigs (*Sus domesticus*). Bird bones from the endemic species Balearic shearwater (*Puffinus puffinus*) have been also recovered. Finally, eggshell fragments (NR = 10) have been identified from the analyzed sediments.

Mollusks are the most abundant and diversified type of animals remains present in CBII. The assemblage of more than 3500 remains included a high variety of both gastropod and bivalve species (Fig. 7 and Table 2) from marine environment. The most represented taxa are *Patella* (including *P. rustica*, *P. nigra*, and *P. ulyssiponensis*) and *Phorcus turbinatus*. These malacofaunal remains represent 82% of the determined individuals (NMI 372) and were probably gathered from the sea-shore for their nutritional value.

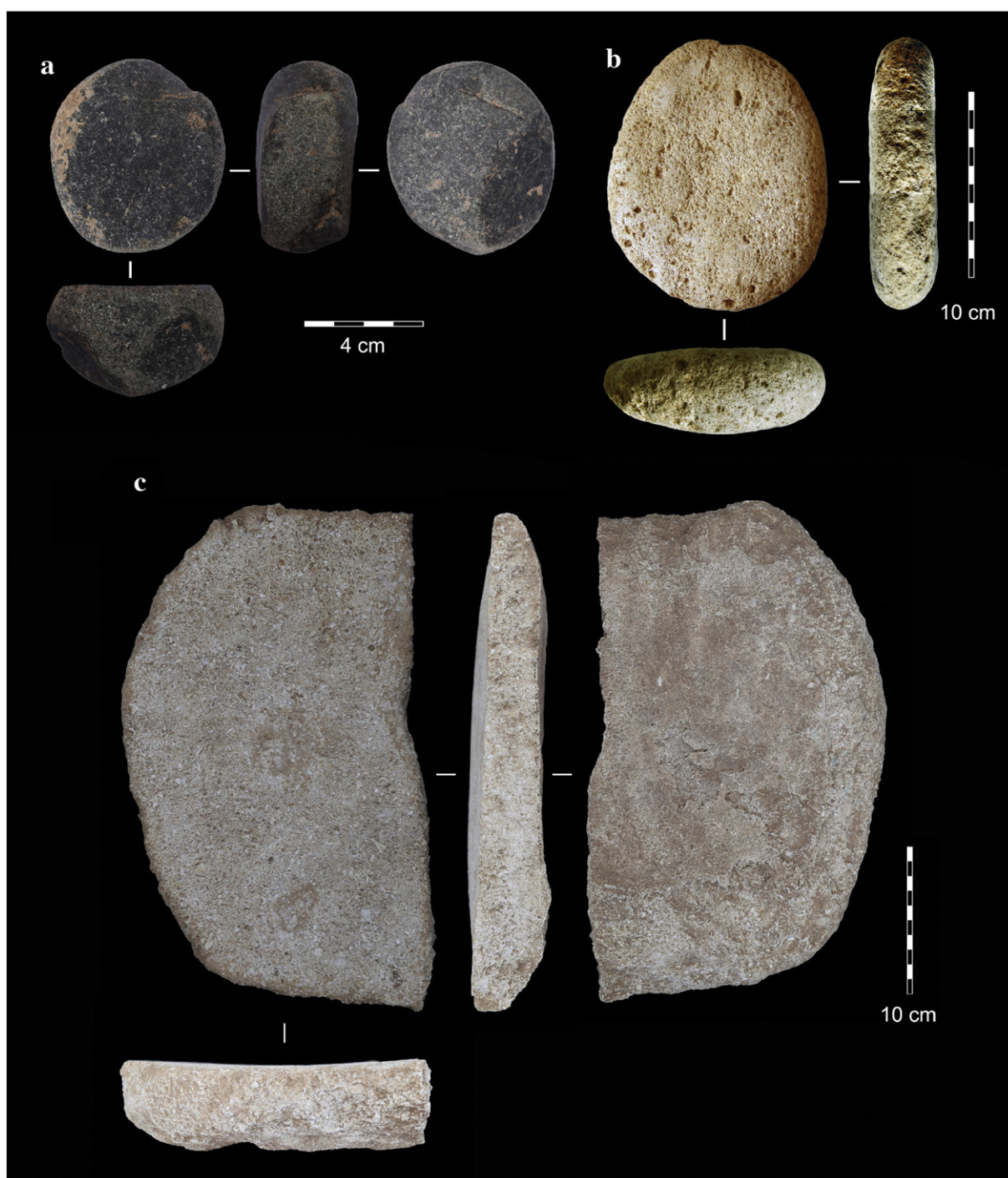


Fig. 4. Macrolithic remains from CBII: a) Abrader/hammerstone (microcrystalline limestone); b) Handstone (organogenic limestone) and c) Grinding slab (organogenic limestone-Lumaquela).

Other species identified in the site include *Collumbella rustica* and *Glycymeris* sp.; both taxa showing marine abrasion and even epifauna in the inner parts of the shells. This allows the inference that these individuals were collected from the coast once the animals were dead. This is related to the use of marine shells as raw materials to produce ornaments. Several remains, including those of *Antalis* sp. and *Glycymeris* sp., have been interpreted as ornaments in the form of pendants, with clear perforations and production/use-wear traces (see Fig. 7i).

Although not yet studied, fish remains represented by otoliths and vertebra bones have been recovered at the site. The ongoing study will provide information on the exploited species, nevertheless, its presence

proves fishing activities at the site also evidenced through the archaeometalurgical studies.

5.3. Archaeobotanical studies

The archaeobotanical studies of CBII involved the analysis of seeds, pollen, charcoal and starch grains (Table 3). This allows the inference of both paleoecological and economic aspects related with CBII subsistence strategies and Bronze Age landscape.

The exploitation of plant resources is indicated by the analysis of seeds (observed through carbonized macroremains and imprints in

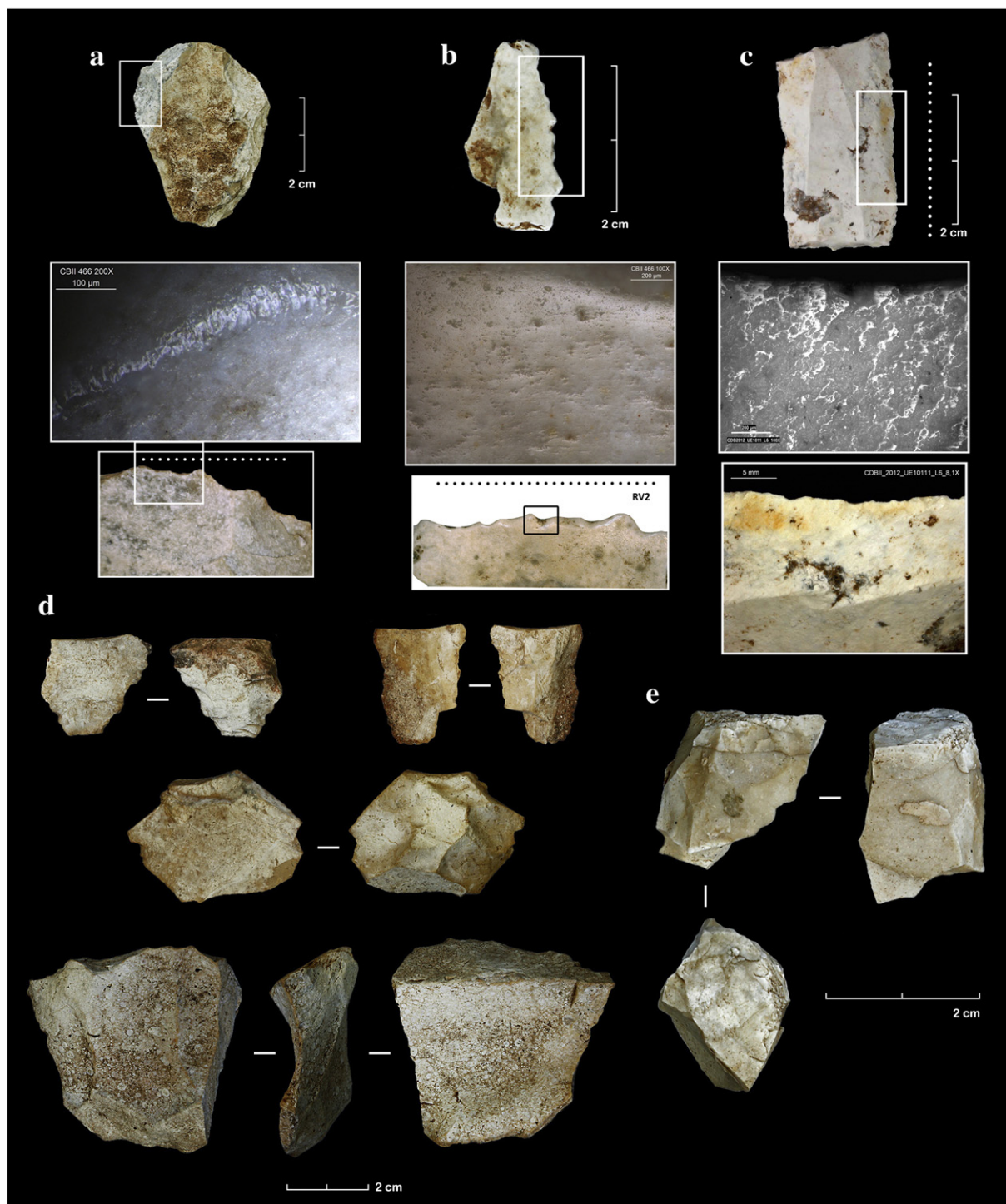


Fig. 5. Lithic tools from CBII: a) Tubular chert with developed wood scraping micro use wears (and use-wear traces); b) Sickle blade with developed low reaping use wears or probable Tribulum; c) Sickle blade with developed high reaping traces; d) Flake blanks and core on limestone; e) flake and probable bladelet flint core.

ceramic fragments) and starch grains extracted from lithic tools. Plant macroremains were scarce in both interior and exterior zone samples, due to preservation and depositional factors, as widely discussed previously in the literature (i.e., Wright, 2003). In this sense, the remains have been subjected not only to the alkaline pH of the karstic bedrock (Braadbaart et al., 2009), but alternately to high sun exposure and moisture (Hansen, 2001), which affected negatively the preservation of charred plant macroremains. Nevertheless, bedstraw seeds (*Galium* sp.) and fruits and fragments of *Juniperus phoenicea* leaves have so far been identified at the site (Table 3). A distinction between *Juniperus*

subspecies was not possible on the basis of leaf morphology, but the present plant distribution suggests *J. phoenicea* subsp. *turbinata* as the most probably form (see Aedo and Castroviejo, 2012). Most of the plant imprints in pottery remain undetermined, although there is a well preserved grain imprint which has allowed the identification of the naked variety of barley (*Hordeum vulgare* var. *nudum*) (López-Dóriga et al., 2015) (Fig. 8).

Starch grains analyzed from four lithic macroremains (two grinding stones and two handstones) (i.e., Fig. 4) also reveal aspects related to plant exploitation. The processed plants were identified as *Setaria* cf.

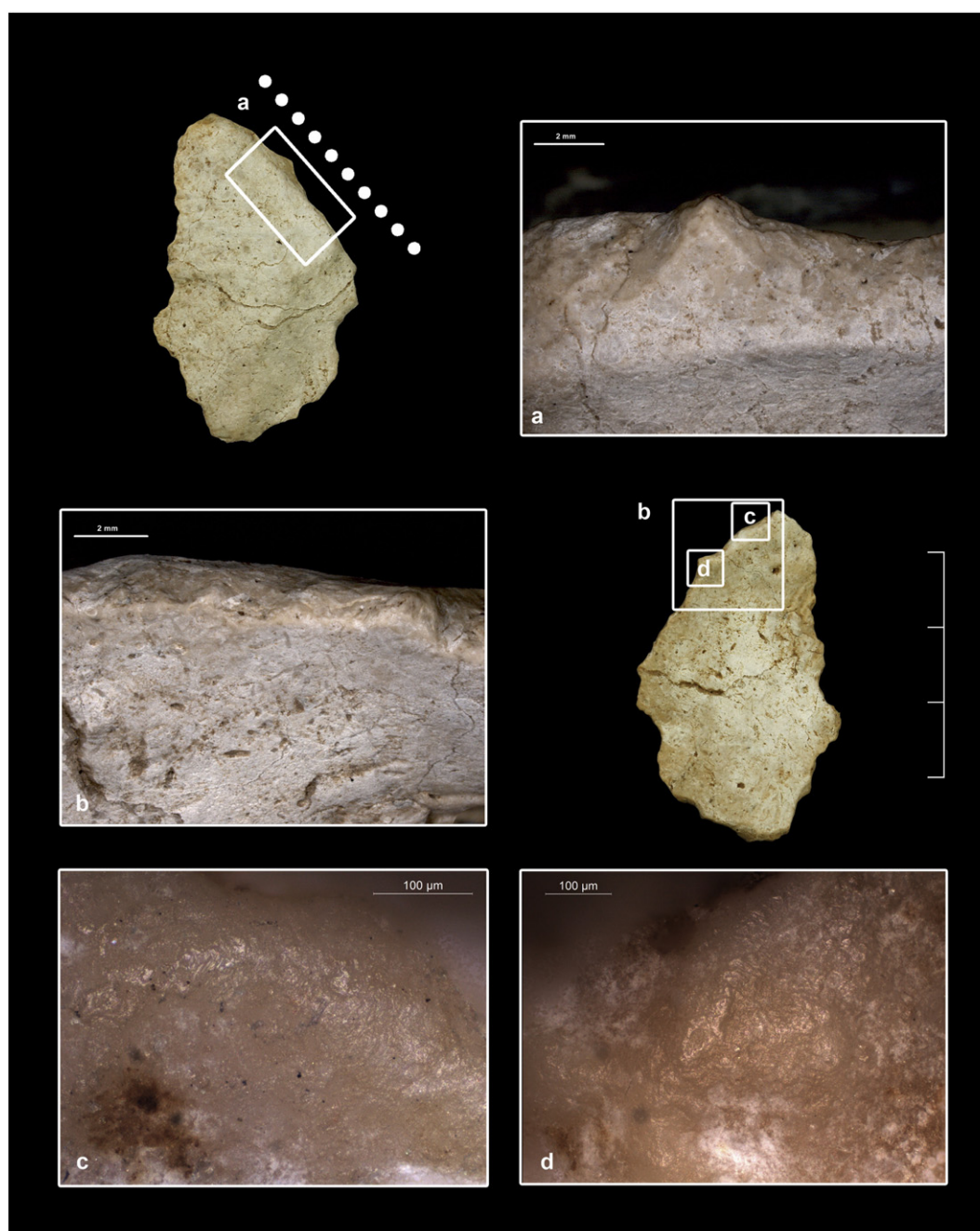


Fig. 6. Retouched limestone flake with developed hide scraping use wears.

italica (NR 130) specifically, as well as grains belonging to the *Paniceae* (NR 10), which include *Panicum miliaceum/Setaria italica*), and the *Triticeae* (NR 1), among other non-identified plants (NR 6) (Fig. 9). The average size of *S. italica* is 16 µm and 40% of the starches are cracked—a phenomenon that occurs during the processing of seeds.

Anthracological (charcoal macroremains) data also indicates the type of exploitation of the landscape conducted in CBII. This preliminary study suggests the use of *Juniperus*, *Pistacia lentiscus*, Labiatae, and *Fabaceae* as firewood, gathered in open landscapes dominated by xeric scrublands and *Juniperus* woodland. The anthracological study, still ongoing, indicates that *Juniperus* dominated the open xeric and heliophilous vegetation. This hypothesis also agrees with the pollen record (11 samples from sectors 1 and 2) from CBII (Fig. 10), which shows an open landscape of xeric shrublands already in the 1st phase of occupation (ca. 1662–1490 cal BCE). Thus, pollen data indicates a vegetal

landscape adapted to summer dryness and poor substrates with the dominance of *Juniperus*, *Cistaceae*, *Pistacia* and *Erica*. Nevertheless, the poor conservation of *Juniperus* pollen grains in inorganic oxidized sediments, together with the anthracological results, explains testimonial values of this taxon in the pollen diagram and the overrepresentation of *Pinus* that may have not been in the immediate surroundings of the settlement (not yet identified in the anthracological samples analyzed).

The high values of grassland and ruderal herbs in the pollen record (*Plantago*, *Asteraceae*, and *Chenopodiaceae*) also indicate the existence of large deforested areas in the settlement surroundings, probably increased by marine/brackish influence. Pollen analysis also suggests the presence of secondary trees, such as *Quercus ilex/coccifera* and *Olea/Phillyrea* and shrub vegetation (*Pistacia*, *Cistaceae*, and *Erica*). Pollen values of trees such as *Quercus* and *Corylus* are too low to consider their tangible local presence, and they could have reached the island



Fig. 7. Some of the mollusk taxa identified in CBII: a) *Spondylus* sp.; b) *Glycymeris* sp.; c) *Columbella rustica*; d) *Stramonita haemastoma*; e) *Semicassis undulata*; f) *Erosaria spurca* and *Luria lurida*; g) *Cerithium lividulum*; h) *Phorcus turbinatus*; i) Anthropically modified *Antalis* sp. and j) Anthropically perforated *Glycymeris* sp.

from the neighboring isle of Ibiza and/or the Iberian Peninsula (see map in Fig. 1), where these taxa could have found suitable conditions for their development.

5.4. Archaeometallurgic studies

Few metallic objects have been recovered in CBII (NR = 5) (i.e., Fig. 11a–b). These metallic elements are, from the functional point of view, an awl, a laminar fragment, a hook, a melting drop, and a morphologically undetermined element.

Fluorescence data indicate the existence of two groups of metallic objects based on their chemical composition. One is defined by objects with pure copper or bronze with little tin, while the other contains objects of bronze with high proportions of tin (Table 4). This

differentiation can be related to the two occupation phases in CBII. In this sense, objects with high levels of tin could correspond to a co-smelting process of copper and tin mineral (possibly cassiterite) during the second phase. The melting drop also suggests local production during this second phase.

From a technological point of view, metallographic studies reveal the activities of hammering and annealing. These are indicated through parallel lines of mechanic deformation and granular formations (see Fig. 12).

5.5. Petrological analysis of the pottery

Pottery analysis has been undertaken through optical microscopy and thin section analysis of over 23 ceramic samples (e.g. of a ceramic

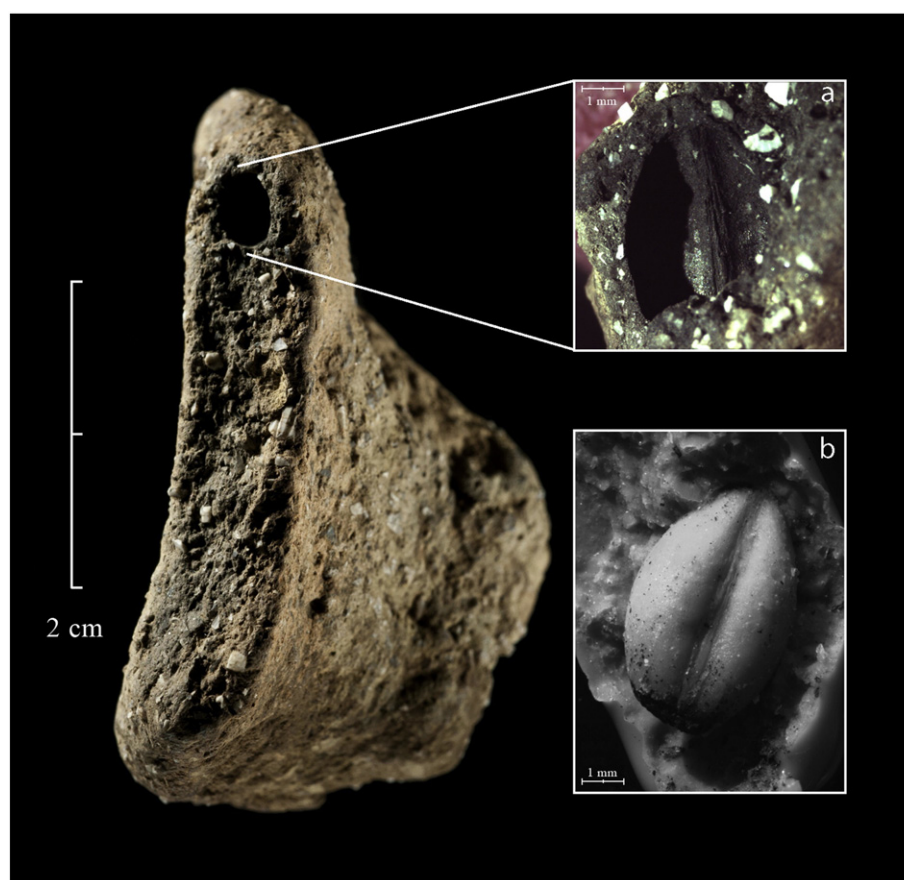


Fig. 8. Imprint (a) and high-resolution silicon positive cast (b) of a seed of the naked variety of barley (*Hordeum vulgare* var. *nudum*) from a CBII ceramic fragment.

object analyzed in Fig. 13). The study allowed the identification of the main fabric within the ceramic assemblage at the site. An optically active and heterogeneous non-calcareous clay matrix characterizes the fabric, suggesting the use of low firing temperatures. The mineral and rock fragments of the coarse fraction have a bimodal grain size distribution (Fig. 14).

On one hand, rounded microcrystalline quartz is observed at frequencies between 10 and 20% (and to lesser extent, polycrystalline quartz). These are well sorted in a medium to coarse silt fraction, with some crystals with dimensions up to 0.8 mm long. In addition, the sections contain a few muscovite laths with dimensions up to 0.1 mm, calcimudstones and rare to absent calcareous sandstones.

On the other hand, identification in some samples of a variable amount (3–15%) of euhedral rhombic to prismatic spathic calcite crystals was possible, sorted in a submillimeter grain-size (mode = 0.6 mm), although some grains were up to 2.5 mm in size.

6. Discussion

6.1. Palaeoenvironment evolution during bronze age

From a chronological point of view, the *naviform* village of CBII was occupied from ca. 1600 to 850 cal BCE. Archaeologically, it does not differ from the other Balearic Islands during the Bronze Age in aspects such as habitation structures, pottery typology, and ornament production, among others (summarized in Guerrero and Gornés, 2000).

Nevertheless, the ecological conditions of the isle of Formentera, which is defined as an extreme environment (Ramis, 2014), and certain degree of isolation of this population from the Mediterranean trade nets during the Bronze Age, resulted in a particularly adapted economic behaviour that affected subsistence strategies and technology.

Until now, little was known regarding the paleoecology of Formentera during the Bronze Age (Costa and Benito, 2000). Nevertheless, our studies infer the existence of an open landscape dominated by *Juniperus* and *Pinus*, and the presence of secondary trees such as *Quercus ilex-coccifera* and *Olea/Phillyrea*. Archaeobotanical studies from CBII, in this sense, are consistent with natural sequences analyzed in the neighboring island of Ibiza, which display an open vegetation defined by xeric and heliophilous Mediterranean taxa during the first half of the fourth millennium cal BP (Yll et al., 2009). These taxa originated by natural dynamics in the context of an aridification process initiated at the end of the Middle Holocene (Burjachs et al., 1997; Yll et al., 1997, 1999; Pérez-Obiol, 2007). The process of becoming increasingly dry was probably enhanced on Formentera due to its meridian location, the absence of permanent watercourses, and the permeability of its calcareous subsoil. Therefore, the landscape of Formentera was a difficult one for subsistence living by the first human colonizers.

6.2. Natural resource exploitation

Economic behavioral adaptations to these ecological conditions were defined by changes and particularities in both local and exogenous resource exploitation, when compared with economic strategies developed by contemporaneous societies from the rest of the Balearic Islands (see Guerrero and Gornés, 2000; Ramis, 2006, 2014; Ramis and Anglada, 2012). The exploitation of local resources was characterized by diversification and innovation. In addition to an economy based on agriculture and animal husbandry, diet was complemented with other wild resources, especially from marine origin. Fish, and especially mollusks, were important sources of protein for these first settlers. An endemic bird, the Balearic shearwater, was also hunted and its eggs sporadically harvested. This particular subsistence pattern, which

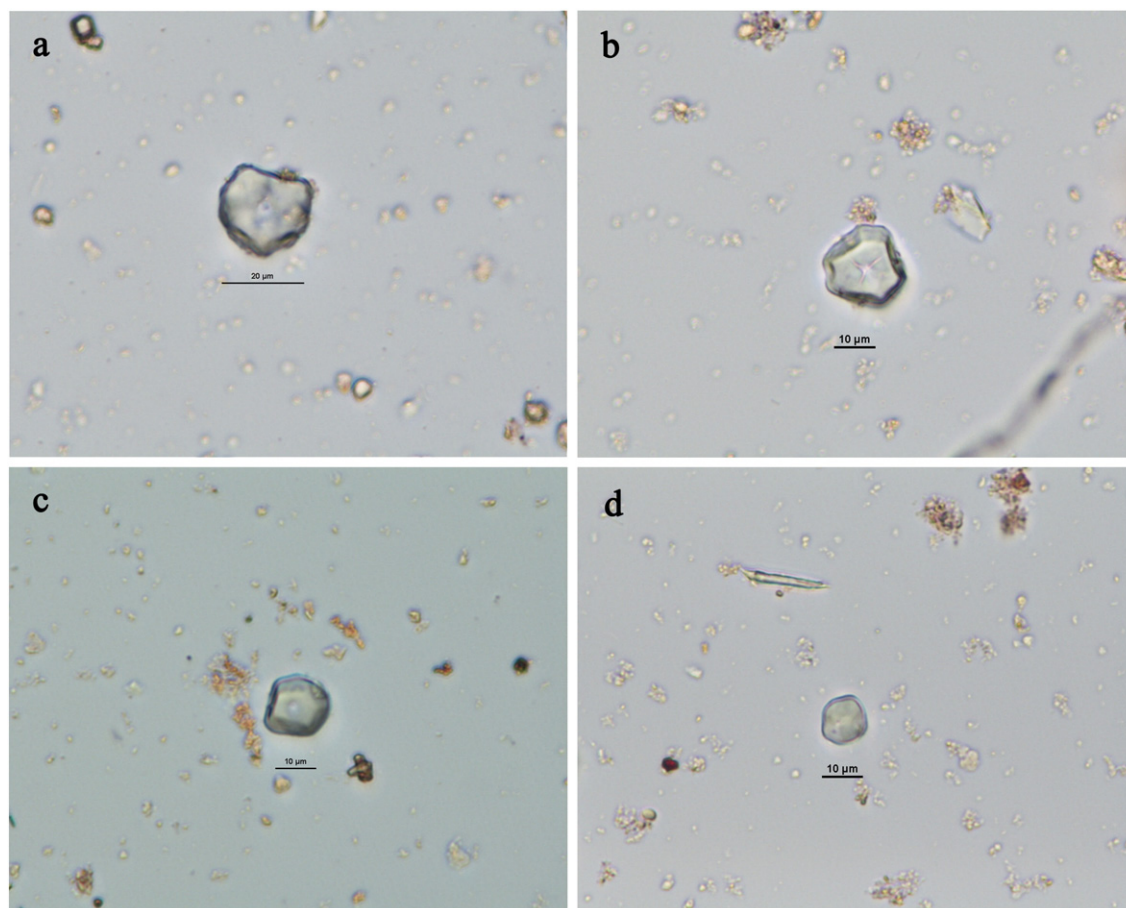


Fig. 9. Archaeological starch grains from CBII: a–b) *Setaria cf. italica* and c–d) Paniceae (*Setaria italica*/*Panicum milliaceum*).

differs from the Balearic insular contexts (summarized in Ramis, 2014), is also inferred for Cova des Riuets (ca. 2000 cal BCE) (Marlasca, 2008; López Garí et al., 2013), also located on Formentera.

In addition to diet, the diversification and innovation in the use of local resources was also developed for other economic purposes. Local quaternary clay collected from nearby deposits was used to develop pottery technology, as petrological composition suggests. Spathic calcite was added to the paste in most samples following the same recipe observed in many other Bronze Age Balearic sites (Gómez-Gras and Risch, 1999; García Orellana et al., 2001; Albero, 2011; Albero et al., 2013). This temper was obtained from the stalactitic and stalagmitic formations that can be found, for instance, in the caves located in the

shoreline. In this sense, the caves on Formentera were not just important as unique places where drinking potable water deposits could be obtained (Marlasca and López Garí, 2014), they were also places where resources could be obtained for technological purposes.

6.3. Economic behavioral adaptation to a changing landscape

The agriculture and husbandry practices also show evidence of innovation and diversification forced by the ecological conditions of the island.

Aridification on Formentera, in addition to low sedimentary conditions, was previously described as natural processes that the first

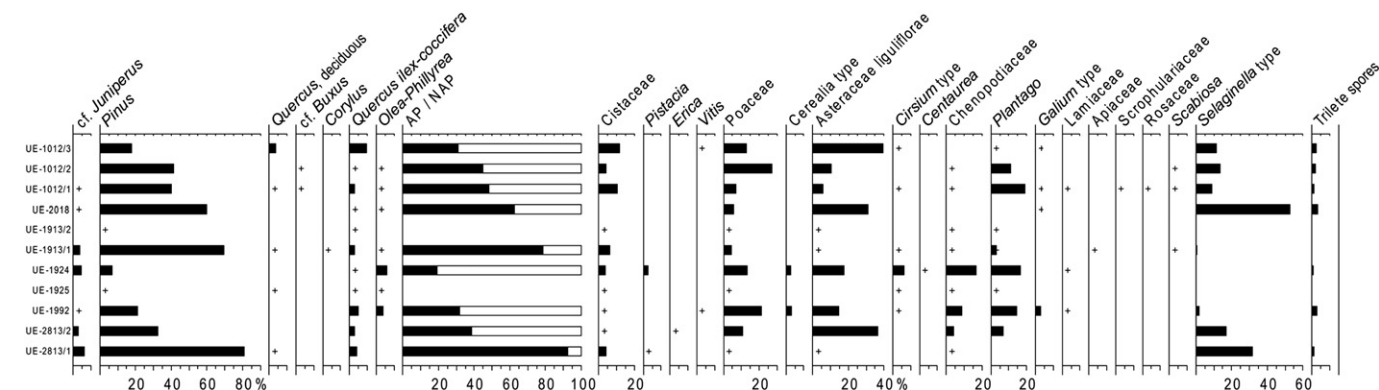


Fig. 10. Pollen diagram in relative frequencies (percentages) and absence/presence in case of poor samples and rare taxa. All the analyzed samples proceed from 1st phase archaeological layers (ca. 1662–1490 cal BCE).



Fig. 11. Metallic and lithic objects recovered in CBII: a) Copper hook from Naviform 8; b) Copper laminar fragments from Naviform 9; c) Pyramidal limestone perforated button and d) Stone bead.

settlers had to deal with. Regarding husbandry, exogenous mammals had to be introduced onto the island and no meat or secondary products could be obtained from local fauna (except from birds, small reptiles,

insects, and marine animals), which can be described as poorly biodiversified (Alcover and Muntaner, 1985; Alcover et al., 1994). Archaeozoological study suggests a very low presence of introduced

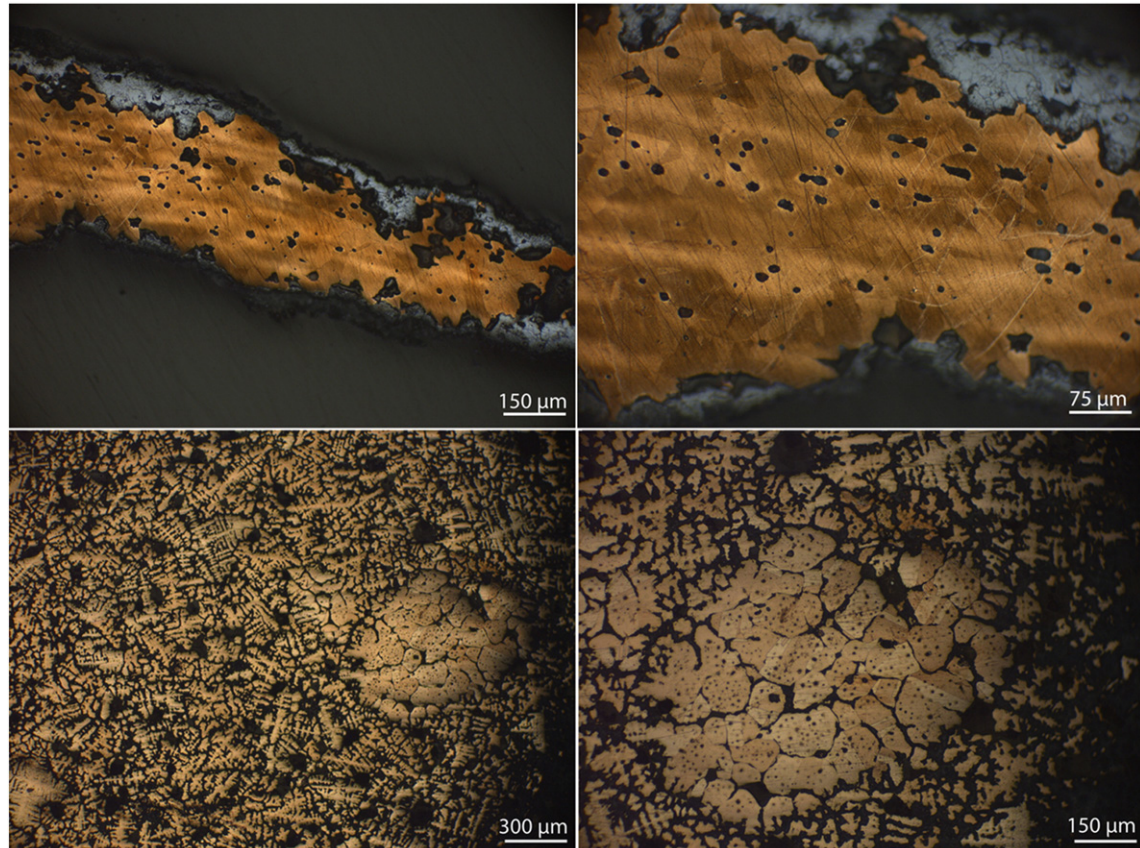


Fig. 12. Micrograph thin section in different scale from metallic objects from CBII (etched with ferric chloride reagent, bright field): a & b) Copper laminar fragment, mechanical lines and annealing can be seen; c & d) Bronze melting drop, dendritic grains from solidification of metal are clearly visible.



Fig. 13. Ceramic object from CBII petrologically analyzed.

animals (i.e., sheep/goat, pigs, and cattle) during this first human settlement; therefore, the diet had to be complemented with other resources. A limited geography, and especially the arid conditions, could also have been limiting factors for a productive and growing husbandry.

The same factors influenced and defined both agricultural practices and development. Archaeobotanical evidence (seeds, imprints in pottery and starch remains) suggests the cultivation of barley and millets. Barley has been previously identified in the prehistoric site of Cova des Riuets (López Garí et al., 2013), but the imprint represent the earliest find of the naked variety in Formentera. This is also the first record of millets in Formentera, and in the prehistory of the Balearic Islands. Millets are short-cycle cereals, of only 60–90 days (Varela, 1993–1994), which could have complemented long-cycle cereals, such as barley. Furthermore, millets had an important advantage over other cereals in the Formentera ecosystem as they require less water and can be positively cultivated in less fertile sediments (Hunt et al., 2011).

Isolation also affected the economic behaviour of the first settlers on Formentera. Exogenous raw material has been identified in CBII, but it is so scarce that a peripheral position of Formentera among the trading networks during most of the Bronze Age is inferred. In this sense, only a few metal and flint tools have been located in CBII and other sites of Formentera to hint at these contacts. These contacts probably concern the different Balearic Islands, and they were sporadic but sustained in time during the *naviform* period. This factor is also important to explain why we found *naviform* constructions and a similar material culture in the entire archipelago during the Bronze Age. In turn, isolation is also present and had influence in the material culture, where *naviforms* or pottery types of Formentera present specific differences from the others in Balearic Islands (Sureda et al., 2013a). These differences increased during the Late Bronze Age (ca. 1.100–850 cal BCE) due to changes in

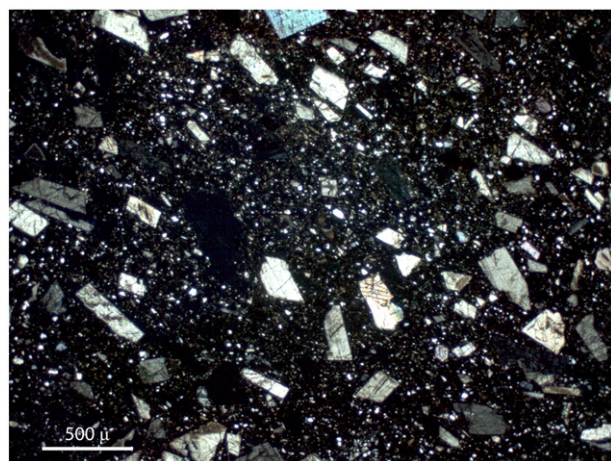


Fig. 14. Thin-section photomicrograph of the main pottery fabric identified in CBII. Note the bimodal distribution and the predominant presence of quartz and euhedral spathic calcite crystals in sample CB-231.

Table 2

Malacological species identified in CBII. Stratigraphic data could be consulted in (Sureda et al., 2013a, 2013b).

	UE 1.0.1.1	UE 1.0.1.2	UE 1.9.1.0	UE 1.9.1.1	UE 1.9.1.2	UE 1.9.1.3	UE 1.9.1.4
GASTERÔPODES							
<i>Patella</i> sp.	X	X			X	X	X
<i>Semicassis undulata</i>	X					X	
<i>Semicassis</i> sp.	X				X		
<i>Stramonita haemastoma</i>	X	X	X		X		X
<i>Phorcus turbinatus</i>	X	X		X	X	X	X
<i>Columbella rustica</i>	X				X	X	X
<i>Erosaria spurca</i>	X	X			X	X	
<i>Luria lurida</i>	X						
<i>Conus mediterraneus</i>					X		X
<i>Hexaplex trunculus</i>	X	X					
<i>Cerithium lividulum</i>	X	X					
Gastropode indet.	X				X		
BIVALVES							
<i>Glycymeris</i> sp.	X	X			X	X	X
<i>Acanthocardia tuberculata</i>						X	
<i>Acanthocardia</i> sp.					X	X	X
<i>Spondylus</i> sp.							
Cardiidae Fam.	X				X	X	X
<i>Cerastoderma</i> sp.	X	X			X		
Undulinidae Fam.						X	
Bivalve indet.	X				X		
Mollusc indet.	X						

the contacts system. In this sense Pithyusic Islands have been more related with the southwest communities of the Iberian Peninsula, than the Balearics (Guerrero, 2008; Sureda, 2016).

This isolation, in turn, promoted diversification and innovation, as indicated through the use of poor quality lithic local resources for lithic knapping (i.e., calcareous stones for expeditive production), and the exploitation of scarce layers of *Lumaquela* limestone for manufacturing the grinding toolkit. Nevertheless, the isolation had the greatest influence on economic behaviour towards intensification of exogenous materials, as reflected through the intensive use of flint tools and cores until their limit, or the type of management used with scarce metallic objects (which were also produced at CBII, as the melting drop suggests).

Intensification also affected local resources, such as wood procurement for fire and tool processing, as evidenced through the pollen

Table 3

Multiproxy archaeobotanical evidence of plant exploitation in CBII.

Taxa	Type of evidence				
	Plant part	Imprint	Macroremain (non-woody)	Macroremain (wood)	Starch granule
<i>Hordeum vulgare</i> var. <i>nudum</i>	Seed	X			
<i>Triticeae</i>	Seed				X
<i>Setaria italica</i>	Seed				X
<i>Panicum</i>	Seed				X
<i>Cerealia</i>	seed	X			
<i>Galium</i> sp.	Seed		X		
<i>Juniperus phoenicea</i>	Seed, stem, leaf, wood		X	X	
<i>Labiatae</i>	Wood			X	
<i>Leguminosae</i>	Wood			X	
<i>Pistacia lentiscus</i>				X	
Indeterminate	Plant tissue, starch granule	X	X		X

Table 4
Chemical composition results for XRF-ED analysis of the metal objects from CBII.

Lab. Code	Material	Fe	Cu	As	Sn	Sb	Pb
PA22803	Indeterminate	0.15	77.16	ND	22.69	ND	ND
PA22790	Drop	0.07	81.02	0.66	17.91	0.29	0.05
PA22792	Sheet	ND	98.84	1	ND	ND	0.16
PA23512	Fish hook	ND	97.2	2.35	ND	ND	0.42
PA24252	Awl	ND	95.8	1.18	2.92	ND	0.1

record. This generated large deforested areas in the settlement surroundings. In this sense, the interaction of the first settlers with the environment is also defined by a high impact of human occupation on the island ecosystem. Deforestation may have accentuated the aridification process, defining the open and xeric landscape that existed from the Bronze Age onwards in the Pithyusic Islands (Yll et al., 2009).

Nevertheless, and as already discussed, the clearest inference concerning human-environment interaction is the adaptation of economic behaviour developed by the human groups on Formentera. As stated, this was defined by a much more marine based diet, which could explain the differences in the isotopic values of prehistoric humans from Ca na Costa (van Strydonck et al., 2002, 2005) when compared to others in the Balearic Archipelago who consumed a fully terrestrial diet (Rihuete, 2003; Fuller et al., 2010). In addition, a particular management of local and exogenous resources was developed that was not observed on the other islands. This management was defined by resource availability and isolation and resulted in a subsistence and technological behaviour based on innovation, diversification, and intensification as a positive strategy for sustaining a stable population on Formentera.

In this sense, we agree with Cherry (1984) concerning the observation that the available resources influence the human settlement of an island. In the case of Formentera, the extreme environment present during the Bronze Age influenced the economic behaviour developed by the first settlers and defined the specific management of local and exogenous resources.

7. Conclusion

The extreme environment of Formentera during the Bronze Age is probably the cause of the late human occupation of the island, which did not occur until in the second millennium cal BCE, far later than the island colonization in the rest of the Mediterranean. Nevertheless, once a stable population was settled, the poor ecological biodiversity and the lack of diverse and necessary resources, in addition to isolation, resulted in adaptations of economic behaviour by these prehistoric settlers.

The open-air *naviform* village of Cap de Barbaria II has been the subject of multidisciplinary archaeological research combining several proxies (lithic, archaeozoological, archaeobotanical, archaeometallurgical, and petrological analysis of the pottery). The present study has allowed the characterization of the economic behaviour developed by the first human groups to settle on Formentera, and the analysis of their subsistence strategies over the centuries, from ca. 1600 to 850 cal BCE, as a positive economic and subsistence strategy adapted to an extreme environment. The key management of resources that permitted this stable settlement was based on innovation, diversification, and intensification. Technological and subsistence strategies were defined by these aspects, resulting in a particular economic behaviour that was unique among the Balearic Islands. The presence of exogenous materials can be explained by sporadic contacts between the Balearic islanders. These are important to characterize an intensive use, in comparison to that of local resources, and also the degree of isolation of these populations. In turn, the first settlers also modified the island ecosystem during prehistory, appearing as a disturbing agent with

a high impact on the environment, which in turn defined future human settlement on Formentera in the historic period.

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